

HUMAN HEALTH RISK ASSESSMENT OF HEAVY METALS IN *Cynothrissa mento* (REGAN, 1917) FROM BADAGRY CREEK, SOUTH-WEST, NIGERIA

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Abstract

This study was conducted to assess the potential impacts of consuming *Cynothrissa mento* from Badagry Creek, which is part of the Lagos Lagoon Complex that receives effluents from industries around Lagos. Water, sediment and fish (*C. mento*) samples were collected monthly for ten consecutive months (January – October, 2018) from four sampling stations in Badagry Creek. Water quality variables and heavy metal (Zn, Pb, Cu, Fe, Cr and Cd) content of water, sediment and *C. mento* were determined using standard procedures. Enrichment factor (EF) varied from 1.86×10^{-6} in Cr to 0.01 in Cd. Geoaccumulation index (Igeo) and contamination factor (CF) followed the trend with the highest values (Igeo = 6.33; CF = 120.97) obtained in Fe while the lowest values (Igeo = -12.7; CF = 2.25×10^{-4}) were recorded in Cr. The estimated daily intake (EDI) ranged from 4.79×10^{-6} mgkg⁻¹day⁻¹ in Cr to 5.4×10^{-3} mgkg⁻¹day⁻¹ in Fe. The lowest target hazard quotient (THQ) (1.65×10^{-5}) was recorded in Cr while the highest (4.94×10^{-2}) was obtained in Cd. The results show that Badagry Creek has low contamination and the consumption of *C. mento* does not constitute health risk to the consumers.

Keyword: *Cynothrissa mento*, estimated daily intake, heavy metal, sediment pollution indices, target hazard quotient

Introduction

Industrial growth in Nigeria is at a slow pace with the sector contributing about 6% of economic activities in the country (Chete *et al*, 2014). This level of industrialization in the country is attributable to over-dependence on crude oil due to failure of successive governments to diversify the economy. The result is a mono-economic system driven by petroleum, which accounts for over 95% of government's export earnings and 85% of government revenue in the last few decades (Adenikinju, 2005). In addition, industrial activity in Nigeria is not nation-wide in spectrum but limited to few states and these are Abia, Anambra, Kano, Rivers, Ogun and Lagos (Oyelaran-Oyeyinka, 1997). The problems plaguing industrialization in Nigeria are: poor state of infrastructure, lack of venture capital, high cost of capital, insecurity, inefficient tax system, poor regulatory mechanisms, etc (Iwuagwu, 2011). In spite of these challenges, Lagos State has maintained stable and reasonably high level of industrialization accounting for about 50% of industrial activities in Nigeria (Chete *et al*, 2014). These industries release their effluents into nearby water bodies and by so doing, disrupt the structure and function of those aquatic ecosystems. More often than not, these effluents are not treated to reduce the harmful effects of their contents on man and his environment. One of the major components of industrial effluent is heavy metal and they are a major environmental concern in contemporary societies because they are non-biodegradable, persisting in the environment for a long time and causing such ailments as cancer, congenital malformation, low intelligent quotient in children, etc (Ndimele *et al*, 2009).

Heavy metal levels in different compartments of the aquatic ecosystem like water, sediment and biota (finfish, shellfish, and plant) have been reported to be high depending on the industrial nature of the immediate environment (Jones *et al*, 2001; Yi *et al*, 2011). These metals are strongly accumulated and biomagnified along water, sediment and food chain causing sub-lethal effects (stunted growth, low reproductive rate, etc) or death of fish and other aquatic organisms in severe cases (Ameida *et al*, 2002; Xu *et al*, 2004). Fish absorbs heavy metal through water when they breathe. Other routes of metal absorption are through the skin or food (Handy, 1993). Sediment also plays significant role in determining the fate of metals in aquatic environment. They function as reservoir of metal load, which can be released back into the water column in response to certain disturbances, eventually threatening the aquatic ecosystem (Agarwal *et al*, 2005; Chow *et al*, 2005). Benthic organisms rely on bottom sediment for provision of habitat and food. Therefore, analysis of the metal content in sediment near a human settlement could be used to estimate the anthropogenic effects of metal pollution on the environment, which could be useful in the assessment of the risks posed to human population within that vicinity. Similarly, the potential health risk associated with the consumption of a fish from a metal-polluted environment can be measured using some indices {estimated daily intake (EDI) and target hazard quotients (THQ)} that depend on the metal content of the fish as an important input (Yi *et al*, 2011). Most of the previous studies on Badagry Creek only monitored the heavy metal concentration in water, sediment, fauna and flora (Ndimele and Kumolu-Johnson, 2012; Agboola *et al.*, 2008; Osundiya *et*

al., 2019) without assessing the potential ecological or health risks that could arise from the consumption of the aquatic organisms from the water body. Therefore, this study investigated the potential health risks associated with the consumption of *Cynothrissa mento* from Badagry Creek.

MATERIALS AND METHODS

Study Area

This study was conducted on Badagry Creek (Fig. 1), which lies between latitudes 6°22’N

and 6°42’N; and longitudes 2° 42’E and 3° 42’E (Ndimele and Kumolu-Johnson, 2012). Badagry is located on the south-west coast of Nigeria. It shares border with Gulf of Guinea to the south. It is 69 km southeast of Lagos and 51 km west of Seme, the town in Benin Republic that borders Nigeria. Badagry Creek flows/discharges directly into Ologe Lagoon, which is a brackish water in Lagos State, Nigeria (Anetekhai *et al.*, 2003). Most of the inhabitants of the area are fishers who depend on the services provided by the water body for sustenance.

