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HEAVY METALS CONCENTRATION IN SOME ORGANS OF TILAPIA (*SAROTHERODON MELANOTHERON*) AND MULLET (*MUGIL CEPHALUS*) HARVESTED FROM OGINIGBA/WOJI CREEK, PORT HARCOURT, NIGERIA

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Abstract
Heavy metals concentration in muscles, gills, livers and intestines of two economically valuable fish species, *S. melanotheron* (Tilapia) and *M. cephalus* (Mullet) harvested from the Oginigba/Woji Creek for two seasons were investigated. Fish samples were collected and analyzed using the Dry-Ashing method, while heavy metals determination was done with the Atomic Absorption Spectrophotometer (AAS). The mean concentrations (mg/kg dry weight) of heavy metals in fish organs were as follows: *S. melanotheron* muscles: (Cd)0.06±0.05, (Pb)0.43±0.18, (Fe)59.98±5.36, (Cu)3.84±0.63, (Zn)20.28±3.36 and (Mn)1.64±0.45; gills:(Cd)0.75±0.25, (Pb)1.85±0.49, (Fe)424.28±71.34, (Cu)7.43±1.05, (Zn)51.60±11.52, and (Mn)6.56±1.42; liver: (Cd)0.08±0.07, (Pb)0.57±0.32, (Fe)802.43±65.22, (Cu)190.37±67.77, (Zn)102.37±18.34, and (Mn)4.58±1.19; intestine: (Cd)0.62±0.23, (Pb)1.59±0.47, (Fe)1440.13±223.95, (Cu)17.68±4.41, (Zn)76.00±15.40 and (Mn)18.93±5.66. *M. cephalus* muscles: (Cd)0.35±0.14, (Pb)1.84±0.55, (Fe)52.45±5.14, (Cu)3.94±0.96, (Zn)22.92±2.26 and (Mn)1.37±0.36; gills: (Cd)0.55±0.18, (Pb)1.56±0.45, (Fe)295.47±68.76, (Cu)7.66±1.31, (Zn)36.58±5.29 and (Mn)11.55±2.28; liver: (Cd)0.06±0.03, (Pb)0.49±0.19, (Fe)487.85±96.50, (Cu)53.99±7.92, (Zn)92.78±13.20 and (Mn)5.77±1.55; intestine: (Cd)0.75±0.30, (Pb)2.30±1.29, (Fe)1005.26±218.42, (Cu)12.95±1.98, (Zn)56.37±7.46 and (Mn)16.90±4.23. The investigation revealed fish organs enrichment of heavy metals most of them above safe limits. The elevated levels of the non-essential metals, Cd and Pb in fish muscles in the selected fish species are pointers to a serious health risk for human consumers, especially during the Dry season, hence the need for restoration and corrective actions to mitigate the toxicity levels of these metals, not only for the wellbeing of the aquatic species but also for the safety of human consumers

Keywords: Heavy metals, Tilapia, Mullet, Ecosystem, Pollution, Toxicity

Introduction

The introduction of sewage, domestic and industrial wastewater into the aquatic ecosystem constitutes a major threat to physicochemical, flora and fauna characteristics of the aquatic ecosystem (Edokpayi & Nkwoji, 2000; Nkwoji et al., 2010), and contribute extensively to heavy metals pollution. More so as most of these coastline dwellers and industries lack good sanitary and waste management facilities. The impact of anthropogenic wastes on the physical and chemical properties of water cannot be overstressed, as these are essential for the well-being of the biotic components of an aquatic ecosystem including fish.

The physicochemical properties of seawater (Navaro et al., 2006), and ecological and biological factors such as seasonal and local variations of heavy metal content, as well as the half-life of the metal species, determine the accumulation of metals in fish (Canli &Atli, 2003; Bukola et al., 2015), and can therefore be used to monitor environmental quality and establish a relationship between fish health status and water quality. Heavy metals are metallic elements that have a relatively high density (Lenntech water treatment solutions, 2012), and constitute an underlined collection of pollutants in aquatic ecosystems for the reasons that they can change aquatic species diversity and ecosystems due to their toxicity and accumulative behaviour (Al-Yousuf et al., 2000; Turkmen et al., 2005). They constitute a large percentage of the functional polluting substances affecting the quality of the ecosystem, with their long-term impact on living organisms, including food species (Censi et al., 2006; Ozturk et

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al., 2009). The quality characteristics of the aquatic environment are the main factor in maintaining the health status of cultured and wild fish. Fish are found towards the end of the aquatic food chain, and toxicants enter the food chain (Tuzen, 2003; Altindag & Yig, 2005) and consequently accumulate in fish foods positioned at trophic levels lower than that of the fish, the fish food acts as toxicant amplifiers making the toxicants available to predator fishes at dangerously high levels (Bukola et al., 2015); therefore, fish can accumulate toxicants far above concentrations within their environment (Afshan et al., 2014). These toxicants may be metabolized into more toxic derivatives, however without any obvious injury to the organism (Bukola et al., 2015), or may alter physiological and biochemical processes in fish blood and different organs, particularly gill, liver, intestine and muscle, and these have been convincingly used as biomarkers to effectively assess and highlight the status and ecological integrity of the aquatic environment (Tejerina-Garro et al., 2005; Al-SayeghPetkovsek et al., 2012; Bukola et al., 2015)

A hostile aquatic environment contributes to high toxicity and stress phenomena that compromise fish immunity and produce some deleterious effects and make fish susceptible to pathogens and parasites (Eissa, 2002). Fish is an important and valuable food item, supplying essential proteins, vitamins, elements and polyunsaturated fatty acids to man (Shirai et al., 2006; Sinn & Howe, 2008; Gladysher et al., 2008). Unfortunately, most of the human health challenges associated with seafood safety originate from the consumption of fish and fish products (Nwani et al., 2010; Otitoju & Otitoju, 2013). Human health is affected when these toxic elemental contaminants and pathogens are transferred into the human system through the consumption of contaminated fish (Alinnor & Obiji, 2010).

