Original Research Article

DETERMINATION OF HEAVY METAL CONCENTRATION IN TWO BONY FISH (CATFISH AND TILAPIA) FROM ORASHI RIVER IN RIVERS STATE, NIGERIA.

ABSTRACT

The research was intended to study the influence of human and industrial activities on the Orashi River and two bony fish (*Clarias gariepinus* and *Tilapia nilotica).* Three groups have impacted the environment – Oil/gas industries, tyre burning from the abattoir, untreated human and animal waste from settlers and the abattoir. The study was carried out between September 2019 to August 2020. The mean concentrations of the parameters studied in some samples were close to or exceeded the World Health Organization (WHO) and the Federal Ministry of Environment (FMEnv) recommended drinking water and seafood limits. The results from this study have provided information on the heavy metals profile of the river's fish.

The level of heavy metals in the muscle of Catfish and Tilapia showed a range of Cd in Catfish (1-3.9mg/kg and Tilapia (0.1-4.2mg/kg), with the highest level occurring in station 2(3.47mg/kg for Catfish and 3.39mg/kg for Tilapia) which is high with regard to FAO (1983), FAO/WHO (1989), EEC (2005) permissible limit of 0.01mg/l and USEPA SQG (1mg/kg) level in seafood.

The levels of essential heavy metals in fish muscle were Cu (Catfish-10.9-33mg/kg, Tilapia -17.3-40.6mg/kg), Fe (Catfish-1.0-2.5mg/kg, Tilapia -0.1-5.6mg/kg) were within the FAO 1983 permissible limit while Zn (Catfish-22-213.2mg/kg) and Tilapia (30.1-196mg/kg) exceeds the limit in some stations. Catfish muscles recorded higher mean value (127.12mg/kg) for all heavy metals than tilapia (44.03mg/kg) and the sequence is Cu > Zn > Fe > Cd. The concentration of heavy metals in Orashi River is in the sequence: Sediment > Catfish > Tilapia >Water. The THC levels in muscle of Catfish (0.5-1.8mg/kg) and Tilapia (0.1-3.8mg/kg) were within permissible limit.

KEYWORDS: Metal, Determination, Industries, Seafood, Orashi River, Contamination.

INTRODUCTION

BACKGROUND INFORMATION

Water is the most critical natural resource, and there is a lot of conflicting demand for them. Skilful management of water bodies is required if they are to be used for such diverse purposes as domestic, industrial supply, crop irrigation, transport, recreation, sports, commercial fisheries, power generation and waste disposal. Water bodies are vulnerable to contamination accidents and bioterrorism attacks because they are relatively unprotected, easily accessible, often isolated and their various use by humans pre-disposes them to contamination. (Gullick *et al*; 2003). Environmental exposure to toxic metals is a critical issue in environmental and public health.

The modern world is aware of the relationship between water and water-borne diseases as a vital public health issue. (Tebbutt 1992., WHO 1997., Olashansky *et al,* 1997., Asonye *et al,* 2007., Okwodu, 2011).

Heavy metals are well-known pollutants in aquatic systems where industrial wastes are discharge, petroleum production and refining, gas flaring, gas processing plants and conveyance pipelines (Okoye *et al*, 1991, Izonfuo and Bariwanli 2001, Olarije 2003). Gas flares are operated in a relatively uncontrolled manner in the Niger Delta region. These effluents discharge and atmospheric emissions from flow stations and refineries often settle in the aquatic environment. When contamination reaches levels over the assimilative capacity of the receiving waters, it may affect the survival, reproduction capacity, growth and behavioral condition of organisms. (Elligard and Rudner 1992., Nash 1993., Chukwu and Odunzeh 1993., Tam and Wang 1995., Asonye *et al,* 2007).

Fishes inhabit different parts of water and are called aquatic organisms. Some live in a cold world and are called temperate fishes, others live in a warm continent and are called tropical fishes-yet others are found in both continents. Some fish live in saltwater and are called marine fishes, and others live in fresh water and are called freshwater fishes. Fishes are important as a source of food, foreign exchange earner, employment, unity in a community and cultural identity, Aesthetic value, scientific study of aquatic life etc.

The fish of interest include the African Mud Catfish (*Clarias geriepinus*) and Tilapia *(Tilapia niloticus*) tropical freshwater fish inhabiting Orashi River. These two species were chosen for the study because they are sedentary or resident in the area of interest, easy to identify, abundant all year round, long-lived, be available for sampling all year. It has economic value to the inhabitant of the area and could be good bio-indicators as they feed on the surface water and sediment directly or indirectly.

In attempting to define and measure the effect and presence of pollutants on aquatic ecosystems, biomarkers or bio-indicators have attracted a great deal of interest. Fish has been used for many years to indicate whether water is clean or polluted. For instance, fish and shellfishes, including bivalves are vulnerable to metal contamination and have been reported as effective bio-monitors used for heavy metal monitoring purposes worldwide (Ferreira *et al*, 2004, Tay *et al,* 2004, Otchere, 2003, Mansour and Sidky 2002., Canli and Atli 2003., Agbozu *et al,* 2007). The increased level of heavy metals in humans has often been traced to heavy metal contamination in the aquatic system (Schuwerack *et al,* 2009).

The heavy metals of interest include the non-essential trace element Cd, Cr, and Pb) and the essential metals such as Cu, Zn, and Fe which have important biochemical functions to the organism at very low concentration (Pinto et al, 2003., Aheam *et al*, 2004., Ranbow 2007). These heavy metals are blacklisted in EEC Directive as dangerous substances in the aquatic environment. These heavy metals can be hazardous to humans, even in a tiny amount. They are taken up by aquatic organisms and passed up the food chain through the process known as bio-magnification. Species vary in their degree of tolerance, with the result that under polluted conditions, a reduction in species diversity is the most apparent effect (Edokpayi *et al,* 2000). The intense industrial activity in the Niger Delta region has attracted a lot of research interest. However, no systematic study has been conducted in Orashi River of ONELGA to ascertain its level of metal concentration and the health effects on the inhabitants. This may be attributed but not limited to the restive nature of the area's inhabitants as researchers may be vulnerable to attack by the youths who always vent their anger on soft targets.

It is, therefore, crucial to conduct this study in view of the rapid growth of population, exploration and exploitation of natural resources, lack of environmental regulations, industrialization, urbanization, clearing of bank vegetations, annual dredging of the river to contain flooding, construction of roads and bridges, drains and embankment walls. Agricultural activities of the inhabitant of Ogba/Egbema/Ndoni LGA (ONELGA) to record the range of the concentration within commercial as well as non-commercial species so that assessment about potential hazardous levels from the human nutritional standpoint can be made.