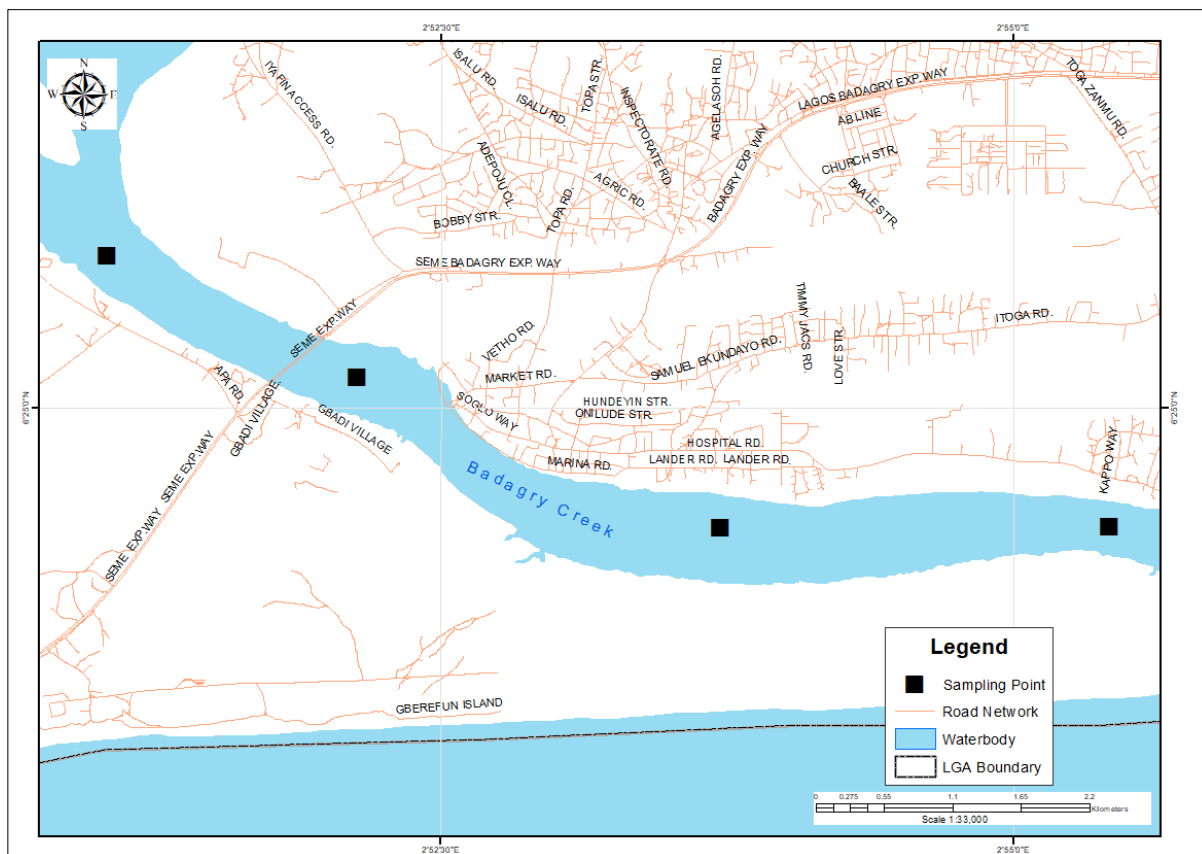


Figure 1: Map of Badagry Creek showing the sampling stations

Methodology

This study was carried out between January and October, 2018. Composite samples were collected monthly from four sampling sites (Gbadi, Marina Road, Hospital Road and Kappo). Data were generated on a monthly basis from these sites with respect to various physico-chemical parameters and heavy metal content of Badagry Creek.

Physico-chemical Parameters

Composite water samples were collected monthly for ten consecutive months (January – October, 2018) from the four sampling sites to determine physico-chemical parameters. The water samples were collected in 1.5-litre plastic containers. The water samples were stored immediately after collection in cooler to ensure that the physical and chemical integrities of the samples

were retained. Temperature and pH were measured *in situ* with a mercury-in-glass thermometer and a pH meter (Metrohm Herisau E520) respectively. The turbidity of the water was determined using nephelometer (Analite portable nephelometer Model 156, Mcvan Instrument, Mulgrave). Alkalinity, dissolved oxygen and salinity were determined by titration (Boyd, 1981). Total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), and biological oxygen demand (BOD) were measured by the methods described by American Public Health Association (APHA, 1985).

Heavy metals

Sample collection, storage and preservation

Sampling was done monthly for ten months (January – October, 2018) during which composite

samples of water, sediment and fish (*Cynothrissa mento*) were collected from the four sampling sites in Badagry Creek for heavy metal analyses. The water samples were collected at each sampling site at a depth of 25 cm below water surface in 250 ml sampling bottles. The sampling bottles were treated before they were used for sample collection. The treatment involved soaking the bottles in 10% nitric acid for about 24 hours and thereafter rinsed with distilled water (Laxen and Harrison, 1981). In order to reduce the adsorption of metals onto the walls of the plastic bottles, 5 ml nitric acid (analar grade) was added to the water samples (APHA, 1985; Ademoroti, 1996).

