Determination of Selected Heavy Metals and Iron Concentration in Two common Fish Species in Densu River at Weija District in Grater Accra Region of Ghana

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Abstract

The concentrations of heavy metals namely; Manganese, Cadmium, Lead, Mercury and Arsenic (Mn, Cd, Pb, Hg and As) including Iron (Fe), were determined in catfish and tilapia samples from Densu River at Weija in 2012. The fish Muscles were carefully dissected for digestion and the levels of heavy metals were determined using Microwave Milestones Ethos 900 double beam Atomic Absorption Spectrophotometer (AAS). Concentrations of heavy metals in the fish samples analyzed in descending order of Fe > Mn > Cd were detected, but, the rest (Pb, Hg and As) were not detected. The highest concentration of Cadmium (0.808mg/kg) was detected in the muscles of Catfish while the lowest value (0.129mg/kg) in Tilapia. The lowest concentration of Mn (0.78mg/L) and Iron (44mg/L) were detected in catfish whereas the highest Mn = 1.74mg/L, Fe = 53mg/L were in the Tilapia samples. Cadmium and Iron accumulated by the two fish species exceeded the maximum permissible limits prescribed by the World Health Organization guideline well as the Food and Agriculture Organization standard. Higher levels of heavy metals accumulated by the fishes might be due to increase in the agricultural influx waters, domestic wastes and some anthropogenic activities which merit further investigation.

Key Words: Heavy metal, tilapia, catfish, Densu River

1.0 Introduction

The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent years, because they are indestructible and most of them have toxic effect on organisms (Mac Farlane and Burchett, 2000).

Among environmental pollutants, metals are of particular concern, due to its potential toxic effect and ability to bio-accumulate in aquatic ecosystems (Censi et al., 2006). Heavy metals refer to heavy metallic chemical elements that have relatively high density and are toxic or poisonous at low concentration. They include essential and non- essential chemical elements such as Hg, Cd, Cr, Cu, Zn, Mn, Pb etc. These heavy metals come in contact with our bodies via food, drinking water and air. They are dangerous, because they tend to bio-accumulate (increase in concentration in biological cells over time).

In Ghana, Densu River in Greater Accra Region represents the main fishing grounds for tilapia and catfish, thus serving as a viable source of income and livelihood for the local people. Its serves as a protein source around the place and even beyond.

1.1 Problem Statement

Weija District has been suffering from different kind of diseases which are alluded to traditional beliefs and human wastes accumulation. For instance it is believed that increase in premature birth; madness and hypertension are due to inability to pacify the gods periodically as compared to the past which was not the case. However, the researcher observed that people living in other districts experience almost nothing like that and therefore believed that there could be more problems rather than beliefs and human wastes. It is due to this background that the researcher chose to determine heavy metals concentrations in fishes caught from the Densu River.

1.2 Justification for the Research

Fishes can accumulate heavy metals in their tissues at concentrations greater than the ambient water and pose a health threat to humans who consume them.

Fish samples can be considered as one of the most significant indicators in freshwater systems for the estimation of metal pollution level. The commercial and edible species have been widely investigated in order to check for those that are hazardous to human health (Begum et *al.*, 2005).

Heavy metals are implicated in neurological disorders especially in the foetus and in children, which can lead to behavioural changes and impaired performance in IQ (intelligent quotient) test (Landner and Lindestrom, 1998). The quality of the ecosystem has been degrading due to agriculture and human activities. Fish is an important component of the human diet in Weija district and for this reason; the results obtained from the study would provide information on background levels of metals in the fish species of the river, contributing to the effective monitoring of both environmental quality and the health of organisms inhabiting the river ecosystem. It is therefore very important for studies to be conducted on the concentration of heavy metals in the tissues of tilapia and catfish of River Densu and check whether or not the concentration levels are within the permissible limits for human consumption in comparison to safety reference standards for the consumption of fish.

1.3 Specific Objectives

The objectives of the study were to:

- Determine heavy metals concentration in some selected Tilapia and Cat fish samples.
- Examine if the concentration of heavy metals in these selected fishes are within WHO and FAO recommended limits and safe for human consumption.