AIM: To determine the concentrations of heavy metals in the two sub tidal edible and commercial Bony fish (*Claries gariepinus* and *Tilapia noliticus*) from Orashi River. This is to enable the assessment of potential hazardous levels from a human nutritional standpoint.

MATERIALS AND METHODS

THE STUDY AREA

The study area is Ogba/Egbema/Ndoni LGA in the Rivers State of Nigeria. (Fig: 1a, b & c). The area has several oil wells and major flow stations within the Niger Delta region of Nigeria. (Plate 2). Nigerian Agip Oil Company (NAOC) and Total E & P Nigeria Limited explore and exploit crude oil and flare gases indiscriminately in Ebocha, Obrikom and Obitte.

The inhabitants of the area are predominantly farmers and fishermen, which is their primary source of livelihood. The area has a growing population of 283, 294 in 2006 and a projection of 398,000 in 2016 (National population commission of Nigeria (web), National Bureau of Statistics (web).

The site is Orashi river, a non-tidal freshwater of the lower Niger basin that runs through some communities in Imo State, Egbema, Ndoni and Ogba communities in Rivers State. The river is a freshwater swamp forest river with several tributaries and originate from River Niger and empties into the Sombrieiro river in Ahoada. (Plate 1). The fishes commonly found in the Orashi River include clarias species, Tilapia, Eels, *Malapterurus electricus, Chysichthys nigrodigitatus* (catfish). The area is tropical with two seasons- the rainy (April –

October) and dry season (November – March), which are usually flooded in the rainy seasons.

Fig 1: maps showing the study area

Fig 1a. Map of Nigeria Showing Rivers State

Fig. 1b Map of Rivers State Showing Ogba/Egbema/Ndoni L.G.A

Fig. 1c Map of Ogba/Egbema/Ndoni L.G.A

Plate 1: Containment of oil spill in Orashi River along station 2 during flooding in October 2019.

SAMPLING STATIONS

A reconnaissance survey was carried out in the study area in November 2018, and then sampling stations were established at five locations along the Orashi River, 5km distance from each other using a Global positioning system navigator (GPS) as shown in Table 5 and represented by station 1 – 5.

Table 1: Geographical positioning system (GPS)

STATIONS	LOCATIONS	COORDINATES
Station 1	Okwuzi	N05^{0}29’08.3” E006^{0}42’26.3”
Station 2	Ebocha	N05^{0}27’49.3” E006^{0}42’06.6”
Station 3	Ndoni	N05^{0}27’24.6” E006^{0}40’27.8”
Station 4	Obrikom	N05^{0}23’31.0” E006^{0}39’03.0”
Station 5	Omoku	N05^{0}20’18.7” E006^{0}38’34.6”

2.3 FIELD STUDY

Water, Sediment and fish samples were collected monthly from the 5 sampling stations monthly beginning from September 2019 for 5 sampling periods during rainy and dry seasons. The sampling of the five stations started at about 8.30 am.

Plate 2: NAOC Oil Well heads near station 1

Plates 3: *T. noliticus* plate 4: *C. gariepinus*

FIELD COLLECTION OF FISH SAMPLES

Fish samples were collected monthly from the five sampling stations from September 2019 to August 2020 for six sampling periods during rainy and dry seasons. The fish samples - catfish (*Clarias gariepinus*) and Tilapia (*Tilapia noliticus*) were purchased from artisanal fishermen from the five (5) stations for each sampling period. The samples were washed in distilled water, kept in labeled airtight plastic containers and packed in a cooler and subsequently transferred to the IPS laboratory of Rivers state University Port-Harcourt for tissue analysis. The samples were frozen until analysis to prevent post Mortem changes that may be either putrefactive or auto-lytic in nature.

DETERMINATION OF HEAVY METALS IN FISHES

The dried and ground samples were taken and digested by the micro- wave digestion method.

In this digestion method, nitric acid (Analar grade) and hydrogen peroxide (Analar Grader) in the ratio of 3:1 were added to the samples. The mixture was digested at 150°C for 30 minutes in the microwave oven.

Microwave digestion was used in this work because studies have shown that it is a more accurate method of digesting samples (especially for organic samples) than other methods such as dry ash and wet digestion. The hydrogen peroxide added to the sample with nitric acid reduces nitrous vapor and speeds up digestion of organic substances by increasing the reaction temperature in the digestion process. The digested samples were filtered with 20ml of de-ionized water. The filtrate was collected with clean acid-washed and appropriately labeled 50ml polyethylene sampling containers for analysis by Atomic Absorption Spectrometric method.

Unicam 969 Atomic Absorption Spectrometer (AAS) was used to determine heavy metals - Zn, Cu, Pb, Cr, Cd, and Fe using the standard method (APHA 1998).

DATA ANALYSIS

All statistical analysis and presentation of results was done using Microsoft Excel and Minitab 16 software.

Raw data was subjected to a two-way analysis of variance (ANOVA) with replication using MINITAB.

Analysis of variance (single factor) was used to test for significant differences between the condition factors values of Catfish and Tilapia from the five study locations.

HEAVY METALS IN FISHES

Six heavy metals were sampled and analyzed in catfish and Tilapia of Orashi River in 5 stations during the monitoring period. These include Chromium, Cadmium, Copper, Lead, Zinc and Iron. Of these metals monitored in fish, Chromium and Lead was not detected throughout the stations during the monitoring period.

CADMIUM (Cd) IN CATFISH.

The concentration of Cadmium recorded in Catfish is presented in appendix 1a and shown in fig. 2. The results indicate that Cadmium levels in Catfish muscle/tissue ranged from 1.0 to 3.9mg/kg in all the stations. The mean values obtained were station 1(3.07), station 2(3.47), station 3(2.93), station 4(3.06) and station 5(1.7).

Seasonal variations in appendix 2 show that Cadmium level was higher during the dry season than in the rainy season.

The analysis of variance (ANOVA) result showed that there is a significant difference ($p < 0.05$) in time (P=O.015).

CADMIUM (Cd) IN TILAPIA.

The concentration of Cadmium recorded in Tilapia is presented in appendix 1b and shown in fig 3. The results indicate that Cadmium levels in tilapia muscle/tissue ranged from 0.1 to 4.2mg/kg in all the stations. The mean values obtained for stations were station 1(2.56), station 2(3.39), station 3(1.07), station 4(2.23) and station 5(2.17mg/kg). Seasonal variations in appendix 3 show that Cadmium level was higher during the rainy season than dry.