Grab samples of sediment were obtained with the aid of a 2-inch diameter steel pipe pressed through the water column. With this, a 30 cm sediment core was obtained (Ali and Fishar, 2005) and placed into clean polythene bags pre-treated with 10% nitric acid. All the sediment samples were stored in a deep freezer at -10°C (Kumolu-Johnson *et al*, 2010). A total of 100 fish samples (*Cynothrissa mento*) were collected from the catches of fishers in the sampling stations. The fishers deploy the following gears: gillnet, baited hook and traps. The fish samples collected were washed and stored at temperature of -10°C (Ndimele and Kumolu-Johnson, 2012).

Sample treatment

The frozen samples were retrieved from the freezer and defrost at room temperature ($\sim 27^{\circ}\text{C}$). Water samples were not subjected to additional treatment, but were mixed vigorously before aspiration into the flames of an atomic absorption spectrophotometer (Alpha-4 Cathodeon) for heavy metal analyses. Sediment samples were dried in an oven to constant weight at $105\pm 18^{\circ}\text{C}$, ground into powdery form and passed through a 2mm mesh sieve to remove coarse particles. The fish and powdery sediment samples were digested using the procedure outlined by American Public Health Association (APHA, 1985) and Food and Agriculture Organisation / Swedish International Development Cooperation Agency (FAO/SIDA, 1986). One gram of fish or sediment sample was digested in a mixture which contained concentrated nitric acid, concentrated sulphuric acid and 70% perchloric acid in the ratio 5:1:1. The digestion was carried out in a fume chamber at a temperature of $80\pm 6^{\circ}\text{C}$. The digestion was continued until the liquid turned colourless. The metal contents of the fish and sediment samples were analysed using Alpha 4 cathodeon atomic absorption spectrophotometer (APHA, 1985). The analytical procedure was checked using reference material (DORM 1, Institute of Environmental Chemistry, NRC Canada).

Ecological and Health Risk Assessment

Bioaccumulation Indices

Biota-sediment accumulation factor (BSAF) and bioaccumulation factor (BAF) were calculated using the following formulae:

$$\text{BSAF} = C_b/C_s \quad (\text{Kwok } et al, 2013) \quad (1)$$

$$\text{BAF} = C_b/C_w \quad (\text{Kumolu-Johnson } et al, 2010) \quad (2)$$

where C_b is the concentration of metal in biota (e.g fish), C_s is metal concentration in sediment and C_w is the concentration of metal in water.

Sediment pollution indices

Enrichment factor (EF) was calculated using the formula of Adaikpoh (2013). The potential harmful effects of the metals are normalized with respect to a reference element like Al, Zn or Fe by enrichment factor (Mediolla *et al*, 2008). In this study as is common with most studies, Fe was used as the normalizer or reference element because of its high concentration in Nigerian soils and about 98% of its input comes from natural sources (Ndimele *et al*, 2017; Nasir and Harikumar, 2011). The crustal abundance data of Bowen (1979) were used for all EF values.

The EF of metal in sediment was calculated using equation (3) (Adaikpoh, 2013):

$$\text{EF} = C_{\text{metal}}/C_{\text{normalizer}} (\text{sediment}) / C_{\text{metal}}/C_{\text{normalizer}} (\text{earth's crust}) \quad (3)$$

where C_{metal} and $C_{\text{normalizer}}$ are concentrations of heavy metal and reference element (Fe) in the sediment and in the earth's crust.

Geoaccumulation index (Igeo): The formula introduced by Muller (1969) was used to calculate Igeo for the metals:

$$\text{Geoaccumulation index} = \text{Log}_2(C_n/1.5 \cdot B_n) \quad (4)$$

where C_n is the metal concentration in the sediment samples and B_n is the geochemical background concentrations in soils (Muller, 1969). Variation of background values attributable to difference in lithology is minimized by introduction of the constant 1.5.

Contamination factor: The contamination factor (CF) was calculated using the formula by Hakanson (1980):

$$\text{CF} = C_m (\text{sample})/C_m (\text{background}) \quad (5)$$

where, C_m (sample) is the sediment metal concentration of the sampling sites and C_m (background) is the metal concentration of background sediment sample. The contamination factor places aquatic ecosystems in 4 categories: Low contamination ($\text{CF} < 1$), moderate contamination ($1 \leq \text{CF} < 3$), considerable contamination ($3 \leq \text{CF} < 6$), and very high contamination ($\text{CF} > 6$) (Wang *et al*, 2006).

Pollution load index (PLI) is described by the equation;

$$\text{PLI} = (\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \dots \times \text{CF}_n)^{1/n}$$

(Tomlinson *et al*, 1980) (6)

where CF = contamination factor, n = number of heavy metals studied.

The modified degree of contamination (mCd) is a generalized expression of the Håkanson (1980) equation put forward by Abraham (2005) for calculating combined contaminations of a site:

$$mCd = \frac{\sum_{i=1}^n CF_i}{n} \quad (7)$$

Modified degree of contamination puts sediments/aquatic environment in the following categories: Very low contamination (mCd < 1.5); low degree of contamination (1.5 ≤ mCd < 2); moderate degree of contamination (2 ≤ mCd < 4); high degree of contamination (4 ≤ mCd < 8); very high degree of contamination (8 ≤ mCd < 16); extremely high degree of contamination (16 ≤ mCd < 32) and ultra high degree of contamination (mCd ≥ 32).