1.4 Limitations of the Study

- The time frame within which the study was carried out was too short; therefore, two common fish samples were collected once in the month of August, 2012.
- Due to inadequate funds the study could not be extended to other areas within the district.
- Additionally, due to inadequate funds, the Global Positioning System (GPS) could not be used to obtain the correct coordinates for plotting the map of the study areas along the River Densu as predetermined.

1.5 Scope of the Study

This study was carried out with the aim to determine and examine the pollutant levels of some heavy metals such as iron, manganese, cadmium, lead, arsenic and mercury in two common fish species that were picked from daily fish catches of the fishermen randomly encountered at the time of visit so it made the random selection of fishes caught from various parts of the river and the Weija Dam convenient.

2.0 Methods and Materials

2.1 Study Area

The study area is located in the Capital City of Ghana, Accra. The River Densu runs from Nsawam to Kasoa where it enters the sea and about 120km long. A total of 5 sites where convergent fishermen display their daily catches along the Densu River were selected as representative regions of the river at Weija for the study.

2.2 Sample Collection

Fish samples (Tilapia and Catfishes) were purchased from the 5 selected sites along the river. The sizes of the fishes collected varied, depending on the species between 12cm and 54cm long.

A total of 100 fish samples (50) each of the species were purchased for the analyses. These species are widely distributed in the aquatic environment and have commercial importance. The fish samples were wrapped with aluminum foil and transported the same day to the chemistry laboratory at Ghana Atomic Energy Commission (GAEC) on ice cubes in an ice chest and were kept under deep frozen condition until analysis.

2.3 Digestion of the Samples

About 100g of fish samples were allowed to thaw. The samples were then placed on an aluminum foil to avoid contact with the working bench. The samples were cut into small pieces using clean scissors and knife into bowl and freeze dried. This was then grounded into fine powder. As much as 0.50g of each of the grinded fish sample was weighed into thoroughly clean plastic crucibles and 6ml of 65% concentrated HNO_3 and 1ml of hydrogen peroxide was added to the weighed samples in a fume chamber and allowed to homogenize. A blank was also prepared for Atomic Absorption Spectroscopy (AAS) reading. The plastic containers were then covered and placed in a jacket for microwave digestion using an Ethos 900 Microwave Lab station. Each digested sample was diluted and made up to 20ml with distilled water after the microwave digestion, for AAS readings.

2.4 Statistical Data Analysis

The data was analyzed using Statistical Package for Social Scientists Version 16.0.

2.0 Results and Discussion

3.1 Results

The results in Table 3.1 show the concentration of selected heavy metals in two species of fish (Catfish and Tilapia) obtained from samples collected from the Densu River in Weija District of Accra, Ghana and compared with standard guidelines on food safety by the WHO and FAO in 2011.

3.1.1 Selected Heavy Metals in Catfish

The data in figure 3.1 showed the comparison of heavy metals in Catfish with that of WHO/FAO guideline and standard respectively. The results revealed some dissimilar pattern in terms of detection limits of the various heavy metals in Catfish. For instance, Pb, Hg and As probable concentrations were below the detection limits in the digested fish samples analyzed. Minimum concentrations of Cd and Mn at levels of 0.808mg/kg and 0.78mg/kg respectively were detected and the differences between the various fish samples for mean Cd concentration was significant ($P < 0.004$) at 0.05 probability limit.

However, the mean Fe level which was 44mg/kg in the Catfish and far above the rest of the metals at its negligible limits was above the WHO/FAO maximum permissible limit of 43mg/kg in food samples (Table 3.1).Apart from manganese which was below the WHO/FAO maximum permissible limits, the graph clearly shows that Cadmium and concentrations were higher in Catfish. The rest of the selected metals were not detected (figure 3.1).