The analysis of variance (ANOVA) results in appendix 17 showed that there is no significant difference (p< 0.05) in location and time observed in tilapia muscle/tissue during the sampling period(P=0.979).

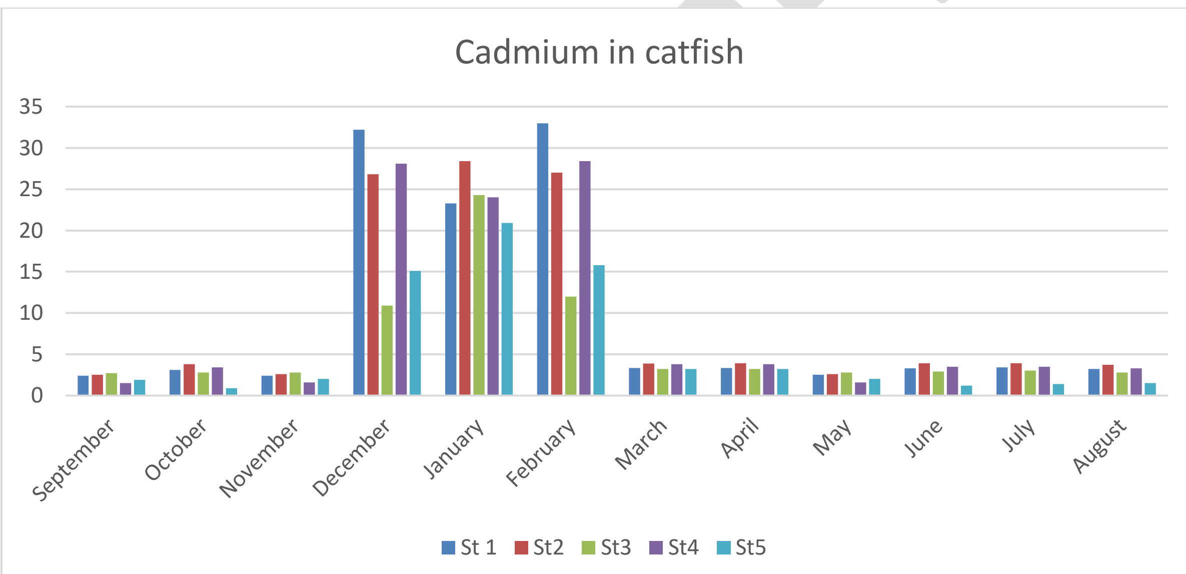

FIG 2: Cadmium (Cd) in Catfish

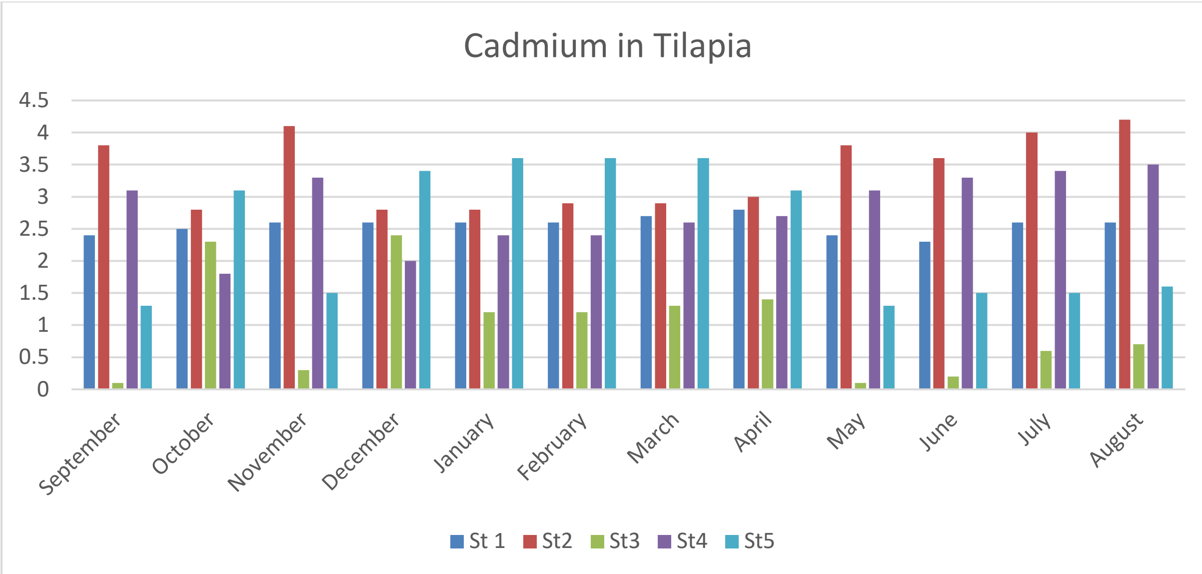

Fig 3: Cadmium (Cd) in Tilapia

COPPER (Cu) IN CATFISH.

The concentration of Copper recorded in Catfish muscle/tissue is shown in fig 4. The results indicate that the Copper levels in this study ranged from 10.9 to 33mg/kg in all the stations. The mean values observed for copper was station 1(28.04), station 2(28.23), station 3(18.18), station 4(26.58) and station 5(19.08mg/kg).

Seasonal variations show that the Copper level was higher during the dry season than the rainy season.

The analysis of variance (ANOVA) result showed there was no significant differences ($P< 0.05$) in time ($P=0.837$)

COPPER (Cu) IN TILAPIA.

The concentration of Copper recorded in tilapia is shown in fig 5. The results indicate that Copper levels in this study ranged from 17.3 to 40.6mg/kg in all the stations. The mean values observed for copper in tilapia was station 1(19.24), station 2(33.68), station 3(28.12), station 4(27.33) and station 5(25.26)mg/kg.