Health risk assessment of heavy metals

The health risk associated with the consumption of *Cynothrissa mento* from Badagry Creek was analysed with two indices; estimated daily intake (EDI) and target hazard quotients (THQ).

$$EDI = C_{metal} \times DNI \times C_f / B_w \quad (8)$$

where *C_{metal}* is the concentration (mg kg⁻¹) of the metals in the muscle of *C. mento*, DNI is the daily nutritional intake (g day⁻¹), and *C_f* is the factor for conversion of fresh fish tissues to dry constant weight. *C_f* (0.335) was calculated from the equation reported by Abubakar *et al* (2015) given that mean moisture content of *C. mento* is 66.50%. The mean body weight of Nigerian adults is 70 kg. The daily nutritional intake of *C. mento* was evaluated by adopting the ingestion rate for Nigeria based on 2011 estimate by FAO. The DNI for adults is 62.60 g capita⁻¹ day⁻¹ (FAO, 2015).

The equation for estimating target hazard quotient suggested by Chen *et al* (2002) was adopted in this study:

$$THQ = \frac{Efr \times EDtot \times FIR \times C \times 10^{-3}}{RfDo \times Bw \times ATn} \quad (9)$$

where THQ is the target hazard quotient; EFr = exposure frequency (365 days/year); EDtot = exposure duration (55.2 years, average lifetime of Nigerians); FIR = rate of ingesting food (g/day); C = metal concentration in fish (mg/g); RfDo = oral reference dose (mg/kg/day); Bw = mean body weight of a Nigerian adult (60.75 kg); and ATn = mean exposure time for non-carcinogens (365 days/year x number of exposure years, assuming 55.2 years).

$$\text{Total THQ} = \text{THQ (toxicant 1)} + \text{THQ (toxicant 2)} + \dots + \text{THQ (toxicant n)} \quad (10)$$

Statistical analysis

Student t-test was used to compare the water quality variables between the two seasons (dry and wet) and the level of significance was set at α = 0.05 (SPSS for windows version 17.0). Pearson moment correlation coefficient (*r*) was used to establish the extent of relationship among the physico-chemical parameters.

RESULTS

The physico-chemical parameters of the sampling stations are presented in Table 1. Seasonal dynamics did not have effect on six {temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity and dissolved oxygen) of the parameters measured. However, total suspended solids (TSS), turbidity, biological oxygen demand (BOD) and alkalinity exhibited significant (p<0.05) seasonal variation. The higher values of TSS (146±15 mg/l), turbidity (33.12±3.34 NTU), BOD (34.12±2.68 mg/l) and alkalinity (145±11 mg/l) were recorded in the wet season while the lower values {TSS (90±23 mg/l), turbidity (21.49±3.46 NTU), BOD (20.52±5.57 mg/l) and alkalinity (116±8 mg/l)} occurred in the dry season.

Table 1: Seasonal variation in physico-chemical parameters of Badagry Creek, South-West, Nigeria

Physicochemical parameter	Wet Season	Dry Season	WHO (2008) Standard
Temperature (°C)	23.00±1.45 ^a	25.00±1.36 ^a	<40
pH	7.48±0.16 ^a	7.34±0.38 ^a	5.5 – 9.0
EC (µS/cm)	349±46 ^a	314±44 ^a	250
TDS (mg/l)	175±36 ^a	158±25 ^a	2100
Salinity (ppt)	0.95±0.43 ^a	1.64±0.78 ^a	NS
TSS (mg/l)	146±15 ^a	90±23 ^b	100
Turbidity (NTU)	33.12±3.34 ^a	21.49±3.46 ^b	5.0
Dissolved oxygen (mg/l)	4.23±0.19 ^a	4.15±0.27 ^a	>2.0
BOD (mg/l)	34.12±2.68 ^a	20.52±5.57 ^b	50
Alkalinity (mg/l)	145±11 ^a	116±8 ^b	120

Figures in the same row and with the same superscript letters are not significantly (p>0.05) different.

All values are expressed as Mean±SE.

EC=Electrical conductivity; TDS=Total dissolved solids; TSS=Total suspended solids; BOD=Biological oxygen demand.

Table 2: Correlation matrix of physico-chemical parameters of Badagry Creek

	Temp	pH	EC	TDS	Salinity	TSS	Turbidity	DO	BOD	Alkalinity
Temp	1									
pH	-0.216	1								
EC	0.193	0.187	1							
TDS	0.198	0.215	0.998**	1						
Salinity	-0.039	0.571	0.380	0.378	1					
TSS	-0.688	0.773*	-0.51	-0.039	0.526	1				
Turbidity	-0.214	0.464	0.473	0.456	0.502	0.407	1			
DO	0.295	0.113	-0.554	-0.533	-0.210	0.099	-0.413	1		
BOD	-0.823*	0.462	0.303	0.300	0.362	0.797*	0.559	-0.356	1	
Alkalinity	0.133	0.744*	0.235	0.233	0.663	0.492	0.701	0.127	0.212	1

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed)

The relationship (Pearson moment correlation coefficient) among the physico-chemical parameters are shown in Table 2. There were strong positive correlations between electrical conductivity and total dissolved solids ($r=0.99$; $p<0.01$; $n=10$), total suspended solids and pH ($r=0.77$; $p<0.05$; $n=10$), total suspended solids and BOD ($r=0.8$; $p<0.05$; $n=10$) and alkalinity and pH ($r=0.74$; $p<0.05$; $n=10$). However, temperature and BOD had strong negative correlation ($r=-0.823$; $p<0.05$; $n=10$).

