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Bioaccumulation of heavy metals in some pelagic and benthic fish species in selected wetlands in oil-bearing communities of the Niger Delta

Ogwu Chukwudi, Ideh Victor, Imobighe Mabel

Department of Vocational Education (Agriculture Unit), Delta State University, Abraka, Nigeria

Key words: Fisheries, Aquaculture, Oil exploitation, Heavy metals, Bioaccumulation, Bioremediation.

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Abstract

This study focused on the determination of heavy metals content of three fish species: *Clarias spp, Chana obscura* and *Tilapia zilli*, in the wetlands of 5 Niger Delta oil-producing communities. The samplings which were carried out with the assistance of artisanal fishermen lasted for 6 months from March to September 2021. The samples collected were bulked, composites taken and stored in ice-cool boxes for analysis. The analytical standards adopted were USEPA and APHA and the analytical instrument deployed for the determination of the heavy metals were Agilent ICP-MS7900 and Agilent atomic absorption spectrophotometer model 240A. The mean results obtained are as follows: V ranged from 0.42 µg/g to 0.61 µg/g with a mean of 0.53 µg/g, Mn, concentration ranged from 2.37 µg/g to 5.28 µg/g with a mean of 3.57 µg/g, Cd concentrations of 0.04 µg/g to 0.07 µg/g has a mean of 0.05 µg/g, Ni concentration is between 0.07 µg/g to 0.08 µg/g with a mean concentration of 0.06 µg/g, while As the concentration of 0.25 µg/g to 1.99 µg/g and has a mean concentration of 1.43 µg/g. The aggregate mean concentrations of the heavy metals were further subjected to a test of significance with ANOVA with SPSS model 21 at a 0.05 level of significance. The p-value is 0.021, thus rejecting Ho. The study recommends that oil companies operating in the Niger Delta should adopt the world's best practices in the oil industry. Aquaculture and fisheries should be discontinued in the wetlands and remediation should be carried out.

* **Corresponding Author:** Ogwu C ✉ chukwudiogwu008@yahoo.com

Introduction

Fish is one of the most valuable components of the human diet that is cherished globally. The consumption of fish has increased tremendously in recent years because of the awareness of its therapeutic and nutritive importance (Baruwo *et al.*, 2018; Nwaeze *et al.*, 2014; Ekundayo *et al.*, 2014). It is rich in protein, healthy fat (omega-3), vitamins and minerals (World Health Organisation, 2014; Dawson, 2017; Jones, 2028). Fish is a rich source of potassium, iodine, and magnesium, which are essential for human health (Paulson, 2018; Stevenson 2019). It contains 16-30 percent protein more than any other animal reared for food (World Health Organization (WHO), 2019; Preye, 2012). Fish should be consumed at least two times a week for sound health (American Heart Association 2018; Obed and Batrand, 2020). The global market for fish was estimated at 11300 billion dollars in the year 2020 and is projected to rise to 138.7 billion in 2027 (Food and Agricultural Organisation, 2021; Organisation for Economic Growth and Development, 2021). It accounts for the global employment of over 41 million people and its contribution towards achieving the United Nations sustainable development goal of zero hunger is very remarkable (World Food Programme, 2019, World Fish Centre, 2018).. Nigeria is a maritime country with an 853 km coastline, a large expanse of inland waters and numerous fish species, but it is unable to meet up with its annual fish demand (Ameo, 2021; Ogweri, 2019; Rufai, 2019).

Nigeria's annual fish demand estimate is 2.7 million metric tonnes, but its fish production from artisanal, industrial fisheries and aquaculture is 850,000 metric tons (Adesina, 2014; Ogbe, 2016; Nanono, 2020; Abubakar, 2021) and this shortfall in fish demand and supply is bridged by importation (Oteriba, 2018; Ruwani, 2020).

Fisheries and aquaculture production have been bedeviled with recurrent issues of marine pollution (Susu *et al.*, 2012, Obasuyi and Omorodian, 2028; Tsav, 2019). Marine pollutions result from industrial activities, agriculture production and oil exploitation and exploration (Okecha, 2013, Aworawo, 2017, Osundiya, 2019). Nigeria is an oil-producing state with oil accounting for 95 percent of its foreign exchange earnings (Buhari, 2021, Emefiele, 2022). The oil production belt of Nigeria in the Niger Delta, as it accounts for over 90 percent of oil extracts in Nigeria (David West, 2013, Ogagaoghene, 2020, Akogun, 2020). Several oil spillage incidents have been recorded in Nigeria and between 2018 to 2021, were 4919 oil spills incidents through illegal refineries, equipment failures, sabotage, and other unwholesome practices with 4.5 trillion litres lost to the environment (Abubakar, 2021; Silva, 2021; Nwankwo, 2022).