Seasonal variations show that the Copper level was higher during the rainy season than the dry season. (Appendix 3)

The analysis of variance (ANOVA) result showed there was significant differences ($p< 0.05$) in time ($p=0.019$)

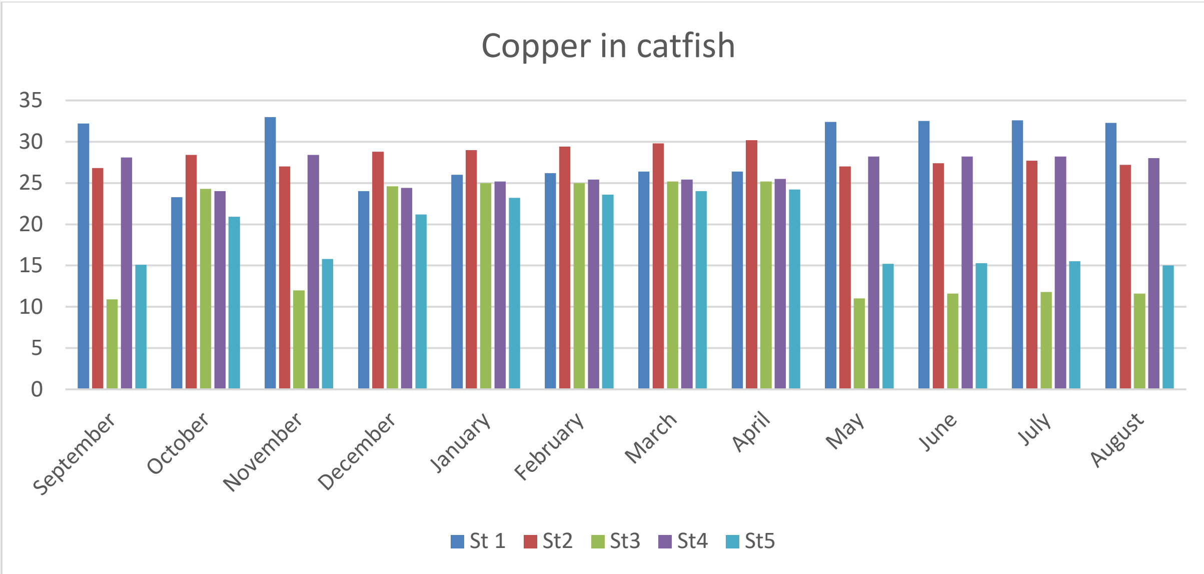

Fig 4: Copper (Cu) in Catfish

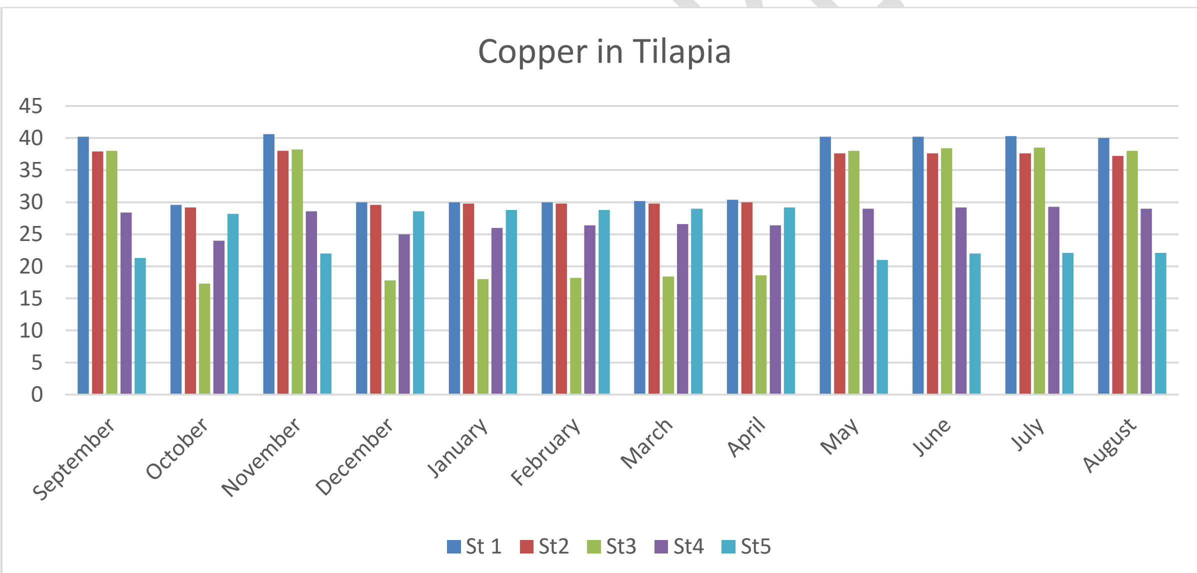

Fig 5: Copper (Cu) in Tilapia

ZINC (Zn) IN CATFISH MUSCLE/TISSUE.

The concentration of Zinc recorded in Catfish muscle/tissue is shown in fig 6. The results indicate that the Zinc levels in this study ranged from 22 to 213.2mg/kg in all the stations. The mean values observed for copper was station 1(59.6), station 2(37.03), station 3(51.87), station 4(139.34) and station 5(80.77) mg/kg.

Seasonal variations show that Zinc level was higher during the dry season than in the rainy season. (Appendix 2)

The analysis of variance (ANOVA) result showed there was no significant differences (p< 0.05) in location and time (P=0.625).

ZINC (Zn) IN TILAPIA.

The concentration of Zinc recorded in tilapia muscle/tissue is shown in fig 7. The results indicate that the Zinc levels in this study ranged from 30.1 to 196mg/kg in all the stations. The mean values observed for Zinc in tilapia was station 1(40.19), station 2(82.29), station 3(79.68), station 4(62.28) and station 5(158.73) mg/kg.

Seasonal variations show that Zinc level was higher during the dry season than in the rainy season. Zinc level was highest in January followed by October, December, February and March. (Appendix 3)

The analysis of variance (ANOVA) result showed there was no significant differences (p< 0.05) in Zn level observed in tilapia muscle/tissue during the study period. (p=0.696)