Table 3 shows the bioaccumulation factor (BAF) and biota-sediment accumulation factor (BSAF) of heavy metals in the muscle of *Cynothrissa mento* from Badagry Creek. The highest BCF was recorded in Fe (1.34×10^{-2}) while the lowest was obtained in Cr (1.75×10^{-4}). The highest (2.13) and lowest (0.02) BSAF values occurred in Cu and Fe respectively. Five sediment pollution indices

were used to analyse the level of contamination of the sediment of Badagry Creek (Table 4). Enrichment factor (EF) varied from 1.86×10^{-6} in Cr to 0.01 in Cd. Geoaccumulation index (Igeo) and contamination factor (CF) followed the trend with the highest values (Igeo = 6.33; CF = 120.97) obtained in Fe while the lowest values (Igeo = -12.7; CF = 2.25×10^{-4}) were recorded in Cr. The health risk associated with the consumption of the muscle of *Cynothrissa mento* from Badagry Creek was evaluated by calculating the estimated daily intake (EDI) and target hazard quotients (THQ) (Table 5). The EDI ranged from 4.79×10^{-6} mgkg⁻¹day⁻¹ in Cr to 5.4×10^{-3} mgkg⁻¹day⁻¹ in Fe. The lowest THQ (1.65×10^{-5}) was recorded in Cr while the highest (4.94×10^{-2}) was obtained in Cd. Total-THQ, which is the sum of the individual THQs of the metal is 0.11.

Table 3: Bioaccumulation Factor (BAF) and Biota-Sediment Accumulation Factor (BSAF) of heavy metals in muscle of *Cynothrissa mento* from Badagry Creek, South-West, Nigeria

	Heavy metal					
	Zn	Pb	Cu	Fe	Cr	Cd
BAF	4.49×10^{-3}	3.57×10^{-4}	2.51×10^{-3}	1.34×10^{-2}	1.75×10^{-4}	3.39×10^{-4}
BSAF	1.76	0.05	2.13	0.02	0.5	0.05

Table 4: Enrichment Factor, Geoaccumulation index (Igeo), Contamination factor, pollution load index and modified degree of contamination of metals in sediments of Badagry Creek, South-West, Nigeria

	Heavy metal						PLI	mCd
	Zn	Pb	Cu	Fe	Cr	Cd		
EF	5.73×10^{-5}	2.68×10^{-4}	4.22×10^{-5}	-	1.86×10^{-6}	0.01		
Igeo	-7.76	-5.53	-8.2	6.33	-12.7	-0.21		
CF	6.93×10^{-3}	0.03	5.11×10^{-3}	120.97	2.25×10^{-4}	1.3	0.059	20.39

Table 5: Estimated daily intake (mgkg⁻¹day⁻¹) and estimated target hazard quotients (THQ) for individual metals and total THQ from consumption of *Cynothrissa mento* from Badagry Creek, South-West, Nigeria

	Heavy metal						Total THQ
	Zn	Pb	Cu	Fe	Cr	Cd	
EDI	5.55×10^{-4}	1.44×10^{-5}	2.35×10^{-4}	5.4×10^{-3}	4.79×10^{-6}	9.57×10^{-6}	
THQ	9.55×10^{-3}	1.85×10^{-2}	3.02×10^{-2}	-	1.65×10^{-5}	4.94×10^{-2}	0.11

DISCUSSION

Some of the values of the water quality variables of this study agree with previous studies on Badagry Creek and other aquatic ecosystems in the Lagos Lagoon complex and even Nigeria, while

some does not (Agboola *et al.*, 2008, Kumolu-Johnson *et al.*, 2010; Adedeji *et al.*, 2019). Agboola *et al.* (2008) reported turbidity (14.13 ± 0.95 NTU), alkalinity (49.33 ± 10.77 mg/l) and total suspended solids (107.83 ± 172.82 mg/l) values, which are lower

than the values obtained in this study. However, the values of electrical conductivity ($432.67 \pm 8.64 \mu\text{S/cm}$) and total suspended solids ($352.83 \pm 1.81 \text{ mg/l}$) reported by Adedeji *et al* (2019) are higher than the values in this study. Temperature, pH, salinity and dissolved oxygen showed similar values as previously reported (Ndimele *et al.*, 2009; Kumolu-Johnson *et al.*, 2010). Some of the physico-chemical parameters showed significant ($p < 0.05$) seasonal variation, having higher values in the wet season. This observation agrees with the findings of previous studies by Ramulu and Benarjee (2013) and Barman *et al.* (2015). These variables are total suspended solids, turbidity, biological oxygen demand and alkalinity. The higher values recorded during the wet season might be due to run-off or inflow caused by increased precipitation, which brings organic and inorganic salts into natural water bodies (Yadav *et al.*, 2013). The organic substances increase the BOD while the inorganics increase turbidity and total suspended solids. The values of turbidity, electrical conductivity, total suspended solids and alkalinity in this study are higher than the values recommended by World Health Organisation (WHO, 2008) as limits for the culture of aquatic organisms including fish.