3.1.2 Selected Heavy Metals in Tilapia

Figure 3.2 compares concentrations of selected heavy metals in Tilapia with that of WHO/FAO maximum permissible limits. It reveals a dissimilar pattern in terms of detection limits of the various heavy metals in Tilapia. The minimum concentration of Cd (0.129mg/kg) and that of Mn (1.74mg/kg) were detected in fishes (table 3.1). Pb, Hg and As levels were below detectable limits. However, Fe concentration (53mg/L) in the Tilapia was similarly far above the rest of the metals at its optimum limits. It was further above the (43mg/kg) WHO/FAO limits. The differences in concentration of heavy metals between the various fish species showed that the probable respective inferred values of Mn ($P < 0.271$) and Fe ($P < 0.753$) from the statistical analysis were insignificant at 0.05 probability limit.

The concentration of Iron (53mg/kg) in tilapia were above WHO/FAO (43mg/kg) maximum permissible limits while that of Mn (1.74mg/kg) and Cd (0.129mg/kg) were slightly below the WHO/FAO maximum permissible limits of (5.5mg/kg for Mn and 0.2mg/kg for Cd) respectively. The rest of selected heavy metals were still not detected in Tilapia (Table 3.1).

3.1.3 Comparison of Selected Heavy Metals in the Two Common Fish Species

Figure 3.3 compares the differences in concentration of heavy metals in tilapia and cat fish species at the same period of sample collection and analysis. The concentration of Cd found in the two fish species ranged between 0.129mg/kg to 0.808mg/kg. The maximum concentration was detected in Tilapia (0.808mg/kg) while the minimum (0.129mg/kg) in Catfish. The Cd level in the tilapia was thus, far above the WHO/FAO maximum permissible limit of 0.2mg/kg in the tilapia but the level detected in the catfish was below it (Table 3.1). The Mn concentration in the two fish species ranged from 0.78mg/kg to 1.74mg/kg. The highest concentration was found in Tilapia while the minimum bioaccumulation was detected in Catfish (Table 3.1).

The iron levels ranged from 44mg/kg to 53mg/kg. The highest bioaccumulation effect was found in the Tilapia while minimum level was detected in the Catfish. However, Lead, Mercury and Arsenic were still below detectable limits. The descending order of metals bioaccumulation in tissues of the two fish species were such that; Fe> Mn > Cd. Tilapia were observed to possess scales on the body while Catfish was smooth and slimy textured.

3.2 Discussion

The results in Table 4.1 juxtapose the heavy metals concentrations in commonest fish samples in the Densu River in June 2012.

The grand mean concentrations of the selected heavy metals in the two fish species were such that, the ascending levels of contamination was: Cd (0.309mg/kg) < Mn (1.26mg/kg) < Fe (49mg/kg). Lead (Pb), Mercury (Hg) and Arsenic (As) were below detection limits.

Cadmium is widely known to be a highly toxic non–essential heavy metal and it does not have a role in biological process in living organisms. Thus, even at its low concentration, cadmium could be harmful to living organisms (Tsui and Wang, 2004). The 0.808mg/kg maximum concentration of Cadmium detected in the muscle of Catfish and the 0.309 mg/kg least concentration in the muscle tissues of Tilapia as shown in Table 4.1 were exhibitive of high potential health effects to the majority of the patronizing fish consumer population at the study area. The grand mean concentration of Cadmium in both common fish species which was above the WHO/FAO maximum permissible limit of 0.2mg/kg for food samples could not be tolerated and the consumers might raise alarm if they were actually aware of its potential health risks.

Literature supports the view that, Cadmium which often accumulates in the human body via food negatively affects several organs: liver, kidney, lung, bones, placenta, brain and the central nervous system (Chouba *et al.,* 2007). Other damages that have been observed include reproductive, and development toxicity, hepatic, haematological and immunological effects. Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. The levels of Cd present in the two selected fish muscles in freshwater may be due to industrial and agricultural operations and suspected lateral inflow of leachates from damaged geomembranes/textile of adjacent landfill sites in the investigated area .