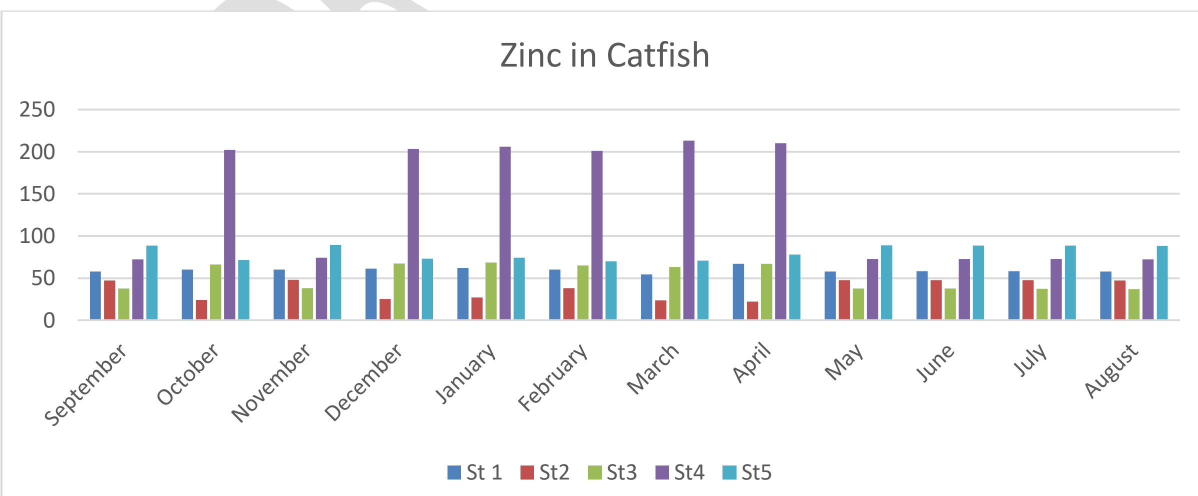

Fig 6: Zinc (Zn) in Catfish

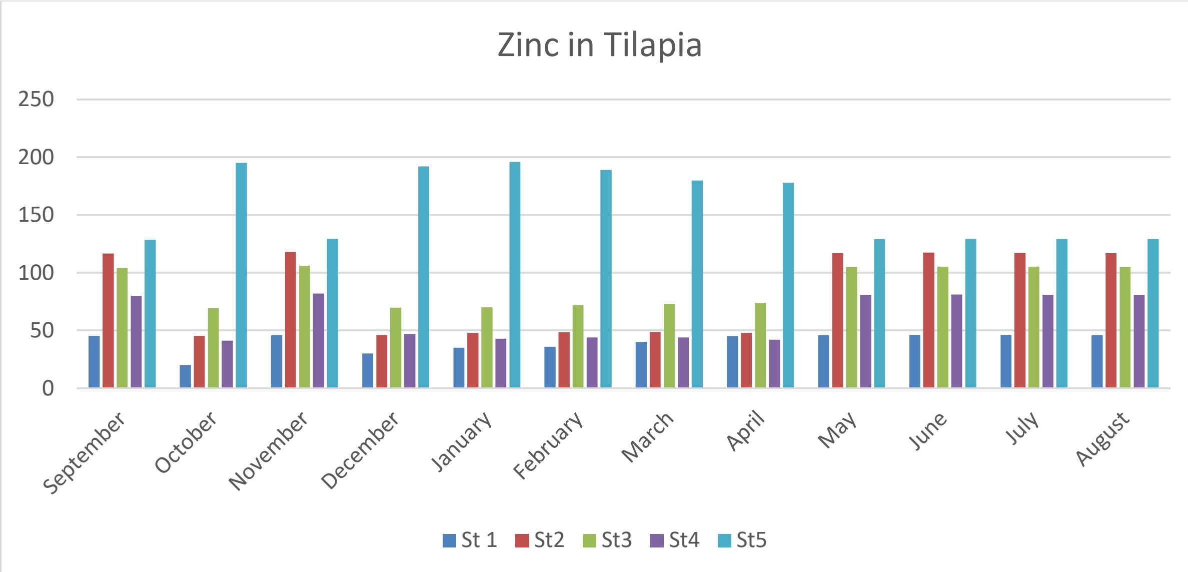

Fig 7: Zinc (Zn) in Tilapia

IRON (Fe) IN CATFISH MUSCLE/TISSUE.

The concentration of Iron recorded in Catfish muscle/tissue is shown in fig 8. The results indicate that the Iron levels in this study ranged from < 0.02 to 2.5mg/kg in all the stations. The mean values observed for copper was station 1(0.72), station 2(1.09), station 3(1.21), station 4(1.46) and station 5(1.15) mg/kg.

Seasonal variations presented in Appendix 2 show that the Iron level was higher during the dry season than the rainy season.

The analysis of variance (ANOVA) result showed there was significant differences (P< 0.05) in location and time (P=0.026).

IRON (Fe) IN TILAPIA.

The concentration of Iron recorded in tilapia muscle/tissue is shown in fig 9. The results indicate that the Iron levels in this study ranged from 0.1 to 5.6mg/kg in all the stations. The mean values observed for Iron in tilapia was station 1(2.9), station 2(1.76), station 3(1.15), station 4(1.17) and station 5(0.91) mg/kg.

Seasonal variations show that the Iron level was higher during the rainy season than the dry season (Appendix 3).

The analysis of variance (ANOVA) result showed there was significant differences (P< 0.05) in Iron levels observed in tilapia muscle/tissue during the study period (P=0.007).