Tilapia (*S. melanotheron*) and Mullet (*M. cephalus*) constitute a large proportion of the catches by artisans and subsistence fishermen in the estuaries and creeks of the Niger Delta, Nigeria, throughout the year. They form a major part of the local people's diet and generate a high market value, indicating the need for deliberate action steps to guard against their contamination and extinction. It is therefore on this premise that this study seeks to determine the heavy metals (Cd, Pb, Fe, Cu, Zn, and Mn) concentration in fish organs (muscles, gills, livers, and intestines) of the two commercially valuable fish species, Tilapia (*Sarotherodon melanotheron*) and Mullet (*Mugil cephalus*), make the comparison of their heavy metals concentration and seasonal variations of metals in fish species, and also educate the public on the health risks associated with heavy metals consumption, as well as give a current account of the environmental quality status of the Creek, which will form the basis for future monitoring of the ecosystem.

Materials and Methods

Study Area: This study was carried out on the Oginigba /Woji Creek. The Creek is bounded on the right by the Trans-Amadi Industrial Area, Port-Harcourt and communities, such as Rumuobiakani, Oginigba, Azuabie, Okujagu, Okuru and Abuloma communities, hosting a myriad of industries and businesses, abattoirs, and markets, and on the left by Woji and Elelenwo communities. The Creek lies between latitude 4º50′ 3.912" N and longitude 7º 2′ 23.114"E, and latitude 4º47′ 47.076"N and longitude 7º 4′ 8.303"E (Fig. 1). The area is characterized by the tropical climate of the Niger Delta region of Nigeria, and experiences approximately equal lengths of the dry season (October to March) and the rainy season (April to September), with annual rainfall ranging between 1,500 and 4000mm (Kuruk, 2004). The temperature of the area varies within a narrow limit of 26º and 30ºC throughout the year (Ewa-Oboho et al., 2006). The coastal area along the Creek is generally low land, not more than 3.0 meters above sea level. The tidal movement of the saline water and the estuarine discharge of freshwater from the aquatic ecology of Oginigba / Woji Creek. The mangrove ecology consists of the nypa palm, white mangrove (*Laguncularia racemose*) and *Rhizophora* species as dominant species (Ewa-Oboho et al., 2006; Ibanga et al., 2018).

The creek is shallow brackish water, about 10km long and 250m wide, with a depth of about 5 meters at high tide. The Oginigba/Woji main creek runs from Rumuobiakani through Trans-Amadi, down to Abuloma on the right, then drains and empties into the Bonny estuary. The abundant natural resources of the creek provide very important ecosystem services such as fishing, swimming, transportation, etc. to the coastline inhabitants, as well as the city dwellers. There is a high population of coastline dwellers without good sanitary and waste management facilities. The riverine inhabitants discharge raw sewage into the creek and openly dump their domestic waste into it. The Creek receives municipal sewer and industrial waste discharges from most of the industries within the Trans-Amadi Industrial Area of Port Harcourt. Some of these industries include: Rivers State Vegetable Oil

Company (RIVOC), Halliburton Energy Services Nigeria Limited, Schlumberger Nigeria Limited, PABOD Breweries, Coca-Cola Bottling Company and Petrol Service Stations, and ALCON Nigeria Limited and other companies on the Woji side of the Creek; other human activities and industries on the bank of the Creek are markets, abattoirs, boat building and sand collection. The wastes generated by these activities and discharged into this water body have the potentials to adversely impact the water quality characteristics, flora and fauna species of the Oginigba / Woji Creek.

Sampling and Sample Preparation: Sampling was done at low tide once a month for twelve months, covering two seasons, Dry and Rainy seasons. The Rainy season sampling was done from April to September 2019, while the Dry season sampling was done from October 2019 to March 2020. Fish samples were collected from along the Oginigba/Woji Creek fresh from a local fisherman that uses a row boat and nylon gillnet to catch the fish, and properly identified. A total of 8 specimens, 4 tilapias and 4 mullets of different sizes were collected during each sampling period. Each fish sample was washed at the bank of the Creek with clean water, weighed using FDA-approved balance (Labtech BL 3002 Japan), and the total length taken from the tip of the snout to the end of the caudal fin using a transparent plastic ruler (Best 12 inch/30cm ruler). Removal of scales and dissection were done using a stainless steel knife to obtain the epaxial muscles, gills, liver and intestine. The fish organs were obtained fresh and collected in separate pre-cleaned, leached and well-labelled plastic plates, properly covered and transported to the laboratory the same day in the plastic cooler for heavy metals analysis.