The BCF values obtained in this study varied from 1.75×10^{-4} to 1.34×10^{-2} . These values are lower than those reported in previous studies in Lagos Lagoon Complex and other water bodies in Nigeria. Kumolu-Johnson and Ndimele (2012) reported BCF values of 0.10-0.40, 0.10-0.40, 0.10-0.40, 0.23-4.10, 2.44-17.40 and 3.91-27.91 for Cd, Pb, Cr, Cu, Zn and Fe respectively for *Oreochromis niloticus* from Ologe Lagoon, Lagos State, Nigeria. Kumolu-Johnson *et al* (2010) also reported BCF of Cu (170-410), Zn (30-80) and Fe (370-2320) for *Cynothrissa mento* from Ologe Lagoon, while Obasohan and Eguavoen (2008) obtained BCF range of 6.67-2535 for *Erpetoichthys calabaricus* from Ogba River, Benin City, Nigeria. According to Regulation (EC) No 1907/2006 (REACH) and USEPA Toxic Substances Control Act (TSCA) (Nenciu *et al.*, 2014), the BCF recorded in this study are smaller than the lower limits admitted for the classification. The low BCF in this study are not just indication of reduction in heavy metals content in Badagry Creek but also a reflection of the ability of *Cynothrissa mento* to accumulate metals at low concentration. The range of values of BSAF in this study is 0.02 to 2.13. The values are similar to those reported by Nenciu *et al* (2016) who worked on *Hippocampus guttulatus* and *Syngnathus acus* from the Romanian Black Sea coast. From our results, it is difficult to classify *C. mento* as a distinct deconcentrator, microconcentrator or macroconcentrator but categorization would depend on the metal being examined. For Pb, Fe, Cr and Cd with $\text{BSAF} < 1$, *C. mento* can be described as a deconcentrator (Dallinger, 1993). The BSAF of Zn >

1, and so, *C. mento* is a microconcentrator in this case, while BSAF of Cu > 2, making *C. mento*, a macroconcentrator also.

Sediment is an essential component of the aquatic ecosystem, which plays a vital role in determining the fate of pollutants in the aquatic environment. Sediment function as reservoir of heavy metals in water bodies (Ndimele and Kumolu-Johnson, 2012). There has been gradual increase in the level of metal in the biotic and abiotic components of aquatic ecosystems in Lagos. In the study conducted by Agboola *et al* (2008) on Badagry Creek, Pb was not detected. However, in this study, Pb was present in measurable quantity. This could be due to natural processes such as biogenic inputs, weathering, etc or anthropogenic activities like industrial effluent. In this study, five sediment pollution indices were used for the assessment and classification of the water body. These indices are: enrichment factor (EF), geoaccumulation index (Igeo), contamination factor (CF), pollution load index (PLI) and modified degree of contamination (mCd). The enrichment factor of Badagry Creek was < 1 for all the metals. Therefore, the water body has no enrichment (Acevedo-Figueroa *et al*, 2006). The index of geoaccumulation for all the metals are < 1 except Fe with Igeo of 6.33. So, Badagry Creek can be described as an uncontaminated site going by the classification of Muller (1969). The high level of Fe in the sediment is due to the naturally high concentration of Fe in Nigerian soils, which has been reported by Kumolu-Johnson *et al* (2010). The contamination factors of four (Zn, Pb, Cu and Cr) of the metals were < 1 and the PLI < 1 as well. The standard for assessing sediment pollution introduced by Håkanson (1980) states that $\text{CF} < 1$ and $\text{PLI} < 1$ implies an environment with low contamination. This further gives credence to the earlier assertion that Badagry Creek has low metal pollution. The health risk associated with the consumption of *Cynothrissa mento* was measured using estimated daily intake (EDI) and target hazard quotient (THQ). The values of EDI {Zn ($5.55 \times 10^{-4} \text{ mgkg}^{-1} \text{ day}^{-1}$), Pb ($1.44 \times 10^{-5} \text{ mgkg}^{-1} \text{ day}^{-1}$), Cu ($2.35 \times 10^{-4} \text{ mgkg}^{-1} \text{ day}^{-1}$), Cr ($4.79 \times 10^{-6} \text{ mgkg}^{-1} \text{ day}^{-1}$) and Cd ($9.57 \times 10^{-6} \text{ mgkg}^{-1} \text{ day}^{-1}$)} obtained in this study are lower than the oral reference doses (RfDo) of the metals; Zn ($3 \times 10^{-1} \text{ mgkg}^{-1} \text{ day}^{-1}$), Pb ($4 \times 10^{-3} \text{ mgkg}^{-1} \text{ day}^{-1}$), Cu ($4 \times 10^{-2} \text{ mgkg}^{-1} \text{ day}^{-1}$), Cr ($1.5 \text{ mgkg}^{-1} \text{ day}^{-1}$) and Cd ($1 \times 10^{-3} \text{ mgkg}^{-1} \text{ day}^{-1}$) (USEPA, 2009). This means that consuming *Cynothrissa mento* from Badagry Creek may not cause a non-cancer health risk. The THQs of the metals were < 1, further affirming that consumers of *Cynothrissa mento* from Badagry Creek are not exposed to significant risk of metal pollution by consuming the fish.

Conclusion

The study shows that Badagry Creek has low heavy metal contamination and the consumption of *C. mento* does not constitute health risk to the consumers.