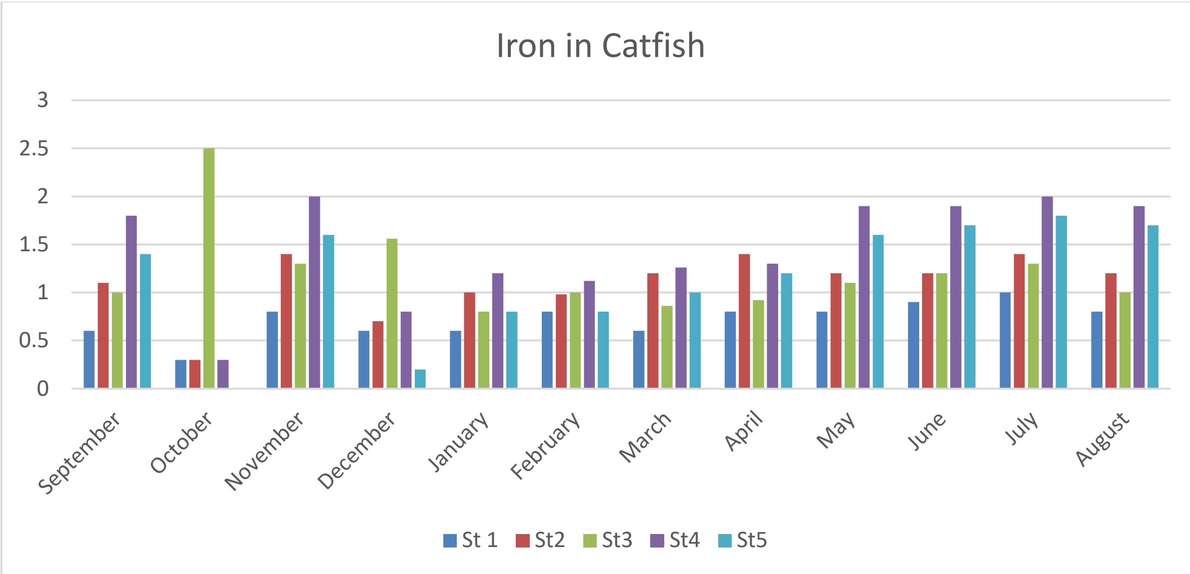

Fig 8: Iron (Fe) in Catfish

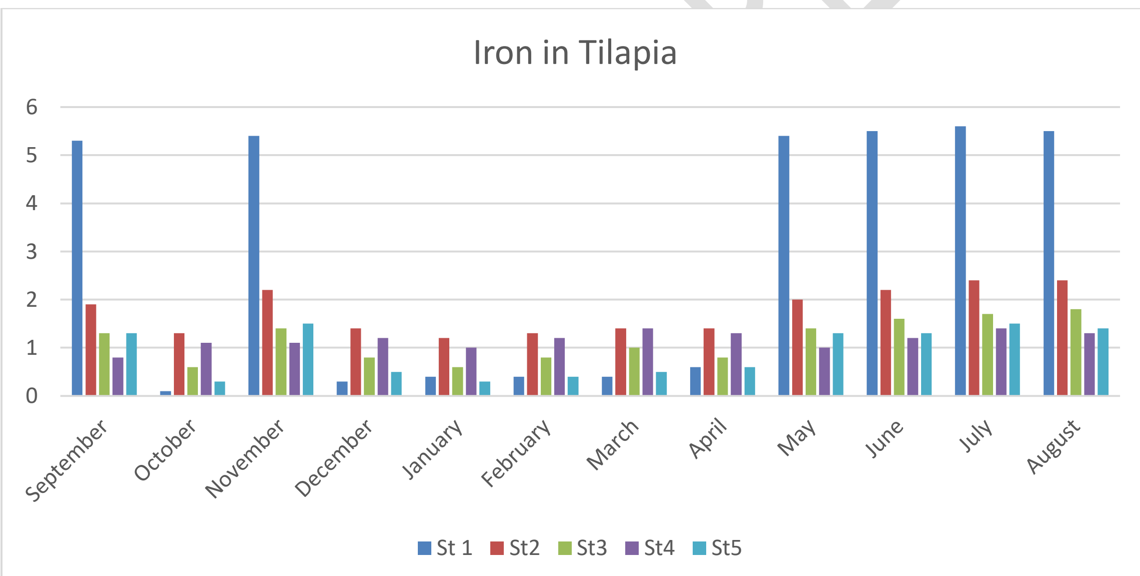

Fig 9: Iron (Fe) in Tilapia

RESULT AND DISCUSION

HEAVY METAL ANALYSIS OF FISH MUSCLES/TISSUE

Aquatic organisms tend to bioaccumulations heavy metals and therefore become susceptible to their effect (Ezemonye and Okeke 2007, Jacinta and Okwodu 2017).

Fishes have been used for many years to determine the pollution status of water and thus regarded as excellent biological markers of metals in the aquatic ecosystems (Rashed, 2001). The above statements are confirmed in this study.

The bioaccumulation of toxic levels of heavy metals are detrimental to organisms generally as they biomagnified them through the food chain and later transferred to human. Increased level of heavy metals in humans has been traced to heavy metal contamination in aquatic systems (Schuwerack *et al*, 2008). Study of fish muscle is one of the means to investigate the amount of heavy metals entering the human body in fish (Obodo 2001).

Generally, heavy metals detected in this study were high in the fish and proved evidence of bioaccumulation. Both essential and non-essential heavy metals were detected in the flesh of Catfish and Tilapia except Chromium and Lead below the detection limit.

There were spatial and seasonal variations of the heavy metals in the flesh of the two fish in all sampled stations.

The results found in Catfish and Tilapia were compared with FAO 1983, FAO/WHO 1989, and EEC 2005 permissible limits to ascertain its level of toxicity.

CADMIUM (Cd) IN CATFISH AND TILAPIA MUSCLE/TISSUES

Cadmium was obtained in the muscle of both Catfish and Tilapia analyzed in the present study.

The results indicate range of Catfish muscle from 1.0 – 3.9mg/kg with mean levels for the various stations are station 1(3.07), station 2(3.47), station 3(2.93), station 4(3.06) and station 5(1.7) mg/kg and Tilapia range from 0.1 – 4.2mg/kg with mean values of station 1(2.56), station 2(3.39), station 3(1.07), station 4(2.23) and station 5(2.17) mg/kg.

The results showed that Cadmium levels in Catfish and Tilapia found in Orashi River exceeded FAO, 1983, FAO/WHO1989 and EEC 2005 permissible limit of 0.01mg/kg.

Generally, Cadmium detected was higher in Catfish than in Tilapia. This can be attributed to their habitat and feeding methods. Catfish are nocturnal and bottom dwellers in contact with sediment, while Tilapia is diurnal and surface dweller deriving its Cd contamination only from water alone.

There are both spatial and seasonal variations of Cadmium in both Catfish and Tilapia.

The analysis of variance (ANOVA) result showed that there was significant differences ($p < 0.05$) between stations and months in Cd level observed in Catfish muscle during the study period ($P = 0.015$).

ANOVA results showed there was no significant differences ($p<0.05$) between stations and months in Cd levels observed in Tilapia muscle during the study period ($P = 0.979$).

COPPER (Cu) IN CATFISH AND TILAPIA MUSCLE/TISSUES

Copper concentration in the muscle ranged 10.9 – 33mg/kg and 17.3 – 40.6mg/kg for Catfish and Tilapia, respectively, analyzed in the present study.

The mean levels for stations 1, 2, 3, 4 and 5 were 28.94, 28.23, 18.18, 26.58 and 19.08mg/kg for Catfish and 19.24, 33.68, 28.12, 27.33 and 25.26mg/kg for Tilapia.

These results are within the FAO (1983) permissible limit of 30mg/kg except in station 2 for Tilapia (33.68mg/kg) and indicator anthropogenic input. Copper is one of the most toxic metals to marine organisms and Mercury and Silver (Bryan 1976), although is not often considered a threat to human health except when present in abnormally high value. It is an essential element, and most animals possess a well developed regulatory mechanism for this metal (Kakulu 1985). It is advisable to guard against the indiscriminate discharge of industrial and domestic waste into Orashi aquatic environment to avoid any possible transfer of this contaminant to aquatic biological resources that are the primary animals' protein source to the local communities.

From the result of Cu concentration in Orashi River, one can infer that the consumption of these fishes do not pose a health risk for its consumers.

There are both spatial and seasonal variations of Copper in both Catfish and Tilapia.