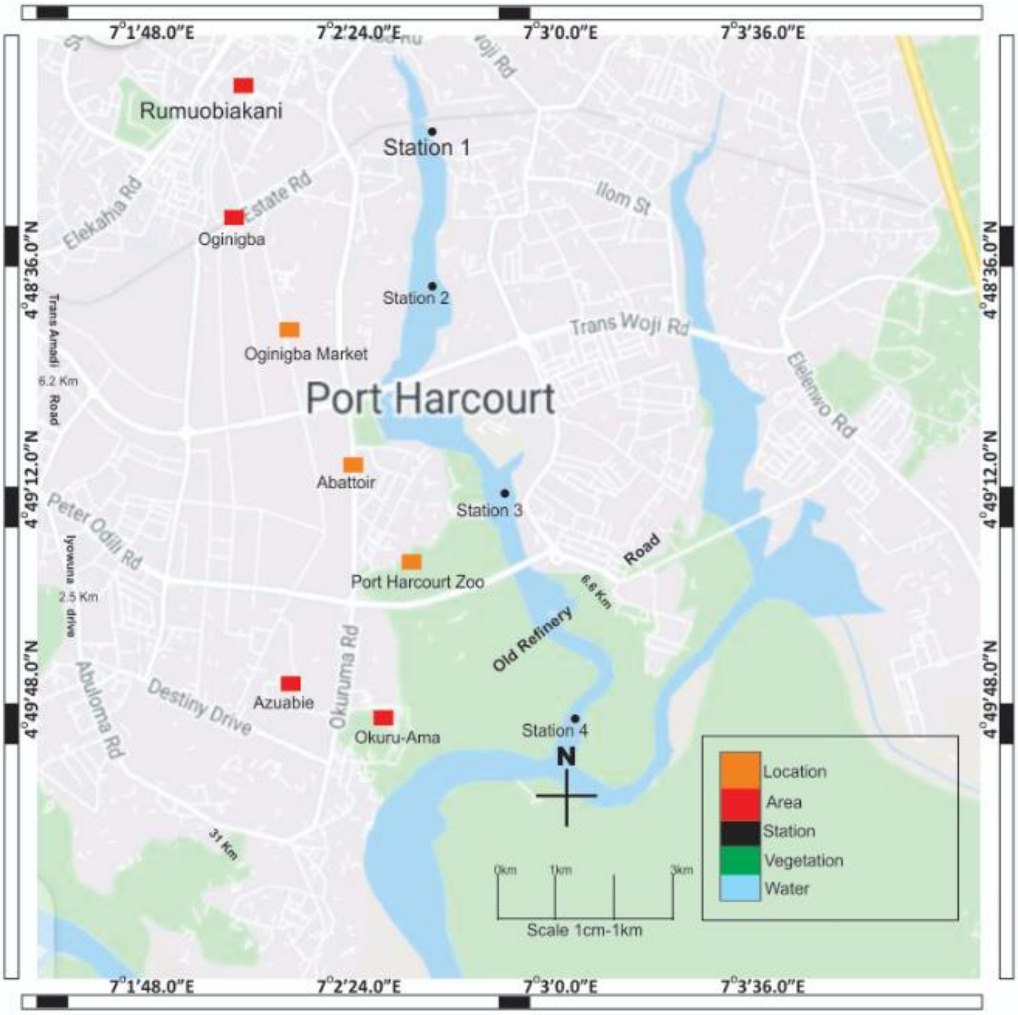

Fig. 1: Map of Oginigba/Woji Creek Showing Study Area

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Heavy Metals Analysis of Fish Organ Samples: Fish organ samples (muscles, gills, livers and intestines) digestion was carried out by Dry Ashing in muffle furnace and extracted with 10% HCL and 10% HNO_3 (Abbruzzini et al., 2014).

Properly cleaned and well dried platinum dishes were placed in the muffle furnace and ignited and covered at 500℃ for 30 minutes. The dishes were then cooled and covered in a desiccator and then weighed until a constant weight was obtained.

2gms of sample was then accurately weighed using a micro balance. The sample is charred, slightly opening the cover for escape of gases, and then in the furnace at 500℃ (loss of chlorides, oxides, sulfates or phosphates due to volcanisation tends to occur above 500℃. The set-up was checked periodically (overnight) for complete ashing, that is, when a whitish residue remains in the platinum dish.

To the ash in the platinum dish, 5ml of 10% HCL solution was added and warmed in a water bath to dissolve. The solution was further treated with 5ml of 10% HNO_3 and warmed in a water bath to completely dissolve the ash. The solution was transferred using a stirring rod through a Whatman 0.45mm membrane filter paper in a filter funnel into a well-cleaned properly dried 20ml standard volumetric flask. The filtrate was diluted to 20ml mark using distilled-deionized water. Aliquots of the ash solution were then aspirated on presentation to the initialized AAS (Model GBC 908 PBMT, Australia).

The concentration of the individual metal(s) was determined thus:

$$\text{Metal concentration (Mg/kg dry weight)} = \frac{A \times V_1 \times DF}{V_2}$$

Where: A = AAS concentration (mg/l)
V_1 = Total volume of Digest (ml)
DF = Dilution factor
V_2 = Initial Weight of sample

Quality Control: Fish organ samples were analyzed at Analytical Concept Limited, Elelenwo Port Harcourt, Rivers State; a government-accredited laboratory, very close to the study area. All glassware and plastics used for sample analysis were thoroughly washed with acid (cleansing reagent) and properly rinsed with distilled-deionized water to avoid metal contamination. Glassware was properly dried in a hot air oven at 160℃ for about 2 hours. Reagents employed in the analysis of samples were confirmed to be of analytical (standard) grade. The concentration of heavy metals was determined against serially diluted standards and blanks with every batch of samples using the Atomic Absorption Spectrophotometer (AAS) (Model GBC 908 PBMT, Australia). All settings and operational conditions of the AAS were carried out in agreement with the manufacturer's instructions.

Statistical Analysis: The data obtained from field and laboratory analysis were subjected to one- and two-way analysis of variance (ANOVA) and t-test to evaluate the difference between sample means. The significance level was set at $P<0.05$. Statistical analysis was done using the window-based statistical package for social sciences (SPSS) software version IBM SPSS statistic 23.0, 2015 IBM corporation, and Microsoft Excel 20. The concentration of heavy metals in fish organs was reported as mg/kg dry weight. Results were compared with maximum permissible limits (MPL) set by national and international regulatory agencies, as well as with previous studies.