Manganese is an essential trace element for both animals and man; necessary for the formation of connective tissues and bone, growth, carbohydrate and lipid metabolism, embryonic development of the inner ear, and reproductive function (WHO, 2011 and DWAF 1996). The grand mean concentration of manganese detected in the fish samples from this study was below the WHO/FAO maximum permissible limit of 5.5mg/kg as stated in Table 4.1. From literature, symptoms of manganese toxicity in man include dullness, weak muscles, headaches and insomnia but from the results of this study, the traces found in the fishes could not cause such severe health effects in a short run among the majority of fish consumers who may not be absolutely dependent on the Densu river catches alone for their dietary fish protein requirements. It perhaps, subjects only frequent or persistent, addicted consumers or people who lack alternatives to fish supply from this source to balance their dietary protein requirements to the risks of bioaccumulation and manifestation of idiosyncratic health effects of manganese such as dullness, weak muscles, headaches and insomnia (WHO, 2011). Mn in the fish samples could also be traced to entry to the river through industrial effluents from steel industries around the catchment area of this study (Rashed, 2004).

Iron is essential to most life forms and to normal human physiology. In humans, iron is an essential component of proteins involved in oxygen transports from the lungs to the tissues (Dallman, 1996). It is also essential for the regulation of cell growth and differentiation (Andrew, 1986). The grand mean concentration of iron 49mg/kg was higher than WHO/FAO maximum permissible limit of 43mg/kg for both the Catfish and Tilapia. Literature on Fe interactions in biological tissues has reported that excess amount of Fe causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness (Davies *et al.,* 2006).

Comparatively the iron levels detected from this study slightly above the regulatory food standards therefore presents some risk of the above health defects to the popular consumers of the fishes from the study area.

5.1 Conclusion

The concentrations of heavy metals detected in samples of the two fish species were quite variable. Cd and Fe found in the fish samples were above the maximum permissible limits as per the WHO/FAO guideline standards comparison. High concentrations of some heavy metals measured in the fish tissues inhabiting that the Weija District catchment were attributed to probable high influx of metals as a result of pollution from the Agriculture activities, Municipal and industrial wastes leachate intrusion, thereby, increasing the potential bioavailability to the fish and also posing the associated risks of affecting the quality human health, particularly the most populous consumers in the long run.

5.2 Recommendations

5.2.1 Aspects for additional Research

The determination of the concentrations of the Cd, Mn and Fe in the whole soft tissues of the fish has provided very valuable and comprehensive baseline information and data on the pollution status of the Densu River. This data can serve as a guideline for researchers and environmental managers to identify future anthropogenic impacts at the study area with respect to the studied metals, and better assess the need for remediation of bio-accumulation by monitoring for changes from the existing levels.

The high levels of some metals in the fish samples suggested that the fish were capable of absorbing the metals in their bodies from the aquatic environment. The ability of the fish samples to incorporate the elements into their tissue is another important factor to consider for further studies.

5.2.2 Stakeholder Response and Management Actions

The data presented in this report indicates that the species have preferences to retain some metals in their tissues than other metals. Although, no immediate health risk was estimated from consumption of the fish species, risk prevention on the consumption of fish should therefore focused on reducing the volume of heavy metals discharged from agriculture area as well as Municipal and Industrial wastes into the catchment area.

The data and findings of this research can also be useful for the management and sustainable development of the studied localities as far as heavy metal pollution is concerned. To preserve the unpolluted state of the Densu River, it remains important that allochthonous inputs from the catchment area are devoid of heavy metals and regulatory mechanisms should be enforced by the Local Government Authoritists to ensure that current trends are not exacerbated.

The University of Education, Winnneba, should disseminate these findings through workshops, seminars, and wide publicity to benefit the majority of the fish consuming population in Ghana. Environmental and public health professionals should be actively involved in this regard in educating the population of fish consumers obtaining their supply from the Densu River about the potential health risks of Cd, Fe and other heavy metals from fish and other food samples such as vegetables from the water source.

Popular fish consumers should be educated to alternate their dependency on different, safer and available sources of fish protein apart from catches obtained from the Densu River in order to avoid bioaccumulation of Cd, Mn, Fe, and other traced metals in order to synchronize their immunity and reduce potential health risks of consuming contaminated food samples.