High values are observed for Catfish in the dry season than in the rainy season, while the rainy season recorded higher values than the dry season in the case of Tilapia. This is similar to higher Cu values reported by Ubalua and Ezeronye 2007 for fishes in Aba River, Abia state, Nigeria.

This can be attributed to their habitat and feeding methods. Catfish are nocturnal and bottom dwellers in contact with sediment, while Tilapia is diurnal and surface dweller deriving its Cu contamination only from water alone.

The analysis of variance (ANOVA) result showed that there were no significant difference ($P< 0.05$) between stations and months in Cu level observed in catfish ($P = 0.837$) while there were significant difference (P< 0.05) between stations and months in Cu levels observed in Tilapia muscle during the study period (P= 0.019).

ZINC (Zn) IN CATFISH AND TILAPIA MUSCLE/TISSUES

Zinc concentration in the muscle ranged from 22 – 213.2mg/kg and 30.1 – 196mg/kg for catfish and Tilapia, respectively, analyzed in the present study.

The mean levels for stations 1(59.6), station 2(37.03), station 3(51.87), station 4(139.34) and station 5(80.77mg/kg) for Catfish and station 1(40.19), station 2(82.29), station 3(79.68), station 4(62.28) and station 5(158.73mg/kg) for Tilapia.

These results were above the FAO (1983) permissible limit of 30mg/kg for Zinc in seafood. This is an indication of anthropogenic input of abattoir impact from runoff, tyre ash and animal blood which is rich in Zn and Fe (Bay *et al,* 2005). Zinc is an essential element in animals and human and its deficiency results in stunted growth, loss of taste and hypogonadism leading to decreased fertility (Kakulu, 1985, Sivapermal et al 2007). Zinc toxicity is rare but at concentration up to 40mg/kg, it may induce toxicity such as irritability, muscular stiffness and pain, loss of appetite and nausea (NAS-NRC, 1974). Others include severe vomiting, diarrhea, bloody urine, liver and kidney failure and anaemia (Fosmire 1990).

There are both spatial and seasonal variations of Zinc in both Catfish and Tilapia.

High values are observed in dry season than in the rainy season for the two fish species. This is similar to higher Zinc values reported by Ubalua and Ezeronye 2007 for fishes in Aba River, Abia state, Nigeria.

The analysis of variance (ANOVA) result showed that there were no significant difference (P< 0.05) between stations and months in Zn level observed in Catfish (P = 0.625) and Tilapia muscle (P = 0.696) during the study period.

IRON (Fe) IN CATFISH AND TILAPIA MUSCLE/TISSUES

Iron concentration in the muscle ranged from 0.02 – 2.5mg/kg and 0.1 – 5.6mg/kg for Catfish and Tilapia respectively analyzed in the present study.

The mean values recorded for two edible fish for stations 1(0.72), Station 2 (1.09), Station 3 (1.21), Station 4 (1.46), and Station 5 (1.15mg/kg) for Catfish and 2.9, 1.76, 1.15, 1.17 and 0.91mg/kg for Tilapia.

These results are within the FMENV (1992) permissible limit of 3mg/kg for Iron in seafood. This indicates anthropogenic input of abattoir impact from runoff, tyre ash and animal blood which is rich in Zn and Fe (Bay *et al.* 2005). Fe is an essential element in animals and humans, and its deficiency results in stunted growth, loss of taste and hypogonadism, leading to decreased fertility (Kakulu, 1985, Sivapermal *et al*. 2007).

There are both spatial and seasonal variations of Iron for both Catfish and Tilapia.

High values are observed in the dry season than in the rainy season for Catfish while, the reverse is the case with Tilapia.

The analysis of variance (ANOVA) result showed that there was a significant difference ($P < 0.05$) between stations and months in Fe level observed in Catfish ($P = 0.026$) and Tilapia muscle ($P = 0.007$) during the study period.

CONCLUSION

The research was intended to study heavy metal concentration due to the influence of human and industrial activities on the Orashi River and the two bony fish (*Clarias gariepinus* and *Tilapia nilotica).*

The results from this study have provided information on the profile of the heavy metal of the fish (Catfish and Tilapia) of the river.

The average mean concentrations of the parameters studied in some samples were close to or exceeded the World Health Organization (WHO) and Federal Ministry of Environment (FMEnv) recommended drinking water and seafood limits.

Essential heavy metals detected in water were Copper (Cu), Zinc (Zn) and Iron(Fe) and were low when compared with international standards (WHO 1989, USEPA 1986, FEPA 1999, FMEnv 1992) recommended limits of 3mg/l. The non-essential metals detected were Cadmium (Cd) which exceed the international standard of 0.01mg/kg but do not constitute a health risk. Heavy metals concentration was generally elevated at and around abattoir and gas flare sites.

The high level of Heavy metals in the fish calls for concern as it can have some health – risk implications in humans who are the final consumers.

RECOMMENDATION

This study has shown that Heavy metals accumulate over time within the aquatic ecosystem. The aquatic resources have also been shown to be the primary source of protein to the indigenous community who are exposed to the hazardous effects of these pollutants. It is therefore recommended that:

(i) The companies operating in the area should adopt improved waste management plans to reduce the levels of pollutants discharged into the environment. To achieve this, more stringent monitoring should be carried out by the companies and adequately supervised by the regulatory bodies such as DPR, FMENV and Rivers State Ministry of Environment. Industries operating in the area should be encouraged to adopt as much as possible a zero-waste management technology at all stages of product life.

(ii) Comparative studies in other biotas of the environment would be helpful in monitoring the rate and mechanism of uptake of the metals in the two fish and other food fish in Orashi River. This will provide data for an informed decision on uptake of what is available in a polluted environment.

(iii) There is need to develop management plan to ensure that petroleum hydrocarbon contamination of the area is prevented/reduced to achieve good water quality and avoid any possible adverse health outbreak through consumption of contaminated water resources by the local communities.

(iv) The local communities should be enlightened about the adverse effects of anthropogenic activities, oil pipeline vandalization/sabotage and bunkering activities to make money without considering the environmental impacts.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly used in our research area and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for litigation but the advancement of knowledge. Also, the research was not funded by the producing company rather, it was financed by the personal efforts of the authors.