Results

The concentration of heavy metals (Cd, Pb, Fe, Cu, Zn and Mn mg/kg dry wt) in the muscles, gills, liver and intestine of *S. melanotheron* and *M. cephalus* are summarized in Table 1. Results of data analysis showed that Cd had its highest mean concentration (mg/kg dry wt) of 0.75±0.25 and 0.75±0.30 in the gills of *S. melanotheron* and intestine of *M. cephalus* respectively and the lowest mean of 0.06±0.05 and 0.06±0.03 in the muscles of *S. melanotheron* and liver of *M. cephalus* respectively**.** Insignificant differences were observed in the mean Cd concentrations among fish organs of *S. melanotheron* and fish organs of *M. cephalus*. Similarly, comparison between the two fish species exhibited insignificant variations at $p>0.05$ in relation to the selected organs (Fig. 2).

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However, comparison with recommended guidelines showed that mean Cd concentrations in the fish organs of both fish species exceeded the maximum permissible limit of 0.05 mg/kg set by the FAO/WHO (2011) for human consumption**.**

Table 1: Mean Concentration of heavy metals in selected fish organs of *S. melanotheron* and *M. cephalus* caught from Oginigba/Woji Creek

Heavy metals	*S. melanotheron*					*M. cephalus*					
Mg/kg	Muscles	Gills	Liver	Intestine	p-value	Muscles	Gills	Liver	Intestine	p-value	Ref. val. (FAO/WHO)
Cadmium	0.06±0.05	0.75±0.25	0.08±0.07	0.62±0.23	0.166	0.35±0.14	0.55±0.18	0.06±0.03	0.75±0.30	0.830	0.05
Lead	0.43±0.18	1.85±0.49	0.57±0.32	1.59±0.47	0.108	1.84±0.55	1.56±0.45	0.49±0.19	2.30±1.29	0.048	0.30
Iron	59.98±5.36	428.28±71.34	802.43±65.22	1440.13±222.95	0.142	52.45±5.14	295.47±68.76	487.85±96.50	1005.26±218.42	0.173	43
Copper	3.84±0.63	7.43±1.05	190.37±67.77	17.68±4.41	0.622	3.94±0.96	7.66±1.31	53.99±7.92	12.95±1.98	0.437	30
Zinc	20.28±3.36	51.60±11.52	102.37±18.34	76.00±15.40	0.122	22.92±2.26	36.58±5.29	92.78±13.20	56.37±7.46	0.051	40
Manganese	1.64±0.45	6.56±1.42	4.58±1.19	18.93±5.66	0.146	1.37±0.36	11.55±2.28	5.77±1.55	16.90±4.23	0.089	5.5

Legend: There were no significant differences (p>0.05) in the mean heavy metal concentrations in selected fish tissues, except Pb in *M. cephalus*.

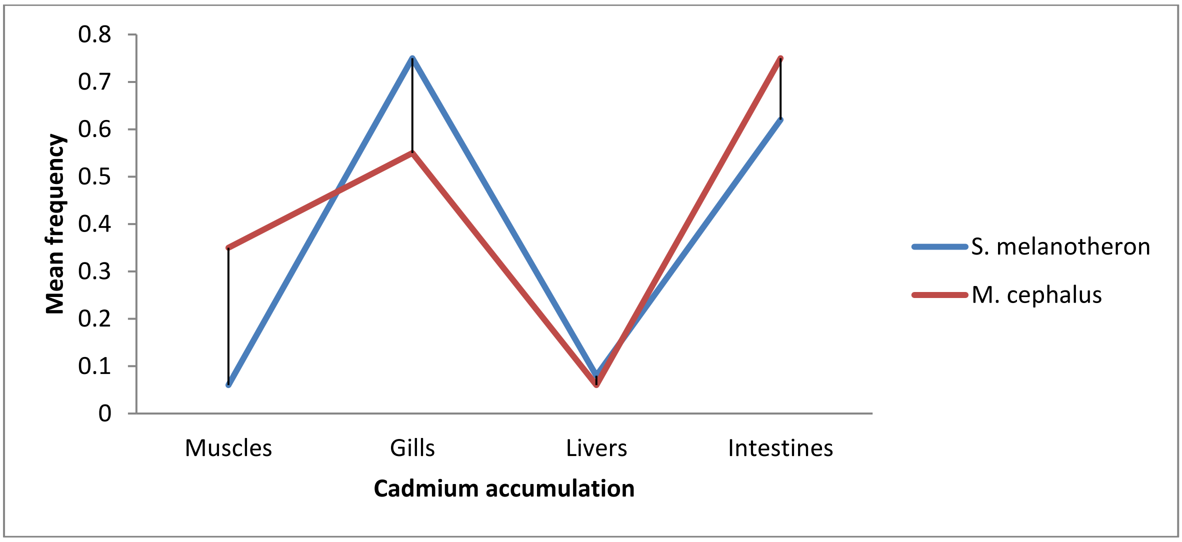

Fig. 2: Accumulation of cadmium in selected fish organs in two fish species from Oginigba/Woji Creek. Legend: p-value = 0.84, not significantly different.

The mean concentrations (mg/kg dry wt.) of Pb in fish organs was maximum (1.85±0.49) in the gills of *S. melanotheron* and in the intestine (2.30±1.29) of *M. cephallus*, whereas the minimum concentrations of Pb were 0.43±0.18 and 0.49±0.19 mg/kg dry wt. obtained in the muscles of *S. melanotheron* and liver of *M. cephalus* respectively (Table 1). The mean levels of Pb in fish organs revealed insignificant (p>0.05) differences in the selected organs of *S. melanotheron*, while mean Pb concentrations amongst organs of *M. cephalus* showed significant variations at p<0.05. However, a comparison between the two fish species (Fig. 3) indicated that there were no significant differences in the mean Pb concentration of the different organs at p>0.05. The mean Pb

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concentrations found in the organs of the two fish species were higher than FAO/WHO (2011) permissible limit of 0.3 mg/kg in food fish.