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Appendixes

Table 2.1 Microwave programme specified for fish samples in the Cook book by Zunk and Planck, 1990

STEP	TIME (Min)	POWER (W)	PRESSURE (ATM)	TEMP1 ^{o}C	TEMP2 ^{o}C
1	00:05:00	250	100	400	500
2	00:01:00	0	100	400	500
3	00:10:00	250	100	400	500
4	00:05:00	450	100	400	500
Vent	00:05:00	0	0	0	0

Rotor control on, Twist on.

Plate1: VARIAN AA 240 Flame Atomic Absorption Spectrophotometer used for analysis of the fish samples

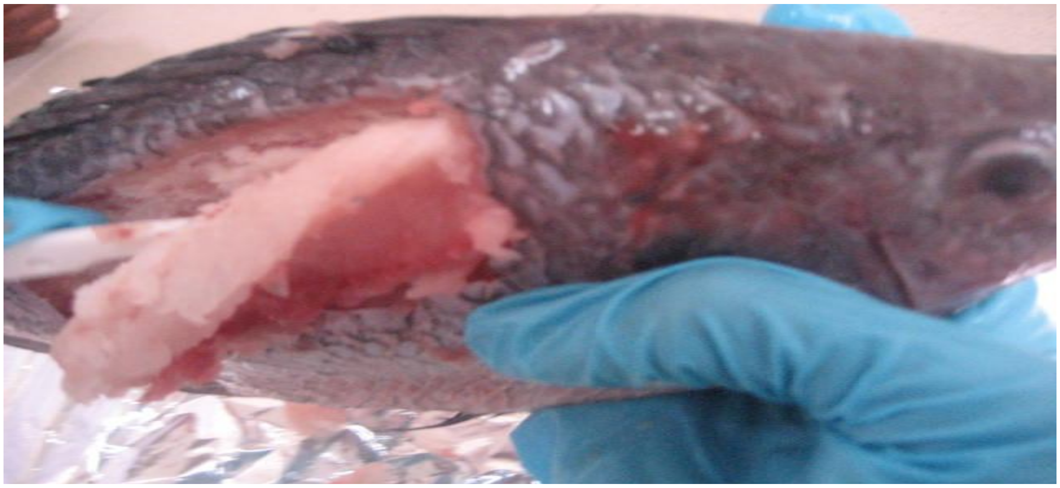

Plate 2: Fish samples spread for slicing on a prepared table

Plate 3: Fish samples sliced with scissors for digestion to aid AAS analysis

Table 3.1 Mean Concentration of selected Heavy Metals in two species of fish (Catfish and Tilapia) from the Densu River in June, 2012

Fish Species	Selected heavy metals (mg/kg) Cd	Mn	Fe	Pb	Hg	As
Catfish	0.808	0.78	44	BD	BD	BD
Tilapia	0.129	1.74	53	BD	BD	BD
G.M	0.469	1.26	49	-	-	-
LSD Value	0.309	2.104	NS	NS	NS	NS
WHO/FAO MPL (P>0.05)	0.2	5.5	43	1	0.6	0.26

* G.M = mean of the means, MPL= maximum permissible limit LSD = Least Significant Difference.