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APPENDIX 1: RAW DATA OF Heavy Metals obtained in Fishes samples

(a) Cadmium in Catfish

CD	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
St 1	2.4	3.1	2.4	32.2	23.3	33	3.34	3.34	2.5	3.3	3.4	3.2
St 2	2.5	3.8	2.6	26.8	28.4	27	3.86	3.9	2.6	3.9	3.9	3.7
St 3	2.7	2.8	2.8	10.9	24.3	12	3.2	3.2	2.8	2.9	3	2.8
St 4	1.5	3.4	1.6	28.1	24	28.4	3.8	3.8	1.6	3.5	3.5	3.3
St 5	1.9	0.9	2	15.1	20.9	15.8	3.2	3.2	2	1.2	1.4	1.5

(b) Cadmium in Tilapia

Cd	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG
St 1	2.4	2.5	2.6	2.6	2.6	2.6	2.7	2.8	2.4	2.3	2.6	2.6
St 2	3.8	2.8	4.1	2.8	2.8	2.9	2.9	3	3.8	3.6	4	4.2
St 3	0.1	2.3	0.3	2.4	1.2	1.2	1.3	1.4	0.1	0.2	0.6	0.7
St 4	3.1	1.8	3.3	2	2.4	2.4	2.6	2.7	3.1	3.3	3.4	3.5
St 5	1.3	3.1	1.5	3.4	3.6	3.6	3.6	3.1	1.3	1.5	1.5	1.6

(c) Copper in Catfish

Cu	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
St 1	32	23.3	33	24	26	26.2	26.4	26.4	32.4	32.5	32.6	32.3
St 2	27	28.4	27	28.8	29	29.4	29.8	30.2	27	27.4	27.7	27.2
St 3	11	24.3	12	24.6	25	25	25.2	25.2	11	11.6	11.8	11.6
St 4	28	24	28.4	24.4	25.2	25.4	25.4	25.5	28.2	28.2	28.2	28
St 5	15	20.9	15.8	21.2	23.2	23.6	24	24.2	15.2	15.3	15.5	15

(d) Copper in Tilapia

Cu	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
St 1	40.2	29.6	40.6	30	30	30	30.2	30.4	40.2	40.2	40.3	40
St 2	37.9	29.2	38	29.6	29.8	29.8	29.8	30	37.6	37.6	37.6	37.2
St 3	38	17.3	38.2	17.8	18	18.2	18.4	18.6	38	38.4	38.5	38
St 4	28.4	24	28.6	25	26	26.4	26.6	26.4	29	29.2	29.3	29
St 5	21.3	28.2	22	28.6	28.8	28.8	29	29.2	21	22	22.1	22.1

(e) Zinc in Catfish

Zn	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
St 1	58	60.2	60	61.4	62	60	54.5	67	58	58.1	58.1	58
St 2	47	24	48	25	27	38	23.7	22	47.6	47.6	47.5	47
St 3	38	66.2	38	67.2	68.6	65	63.3	66.8	37.6	37.7	37.4	37
St 4	72	202.2	74.2	203	206	201	213.2	210	72.5	72.6	72.5	72.2
St 5	89	71.6	89.4	73	74	70	70.6	78	88.8	88.6	88.4	88.2

(f) Zinc in Tilapia

ZN	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
St 1	45.5	20.1	46	30.1	35.2	36	40	45	46	46.2	46.2	46
St 2	116.6	45.3	118	46	48	48.4	48.6	48	117	117	117	117
St 3	104.1	69.3	106	69.8	70.2	72	73	74	105	105	105	105
St 4	80	41.3	82	47	43	44	44	42	81	81.2	81	80.8
St 5	128.5	195	130	192	196	189	180	178	129	129	129	129

(g) Iron in Catfish

Fe	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG
St 1	0.6	0.3	0.8	0.6	0.6	0.8	0.6	0.8	0.8	0.9	1	0.8
St 2	1.1	0.3	1.4	0.7	1	0.98	1.2	1.4	1.2	1.2	1.4	1.2
St 3	1	2.5	1.3	1.56	0.8	1	0.86	0.92	1.1	1.2	1.3	1
St 4	1.8	0.3	2	0.8	1.2	1.12	1.26	1.3	1.9	1.9	2	1.9
St 5	1.4	0	1.6	0.2	0.8	0.8	1	1.2	1.6	1.7	1.8	1.7

(h) Iron in Tilapia

Fe	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG
St 1	5.3	0.1	5.4	0.3	0.4	0.4	0.4	0.6	5.4	5.5	5.6	5.5
St 2	1.9	1.3	2.2	1.4	1.2	1.3	1.4	1.4	2	2.2	2.4	2.4
St 3	1.3	0.6	1.4	0.8	0.6	0.8	1	0.8	1.4	1.6	1.7	1.8
St 4	0.8	1.1	1.1	1.2	1	1.2	1.4	1.3	1	1.2	1.4	1.3
St 5	1.3	0.3	1.5	0.5	0.3	0.4	0.5	0.6	1.3	1.3	1.5	1.4

Appendix 2: Seasonal Variation in Heavy Metal Concentration in Catfish

Heavy Metal	DRY SEASON							RAINY SEASON						
	OCT	NOV	DEC	JAN	FEB	MAR	$\bar{x}$ con	APR	MAY	JUN	JUL	AUG	SEP	$\bar{x}$ con
Cd	2.8	2.28	2.26	2.42	2.32	3.5	**2.59**	3.49	2.3	2.96	3.04	2.9	2.2	**2.81**
Cu	24.2	23.2	24.6	25.7	25.9	66.2	**31.6**	26.3	22.8	23	23.2	22.8	22.6	**23.44**
Zn	84.8	61.9	85.9	87.5	86.8	29.8	**72.8**	86.8	60.9	60.9	60.8	60.5	60.8	**65.44**
Fe	0.68	1.42	0.77	0.88	0.94	0.98	**0.95**	1.52	1.32	1.38	1.9	1.32	1.18	**1.44**

Appendix 3: Seasonal Variation in Heavy Metal Concentration in Tilapia

Heavy Metal	DRY SEASON							RAINY SEASON						
	OCT	NOV	DEC	JAN	FEB	MAR	$\bar{x}$ conc.	APR	MAY	JUN	JUL	AUG	SEPT	$\bar{x}$ con
Cd	2.5	2.36	2.64	2.52	2.54	2.62	**2.09**	2.6	2.14	2.18	1.7	2.12	2.14	**2.15**
Cu	25.2	33.5	26.2	26.5	26.6	26.8	**27.6**	26.9	33.2	33.5	33.6	33.3	33.2	**32.3**
Zn	74.2	96.4	77	78.5	77.9	77.1	**80.2**	77.4	05.6	95.7	75.6	05.6	94.9	**92.5**
Fe	0.68	2.32	0.84	0.7	0.82	0.94	**1.05**	0.94	2.22	2.36	2.52	2.48	2.12	**2.1**