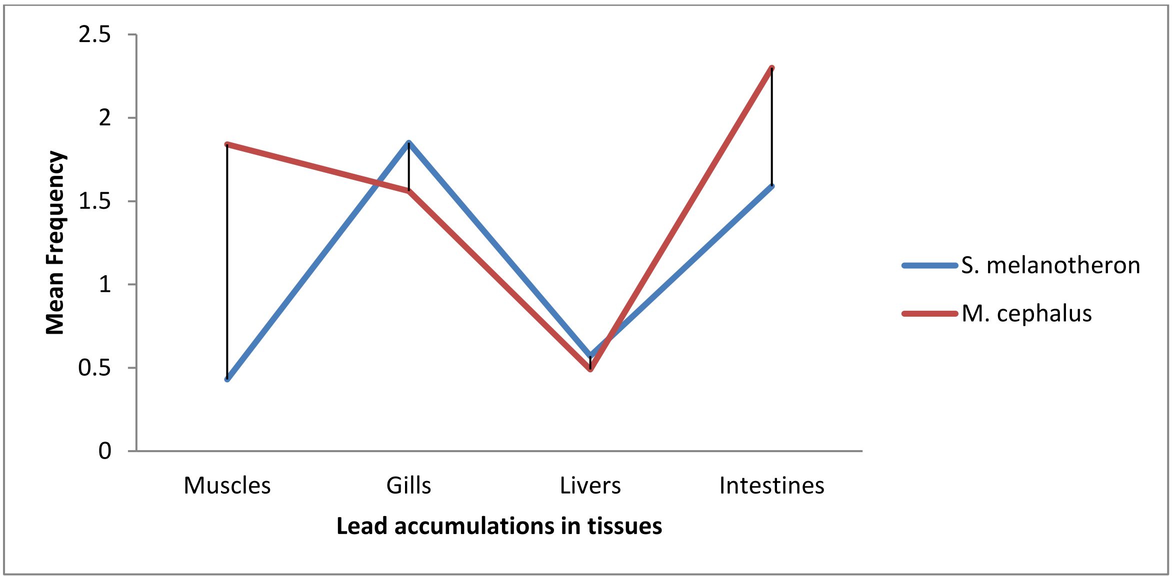

Fig. 3: Accumulation of Lead in selected fish organs in two fish species from Oginigba/Woji Creek.
Legend: p-value is 0.44; not significantly different.

Mean Fe concentrations (mg/kg dry wt.) in selected fish organs ranged from 59.98±5.36 (in the muscles) to 1440.13±223.95 (in the intestine) in *S. melanotheron,* and 52.45±5.14 (in the muscles) to 1005.26±218.42 (in the intestine) in *M. cephalius* (Table 1)**.** Fe concentration levels amongst the organs of *S. melanotheron* and the organs of *M. cephalus* were not significant at p>0.05. Comparison between the two fish species (Fig. 4) also showed insignificant variations in the mean Fe concentrations of fish organs at p>0.05. However, the obtained data revealed that mean Fe concentrations exceeded the maximum permissible limit of 43 mg/kg (FAO/WHO, 2011) in fish tissues of *S. melanotheron* and *M. cephalus.*

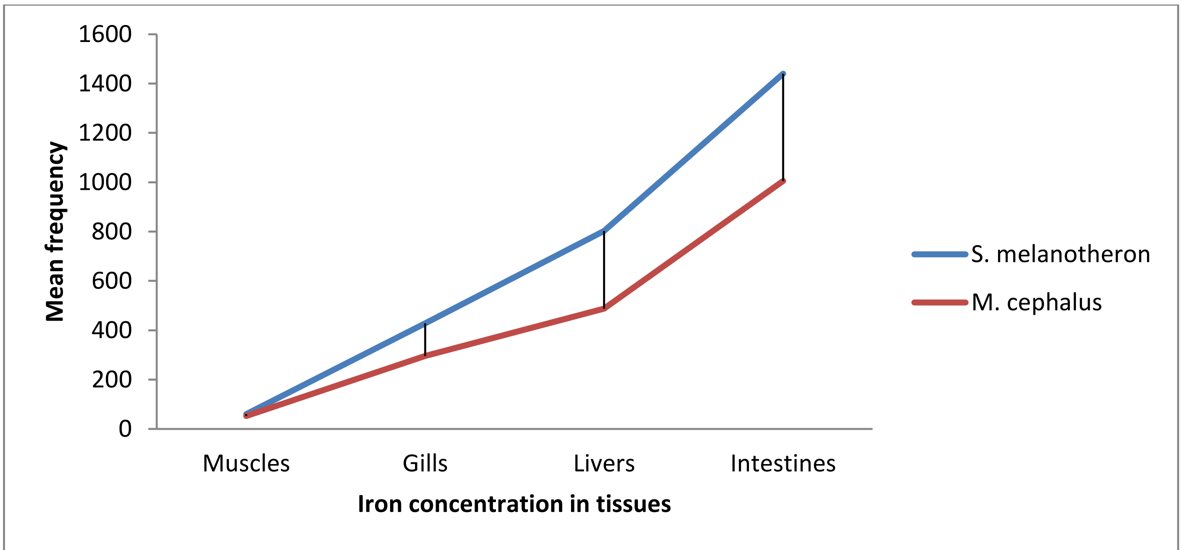

Fig. 4: Accumulation of Iron in selected fish organs in two fish species from Oginigba/Woji Creek.
Legend: p-value = 0.56; not significantly different in the two fish species in different organs examined.