References

- Abraham, G.M.S. (2005). Holocene sediments of Tamaki Estuary: Characterization and impact of recent human activity on an urban estuary in Auckland, New Zealand, PhD Thesis, University of Auckland, Auckland (New Zealand), 361pp.
- Abubakar, A., Uzairu, A., Ekwumemgbo, P.A. and Okunola, O.J. (2015). Risk assessment of heavy metals in imported frozen fish *Scomberscombrus* species sold in Nigeria: A case study in Zaria metropolis. *Advances in Toxicology*. doi: **10.1155/2015/303245**.
- Acevedo-Figueroa, Jimenez-Velez, B.D. and Rodríguez-Sierra, C.J. (2006). Trace metals in sediment of two estuarine lagoons from Puerto Rico. *Environmental Pollution*. 141(2):336-42.
- Adaikpoh, E.O. (2013). Distribution And Enrichment Of Heavy Metals In Soils From Waste Dump Sites Within Imoru And Environs, Southwest Nigeria. *Journal of Environment and Earth Science*. 3: 45-54.
- Adedeji, H.A., Idowu, T.A., Usman, M.A. and Sogbesan, O.A. (2019). Seasonal variations in the physico-chemical parameters of Lake Ribadu, Adamawa state Nigeria. *International Journal of Fisheries and Aquatic Studies*. 7: 79-82.
- Ademoroti, C. M. A. (1996). Standard methods for water and effluent analysis. Foludex Press Ltd, Ibadan. 182pp.
- Adenikinju, A. F. (2005). African imperatives in the New World Order: country case study of the manufacturing sector in Nigeria. In: O.E. Ogunkola A. and Bankole (eds.). Nigeria's imperatives in the New World Trade Order. Nairobi. African Economic Research Consortium and Ibadan: Trade Policy Research and Training Programme.
- Agarwal, A., Singh, R.D., Mishra, S.K. and Bhunya, P.K.. (2005). ANN-based sediment yield river basin models for Vamsadhara (India). *Water SA*. 31 (1): 95-100.
- Agboola, J.I., Anetekhai, M.A. and Denloye, A.A.B. (2008). Aspects of the ecology and fishes of Badagry Creek, Nigeria. *J. Fish. Aquat. Sci*. 3(3): 184-194.
- Ali, M.H.H. and Fishar, M.R.A. (2005). Accumulation of trace metals in some benthic invertebrates and fish species relevant to their concentrations in water and sediment of Lake Qarun, Egypt. *Egyptian Journal of Aquatic Research*.31: 289-301.
- Almeida, J.A., Diniz, Y.S., Marques, S.F.G., Faine, I.A., Ribas, B.O., Burneiko, R.C. and Novelli, E.I.B. (2002). The use of oxidative stress responses as biomarkers in Nile Tilapia (*Oreochromis niloticus*) exposed to in vivo cadmium contamination. *Environment International*. 27: 673-679.
- Anetekhai, M.A., Akin-Oriola, G.A., Jimoh, A.A., Akintola, S.L. and Kumolu-Johnson, C.A. (2003). Preliminary report on fish and fisheries of Ologe Lagoon, Lagos, Nigeria. In: Proceedings of the Third International Conference of the Pan-African Fish and Fisheries Association, 10–14 November, 2003, Cotonou, Benin. pp 1–5.
- American Public Health Association (APHA). 1985. Standard methods for the examination of water and waste water. 16th edition. American Public Health Association, Washington, D.C. 1268 pp.
- Barman D., Roy B. and Roy S. (2015). Seasonal variations of physico-chemical characteristics of wetlands in the West Garo Hill, Meghalaya, India. *Int. Res. J. of Biological Sci*. 4(1): 60-65.
- Bowen, H.J.M. (1979). Environmental Chemistry of the Elements. Academic Press, London, 333.
- Boyd, C.E. (1981). Water quality in warm water fish ponds. Alabama Agricultural Experimental Station, Auburn University, Alabama. 358pp.
- Chen, J.C., Sun, Z.Z., Qu, J.H., Wu, W., Hu, G.D. (2002). Water pollution and its toxicity to fishes in the major areas of the lower reaches of the Yangtze River. *Acta Hydrobiologica Sinica*. 26 (6), 635-640 (in Chinese).
- Chete, L.N. Adeoti, J. O., Adeyinka, F. M. and Ogundele, O. (2014). *Industrial development and growth in Nigeria: Lessons and challenges*," WIDER Working Paper Series 019, World Institute for Development Economic Research (UNU-WIDER).
- Chow, T.E., Gaines, K.F., Hodgson, M.E. and Wilson, M.D. (2005). Habitat and exposure modeling for ecological risk assessment: a case study for the raccoon on the Savannah River Site. *Ecological Modelling* 189, 151-167.
- Dallinger, R. (1993). Strategies of metal detoxification in terrestrial invertebrates. In: Dallinger, R. and Rainbow, P.S. (Eds.). *Ecotoxicology of metals in invertebrates*. Lewis Publishers, London, 240-289.