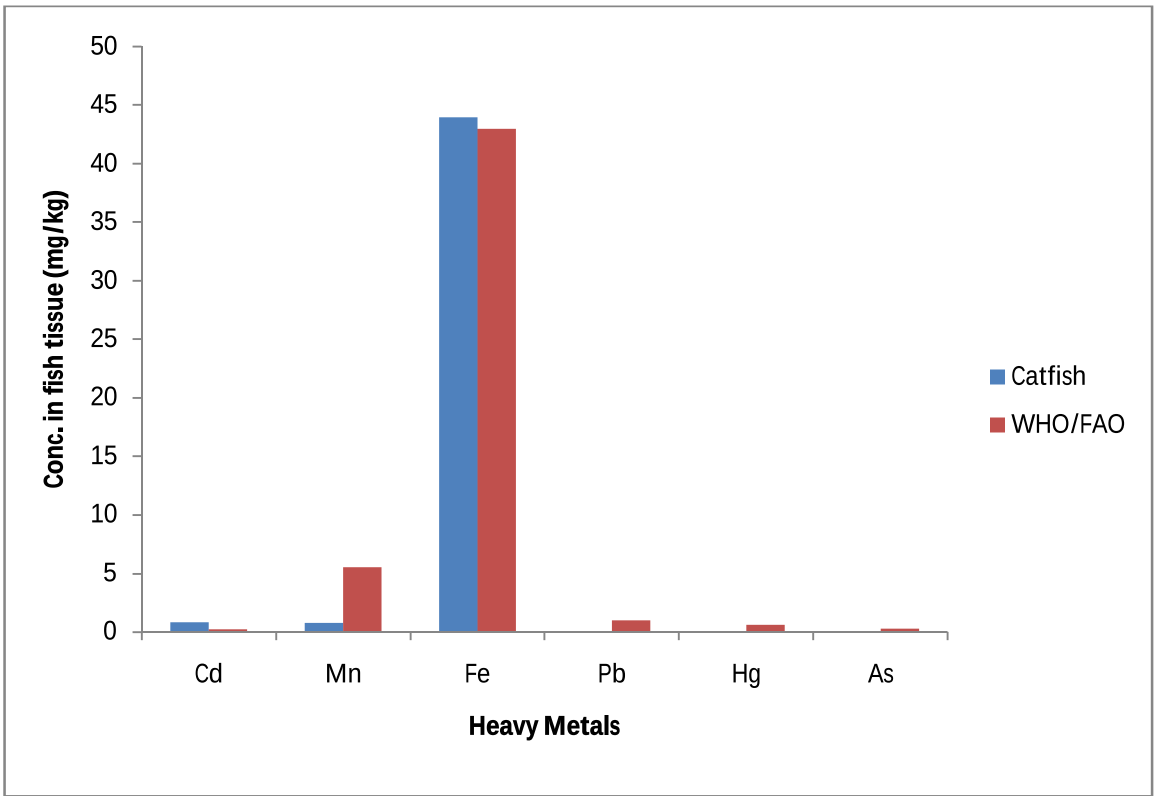

Figure 3.1 Comparison of heavy metals in Catfish with WHO/FAO MPL.

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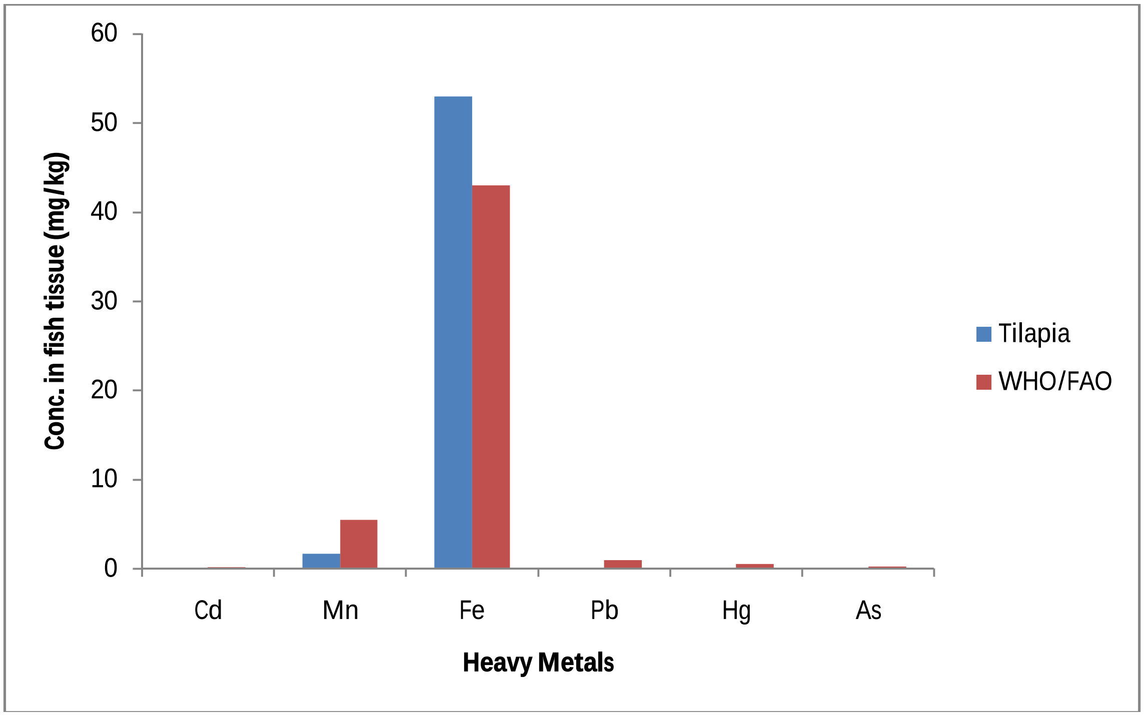