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Mean Cu concentrations (mg/kg dry wt.) in the tissues of *S. melanotheron* ranged from 3.84±0.63 to 190.37±67.77 with the highest mean concentration detected in the liver and the lowest in the muscles. It ranged from 3.94±0.96 in the muscles to 53.99±7.92 in the liver in *M. cephalus* (Table 1). Statistical analysis showed that mean Cu concentration in the different organs of *S. melanotheron* and organs of *M. cephalus* exhibited insignificant variations at p>0.05. Comparison between the two fish species of *S. melanotheron* and *M. cephalus* (Fig. 5) showed that there were no significant differences (p>0.05) in the mean Cu concentrations in the different organs except in the liver. The mean Cu concentration detected in the liver tissues of *S. melanotheron* was higher than the maximum acceptable limit, whereas mean concentrations in the muscles, gills and intestine were within recommended limit of 30 mg/kg set by FAO/WHO (2011). Similarly, mean Cu concentration in the liver tissues of *M.cephalus* exceeded the maximum acceptable limit, while mean Cu levels in the muscles, gills and intestine were within guidelines in food fish.

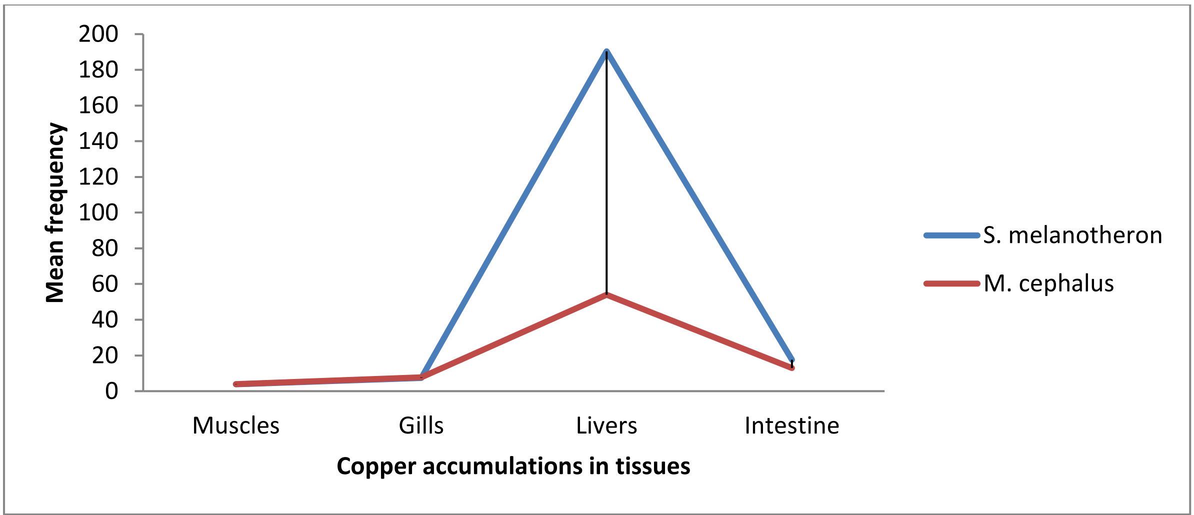

Fig. 5: Accumulation of Copper in selected fish organs in two fish species from Oginigba/Woji Creek.
Legend: p-value is 0.4799; not significantly different except in liver.

Data analysis also showed that mean Zn concentration (mg/kg dry wt.) ranged from 20.28±3.36 in the muscle to 102.37±18.34 in the liver of *S. melanotheron*, representing the lowest and highest mean concentrations respectively. In like manner, the mean Zn concentration of *M.cephalus* ranged between 22.92±2.26 mg/kg dry wt. in the muscles and 92.78±13.20 mg/kg dry wt. in the liver, representing the lowest and highest mean concentrations respectively (Table 1). Analysis of variance at p>0.05, indicated that organ variations in mean Zn concentrations in *S.melanotheron* and mean Zn concentrations in *M.cephalus* were insignificant. Similarly, comparison between different fish organs (muscles, gills, liver and intestine) of the two fish species (Fig. 6) revealed that mean values of Zn concentration were statistically insignificant at p>0.05. The mean Zn concentrations among fish organs of *S.melanotheron* were higher than the safe limit (40 mg/kg) proposed by the FAO/WHO (2011), except in the muscles (20.28 mg/kg). The mean Zn levels of muscle and gills of *M.cephalus* were within the reference limit, while mean levels in the liver and intestine exceeded the safe limit.

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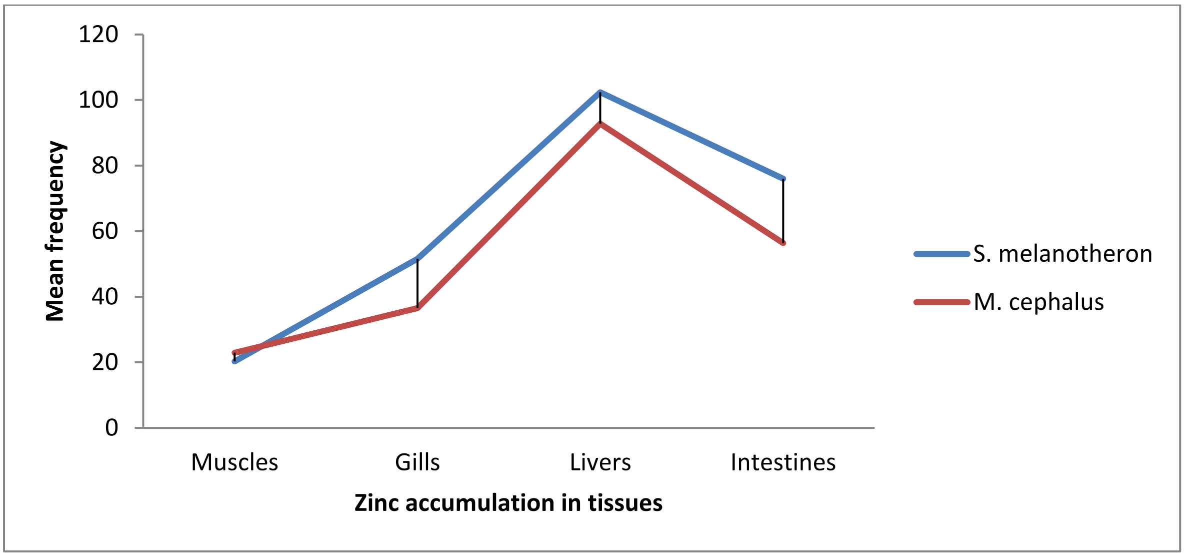