- Food and Agriculture Organization of the United Nations (FAO) Food balance sheet of fish and fishery products in live weight and fish contribution to protein supply: 2011 world by continent 2015 Available: <http://faostat3.fao.org/browse/FB/FBS/E>.
- Food and Agricultural Organization (FAO) / Swedish International Development Cooperation Agency (SIDA) (1986). Manual of methods in aquatic environmental research part 9. Analysis of metals and organochlorines in fish. FAO Fisheries Technical Paper 212: 21-33.
- Håkanson, L. (1980). An ecological risk index for aquatic pollution control of sediment ecological approach. *Water Research*. 14, 975-1000.
- Handy, R.D. (1993). The accumulation of dietary aluminum by rainbow trout, *Oncorhynchus mykiss*, at high exposure concentrations. *Journal of Fish Biology*. 42: 603-606.
- Iwuagwu, O. (2011). The Cluster Concept: Will Nigeria's New Industrial Development Strategy Jumpstart the Country's Industrial Takeoff? *Afro-Asian Journal of Social Science*. 2: 1-24.
- Jones, I., Kille, P. and Sweeney, G. (2001). Cadmium delays growth hormone expression during rainbow trout development. *Journey of Fish Biology*. 59: 1015-1022.
- Kwok, C. K. Liang, Y. Leung, S. Y. Wang, H. Dong, Y. H. Young, L. Giesy, J. P. and Wong, M. H. (2013). Biota-sediment accumulation factor (BSAF), bioaccumulation factor (BAF), and contaminant levels in prey fish to indicate the extent of PAHs and OCPs contamination in eggs of waterbirds. *Environmental Science and Pollution Research*. 20: 8425-8434.
- Kumolu-Johnson, C.A., Ndimele, P.E. Akintola, S.L. and Jibuike, C.C. (2010). Copper, zinc and iron concentrations in water, sediment and *Cynothrissa mento* (Regan, 1917) from Ologe Lagoon, Nigeria: a preliminary survey. *African Journal of Aquatic Science*. 35(1): 87-94.
- Laxen, D.P.H. and Harrison, R.M. (1981). A scheme for the physiological specification of trace metals in fish samples. *Science of the Total Environment*. 19: 59-82.
- Mediolla, L.L., Domingues, M.C.D. and Sandoval M.R.G. (2008). Environmental assessment of an active tailings pile in the state of Mexico (Central Mexico). *Research Journal of Environmental Sciences*. 2(3): 197-208.
- Muller, G. (1969). Index of geoaccumulation in the sediments of the Rhine River. *Geojournal*. 1(2): 108-118.
- Nasir, U.P. and Harikumar, P.S. (2011). Ecotoxicity and Ecosystem Health of a Ramsar Wetland System of India. *Journal of Environmental Protection*. 2: 710-719.
- Ndimele, P.E., Jenyo-Oni, A. and Jibuike, C.C. (2009). The levels of lead (Pb) in water, sediment and a commercially important fish species (*Chrysichthys nigrodigitatus*) (Lacepède, 1803) from Ologe Lagoon, Lagos, Nigeria. *Journal of Environmental Extension*. 8: 70-75.
- Ndimele, P.E. and Kumolu-Johnson, C.A. (2012). Some aspects of the physicochemistry and heavy metal content of water, sediment and *Cynothrissa mento* (Regan, 1917) from Badagry Creek, Lagos, Nigeria. *Trends in Applied Sciences Research*, 7(9): 724-736.
- Ndimele, P.E.; Pedro, M.O.; Agboola, J.I.; Chukwuka, K.S. and Ekwu, A.O. (2017). Heavy metal accumulation in organs of *Oreochromis niloticus* (Linnaeus, 1758) from industrial effluent-polluted aquatic ecosystem in Lagos, Nigeria. *Environmental Monitoring and Assessment*. 189: 255.
- Nenciu M. I., Coatu, V., Oros, A., Roşioru, D., Ţigănuş, D. and Roşoiu N. (2014). Pollutant bioaccumulation in the long-snouted seahorse at the Romanian Coast. *Journal of Environmental Protection and Ecology*. 15(4): 1650-1659.
- Nenciu M. I., Oros, A., Roşioru, D., Galatchi, M., Filimon, A. Tiganov, G., Danilov, C. and Roşoiu N. (2016). Heavy metal bioaccumulation in marine organisms from the Romanian Black sea coast. *Academy of Romanian Scientists Annals -Series on Biological Sciences*. 5(1): 38-52.
- Obasohan, E.E. and Eguavoen, O.I. (2008). Seasonal variations in bioaccumulation of heavy metals in a freshwater fish (*Erpetoichthys calabaricus*) from Ogba River, Benin City, Nigeria. *African Journal of General Agriculture*. 4: 153-163.
- Osundiya, M.O., Olowu, R.A., Alegbe, M.J., Igbasan, S.O., Jimoh, A.A., Olawoye, C.O. and Emmanuel, J. (2019). Bioaccumulation of Heavy Metals in Parts of the Silver Catfish (*Chrysichthys nigrodigitatus*) Harvested from Badagry Creek and Fish Ponds in Badagry, Lagos, Nigeria. *American Journal of Chemistry*. 9(3): 95-102.
- Oyelaran-Oyeyinka, B. (1997). Industrial technology policy - making and implementation in Nigeria: an assessment. NISER Occasional Paper. Ibadan: NISER.

- Ramulu, N.K. and Benarjee, G. (2013). Physicochemical factors influenced plankton biodiversity and fish abundance- A case study of Andhra Pradesh. *Int. J. Life Sc. Bi. & Pharm. Res.* 2(2): 248-260.
- Tomlinson, D.C., Wilson, J. G., Harris, C. R. and Jeffery, D.W. (1980). Problems in the assessment of heavy Metals levels in estuaries and the formation of a pollution index. *Helgol Wiss Meeresunters.* 33(1-4): 566-575.
- USEPA, (2009). Risk-based concentration table. Philadelphia PA: United States Environmental Protection Agency, Washington, DC.
- Wang, H.H., Li, L.Q., Wu, X.M. and Pan, G.X. (2006). Distribution of Cu and Pb in particle size fractions of urban soils from different city zones of Nanjing, China. *J. Environ. Sci. (China).* 18: 482-487.
- World Health Organisation (WHO) (2008). Guidelines for drinking water quality (3rd Edition): Health criteria and supporting information. WHO, Geneva. 668pp. http://www.who.int/water_sanitation_health/dwq/fulltext.pdf
- Xu, Y.J., Liu, X.Z. and Ma, A.J. (2004). Current research on toxicity effect and molecular mechanism of heavy metals on fish. *Marine Science.* 28(10), 67-70.
- Yadav, P., Yadav, V.K., Yadav, A.K. and Khare, P.K. (2013). Physico-chemical characteristics of a freshwater pond. *Octa. J. Biosci.* 1(2): 177-184.
- Yi, Y., Yang, Z. and Zhang, S. (2011). Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River basin. *Environmental Pollution.* 159: 2575-2585.