Figure 3.2 Comparison of heavy metals in Tilapia with WHO/FAO MPL

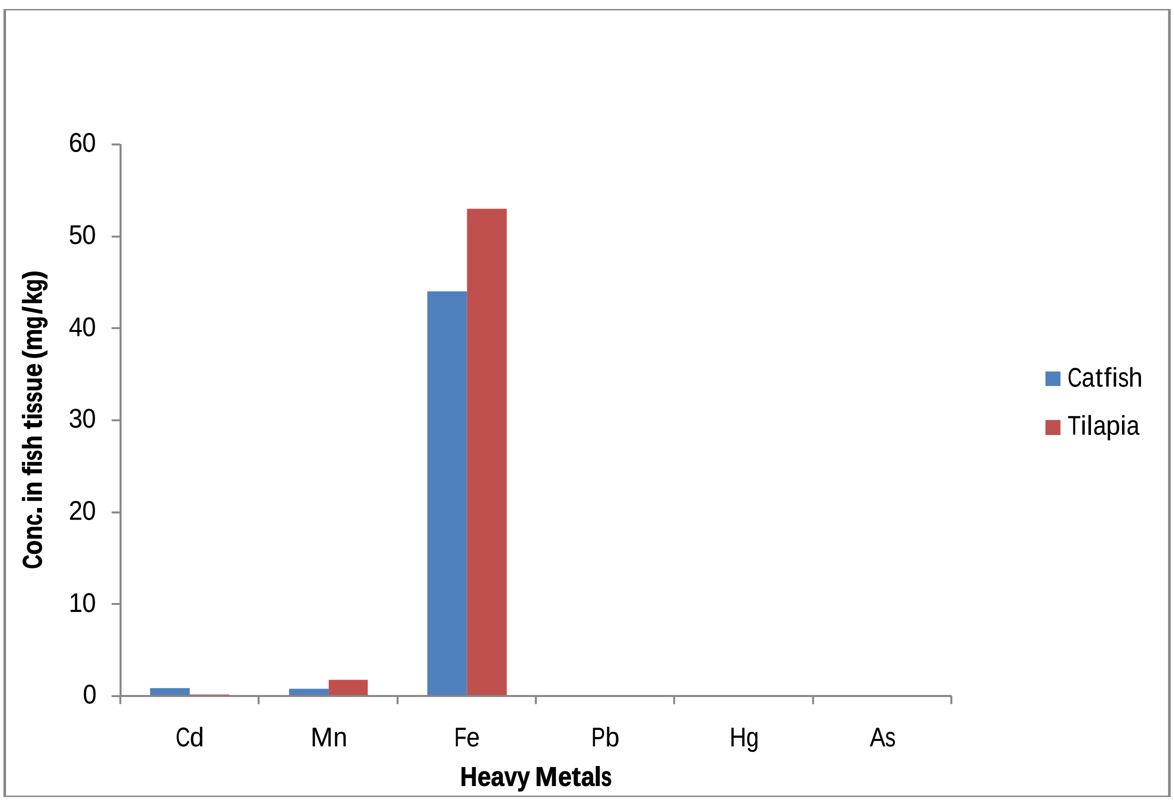

Figure 3.3 Comparison of heavy metals in catfish with Tilapia from Densu River