Fig. 6: Accumulation of Zinc in selected fish organs in two fish species from Oginigba/Woji Creek.
Legend: p-value is 0.67; statistically insignificant

The highest mean value (18.93±5.66 mg/kg dry wt.) of Mn was recorded in the intestine and the lowest value (1.64±0.45 mg/kg dry wt.) was obtained in the muscles of *S.melanotheron*. In *M.cephalus*, the highest mean value (16.90 ±4.23 mg/kg dry wt.) was found in the intestine and the lowest value (1.37±0.36 mg/kg dry wt.) in the muscles (Table 1). Data analysis showed that organ variations in mean Mn concentration in *S. melanotheron* and in *M. cephalus* were not significant at p>0.05. It was also noticed that differences between mean Mn levels in fish organs of *S.melanotheron* and fish organs of *M.cephalus* were insignificant at p>0.05 (Fig. 7). However, mean Mn concentrations in muscle tissues of both fish species, and in the liver of *S. melanotheron* falls within the reference value of 5.5 mg/kg set by FAO/WHO (2011) in food fish, whereas the other fish organs exceeded the safe limit

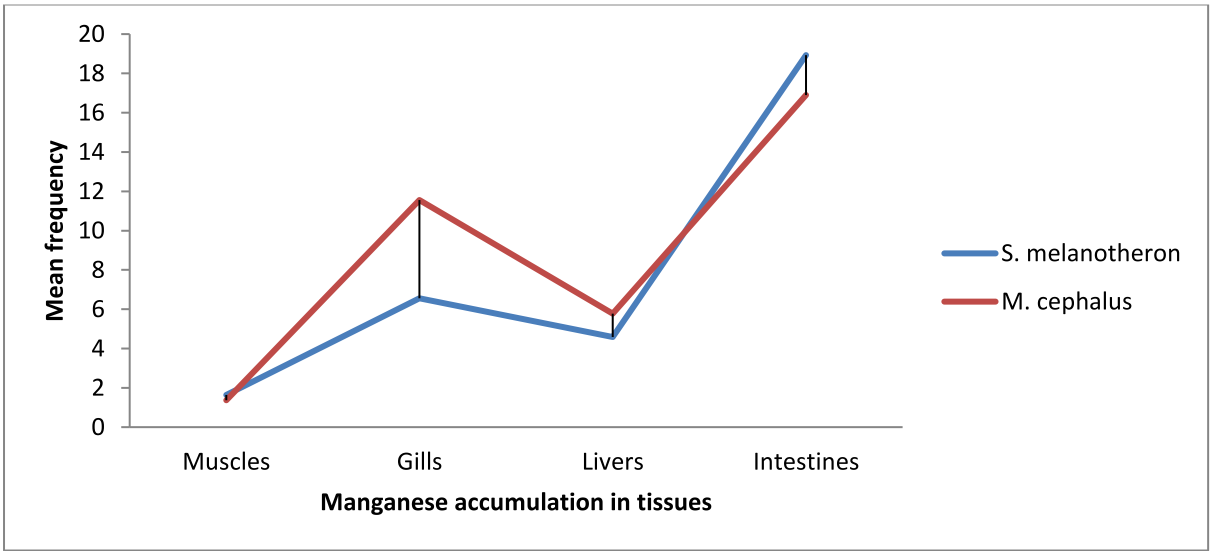

Fig. 7: Accumulation of Manganese in selected fish organs in two fish species from Oginigba/Woji Creek.
Legend: p-value is 0.86; not statistically significant.

The distribution of heavy metal concentrations in the selected organs of *S. melantheron* was in the sequence:
Muscles – Fe > Zn > Cu > Mn > Pb > Cd
Gills – Fe > Zn > Cu > Mn > Pb > Cd
Liver – Fe > Cu > Zn >Mn > Pb > Cd
Intestine – Fe > Zn > Mn > Cu > Pb > Cd
Whereas the heavy metal concentrations in organs of *M.cephalus* were detected in the following order:
Muscles – Fe > Zn > Cu > Pb > Mn > Cd
Gills – Fe > Zn > Mn > Cu > Pb > Cd
Liver – Fe > Zn > Cu > Mn > Pb > Cd
Intestine – Fe > Zn > Cu > Mn > Pb > Cd

Table 2: Seasonal variations in heavy metals in two fish species from Oginigba/Woji Creek.

Parameters-	The rainy season (April – Sept.) (*S.melanotheron*)	Dry season (Oct. – March) (*S.melanotheron)*	P-Value	Rmk.	The rainy season (April – Sept.) (*M.cephalus*)	Dry season (Oct.– March) (*M.cephalus*)	P-Value	Rmk.	Ref. Value (FAO/ WHO)
Cd	0.01±0.01	0.76±0.13	0.041	SIG.	0.02±0.01	0.82±0.30	0.038	SIG.	0.05
Pb	0.17±0.08	2.03±0.14	0.026	SIG.	0.33±0.18	4.70 ± 2.07	0.080	NS	0.30
Fe	495.44±48.19	864.75±174.07	0.439	NS	250.02±94.48	680.07±319.32	0.244	NS	43
Cu	24.70 ± 5.04	84.94±7.36	0.450	NS	12.89±7.59	26.38±15.61	0.467	NS	30
Zn	35.24±2.53	89.49±10.87	0.105	NS	38.88±9.45	69.43±20.92	0.183	NS	40
Mn	1.87±0.55	13.98±3.19	0.141	NS	3.32±1.44	14.45±5.47	0.097	NS	5.5

Legend: Cd varied with the season in the two species examined, Pb varied with the season in *S. melanotheron*, while there were no significant differences in the other four heavy metals examined, i.e. no seasonal effect.