Petroleum is composed of oxygen, nitrogen, polyaromatic hydrocarbons, naphthalene heterocampounds and varying concentrations of heavy metals (Samuelson, 2014; Andrew, 2012; Odezugo, 2015). The bioavailability of heavy metals in aquatic environments results in bioaccumulation and biomagnification in aquatic species (Annabi *et al.*, 2003; Nhiwatiwa *et al.*, 2011; Rurger and Gochfield 2015; Korkmaz, 2012). Consumption of heavy metals polluted fish and fish products result in health complications (Egila and Daniel, 20111; Obasohan and Orosanya, 2008, Vinodluni and Nareyonan, 2009). Several studies have been carried out on the bioaccumulation of heavy metals in some oil-producing areas, but studies on the effect of oil exploitation covering the Niger Delta remain unavailable hence this study. The purpose of this study, therefore, is to assess the concentration of heavy metals in some fish species in the wetlands of oil-bearing Niger Delta. The heavy metals to be investigated in this study are V, Mn, Cd, Ni and As.

This study is guided by the following research questions:

First, what are the concentrations of heavy metals in the fish species in the wetlands of oil-bearing Niger Delta?

Second, are the concentrations of the heavy metals in the fish species within the maximum allowable concentrations for heavy metals in fish as

recommended (WHO 2006, 2014)?

Third, Can fishery and aquaculture practices be continued in these Niger Delta wetlands?

The study is guided by a hypothesis as below:

H_0: There is no significant difference between the concentrations of the heavy metals in the fish species in the wetlands in the Niger Delta and WHO maximum allowable concentrations of heavy metals in fish.

Materials and methods

Study area

The Niger Delta region of Nigeria is made up of 9 states with each state having varying quantities of crude oil deposits. The Niger- Delta situated in the Gulf of Guinea at the Atlantic Ocean, lies within latitude 5°,1920.40``N and longitude 6°28` 8.99E.

The people who inhabit Niger Delta are mainly fishermen, farmers, petty traders and artisans. Some are public and civil servants working in Ministries, Agencies and Departments.

The Niger Delta is the oil belt of Nigeria and plays host to 3 out of the four petroleum refineries in Nigeria and the largest gas plant in Africa Okpai gas plant. The terrestrial and aquatic environments are the recipients of effluent discharges from petroleum and gas activities within the Niger Delta regions.