Table 3: Comparison between metal concentration in fish species of the present study and previous studies in the Bonny estuaries.

Heavy metals (mglkg)	Present study		Previous Studies			
			Marcus *et al* (2013)		**Miebaka (2017)**	**Moslen & Miebaka (2017)**
	S.melanotheron	*M.cephalus*	*M.cephalus*	*T.guineensis*	*M. cephalus*	*S. Melano-theron*
Cd	0.38	0.43	ND	ND	0.33	0.38
Pb	1.11	1.55	1.09	0.63	2.96	5.12
Fe	682.71	460.26	-	-	-	-
Cu	54.83	19.64	-	-	4.12	5.59
Zn	64.56	52.16	-	-	-	-
Mn	7.93	8.90	-	-	-	-

Legend: Metal concentrations in fish species of the present study are means of the four organs. The concentration of heavy metals in fish species of the present study were generally elevated compared to previous studies in the Creeks of Bonny estuaries.

Discussion of findings

The distribution of heavy metals in fish organs in the present investigation demonstrated the bioconcentration of investigated metals in various organs in different amounts in the selected fish species.

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The fish muscle is the edible part of the fish, rich in essential nutrients, and has been reported to contain the lowest level of metals compared to other tissues (Jezierska & Witeska, 2006; Samir & Ibrahim, 2008; Alireza et al., 2011; Abdulali et al., 2011; Bawuro et al., 2018; Rajeshkumar & Li, 2018). This investigation revealed that, generally, metal concentration in the muscles was lower than in the other organs, however, the non-essential metals, Cd and Pb, showed concentration levels above established guidelines, reflecting the high input of these metals from anthropogenic activities in and around the study Creek, whereas the essential metals, Cu, Zn and Mn were within recommended limits. These observations are pointers to serious health risks for human consumers of *S. melanotheron* and *M. cephalus* from the Oginigba/Woji Creek.

The concentrations of Cd, Pb, Zn and Mn obtained in fish organs of both fish species in this study, were similar to the observations reported by Vincent–Akpu and Babatunde (2013) in fish species collected from Elechi Creek, and Akankali et al. (2018) for Zn concentrations in *M. cephalus* collected from the Iwofe section of the New Calabar River. However, Akakanli et al. (2018) did not find Cd in *M. cephalus*, but reported high Pb concentration levels (7.97±0.02 - 31.96±0.05 mg/kg) in fish organs. Oboh et al., (2019) assessed heavy metals in fish collected from Ikpoba River, Edo State, Nigeria, and reported generally similar metal concentrations in fish organs.

The mean heavy metal concentrations (mg/kg dry wt.) in *S. melanotheron* and *M. cephalus* from Oginigba/Woji Creek with seasonality are given in Table 2. The distribution of heavy metals in fish organs of *S. melanotheron* and *M. cephalus* were elevated in the Dry season. This may be due to their feeding habits (as bottom feeders), increased metabolic rate, high rate of metal uptake and binding, and high level of sedimentation of heavy metals during the Dry season under the influence of high temperature and pH. Previous studies on seasonal variations of heavy metal levels in fish organs reported similar observations (Jezierska & Witeska, 2006; Alireza et al., 2011; Hany & Elwoa, 2012; Ayanka et al., 2016; Rajeshkumar & Li, 2018; Ibanga et al., 2018). Obeka and Numbere (2020) studied the heavy metal concentrations and public health risks of consuming *Sardinella maderensis* (Sardine*), S. melanotheron* (Tilapia), and *Liza falicipinis* (Mullet) from Bonny River, Niger Delta, Nigeria, and discovered that metal accumulation in fish was higher during the dry season.

This investigation found that Cd and Pb varied significantly in *S. melanotheron,* while Cd varied significantly in *M. cephalus* concerning seasonality. There were no significant variations in the other remaining metals investigated. Al-Majed and Preston (2000) and Sadiq et al. (2002), had attributed the variations in the heavy metals content of fishes to their body size, whereas Yi and Zhang (2012), linked heavy metal variations in fish tissues to size, pollution load and sediment enrichment of the area.

Conclusion

This investigation showed that there was heavy metals enrichment of fish organs, most of them above safe levels, which reflects the sustained input of these metals from industrial and municipal wastewaters, and myriads of anthropogenic activities in and around the study Creek. Heavy metals level was generally higher in fish liver, followed by fish intestine and then the gills, the muscle recorded the least concentration in the studied fish species. However, the non-essential metals, Cd and Pb in both fish species showed concentration levels above safe limits, while the essential metals, Cu, Zn and Mn were within safe limits. The elevated levels of the non-essential metals, Cd and Pb in the selected fish species are pointers to serious health risks for human consumers, especially during the Dry season. Therefore, there is a need for restoration and corrective actions to mitigate the toxicity levels of the non-essential metals in the study Creek.

Contributions to knowledge

1. This study revealed that sediment is the major source of heavy metal enrichment in fish organs of the two fish species examined.
2. The livers and intestines of these fish species should be excised before consumption to avoid heavy metals toxicity and to guarantee the provision of the needed essential nutrients.
3. Heavy metal concentration levels in the water, sediment and fish are generally elevated during the dry season.

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