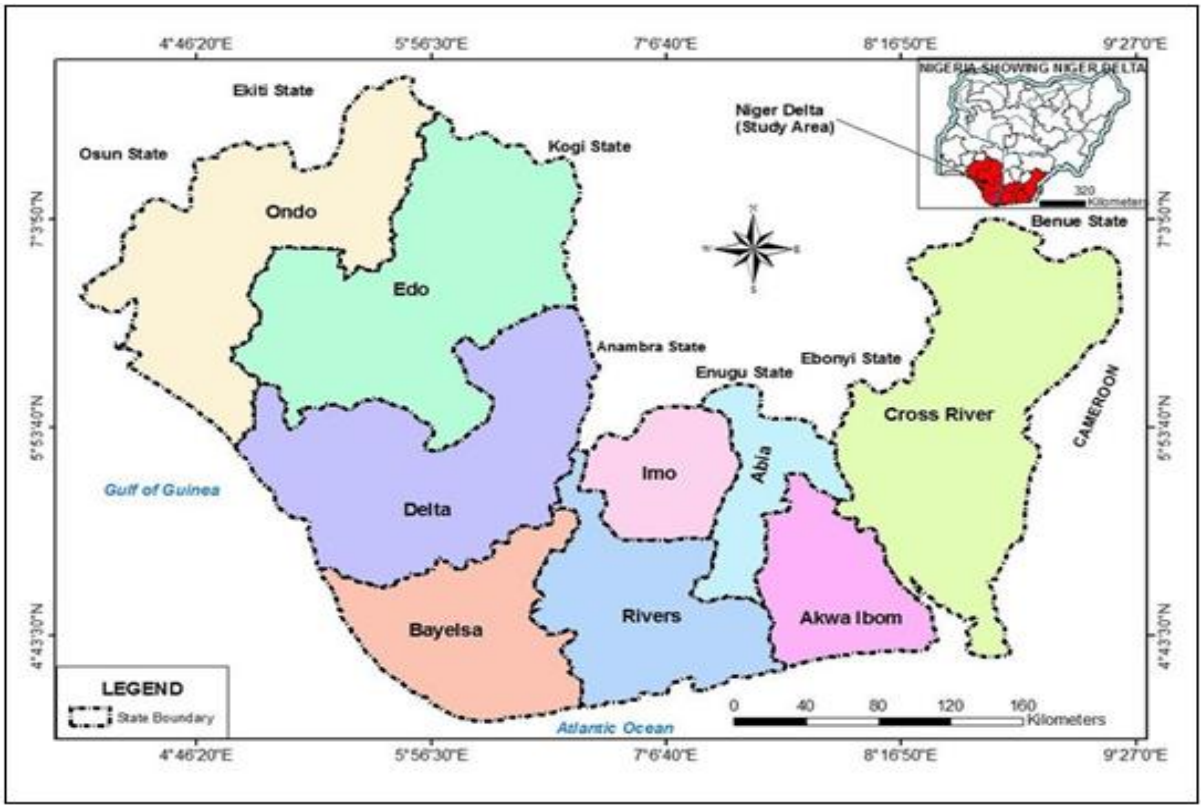

Fig. 1. Map of the Niger Delta, Source: Oweikeye, Endoro. (2017).

Ethical statement

The samples for this study were collected from the wild by artisanal fishermen. The sample species were not endangered, nor were they protected. The permit was not sought because the wetlands were not under any protection and a law prohibiting the fishing in the wetland was not in place. There was no ethical consideration in this study.

Sampling

The nine (9) Niger Delta oil-bearing states constituted the population of this study and 5 states that is 56 percent of the Niger Delta state (Jamodu, 2017, Garuba, 2018) were randomly selected to make the sample. These states were Delta, Bayelsa, Rivers, Akwa Ibom and Imo States. From each of the 5 states, oil-bearing communities with the heavy presence of

oil exploration and exploitation activities were randomly selected as research stations (RS) and from each of the research stations (RS) five sampling cells (SC), that is 5 different wetlands were mapped out for samples collection (Adetabi, 2016, Ajumogobia, 2017, Layiwola, 2019).

The sample cells for each state were Sagbama in Bayelsa, Uzere in Delta State, Ibeno community in Akwa-Ibom state and Adoni in River state.

The communities where samples were collected in Ibeno Akwa Ibom state were Ibeno Edo, Ikot Iben, Uquo Ibeno, Eyet-Ibeno and Ukpenekag (Jamodu, 2017, Garuba, 2018). The wetlands where fish samples were collected in Sagbama community in Bayelsa state were Abuku, Adagbabiri, Agoro, Agalabiri and Agorogbene wetlands.

In Delta, the wetlands where fish samples were collected in Uzere, were Ezede, Uweye, Afikoro, Uhroko and Iboro and in Oguta oil-producing community in Imo state, the wetlands sampled were Orsu Obodo, wetland, Igbugankwo, Mbachi, Abutu and Ishibe while the wetlands sampled in Andoni in Rivers state were Afradiki, Agomotor, Agbadama, Aganna and Agbachichama. The fish species ubiquitous in the Niger Delta wetland ecosystem were sampled for the study and the species were catfish *Clarias* spp (*angularis*, and *gariepinus*), *Tilapia zilli* and snake head (*Chana obscura*). Samples of the 3 species collected from 5 wetlands in each of the sampling stations in each state were bulked and composites drawn and stored in -20° ice-cool boxes and taken to the laboratory for analysis The samples were collected with the help of artisanal fishermen through the deployment of seine, gill and cast nets.

The sample collection was carried out within a period of six months (March to August) in 2021.

Sample preparation

The samples were rinsed with distilled water after thawing and removing the scales of Tilapia zilli and *Chana obscura*.

The specimen was then dissected using stainless steel scalpels and dried with an automatic freeze drying machine/siccatama FD500 Demark) for 24 hours. After cooling, 5g of the sample were weight out and digested (Voegborlo *et al*. 2012) perchloric and nitric acid HNO_3-$HClO_4$ at 1:1 were employed in the digestion and this was followed with the addition of sulphuric acid. The resulting mixture was subjected to the heat source for 30 minutes at 200°C. The digest was allowed to cool completely at room temperature and then distilled water was added to make up a 50 ml scale standard flask.

Determination of the Heavy Metals

Determination of the metals investigated; V, Mn, Cd, Ni and as were done using Agilent inductively coupled plasma-mass spectrometry (ICP-MS) model 7900 and Agilent atomic absorption photospectrometer model 240A equipped with an acetylene. Working standards for instrument calibration were made from the stock, 1000 ppm for each metal by serial dilution using distilled water (Uyimadu, 2020) Blank samples were equally made to check for background contamination (Ajayi, 2021).

The aggregate mean concentrations of the heavy metals in fishes the Niger Delta wetlands were subjected to test of significance with special package for social sciences (SPSS) statistical tool model 21 at 0.05 level of significance. The p value is 0.021 thus rejecting H_o.

Results

The results of the analysis of the heavy metals in fish samples in the Niger Delta are as in Figure 2 to 6 withaggregate heavy metal comparison in Figure 7.

Discussion

Marine pollution is a global phenomenon that is attaining crises point with its concomitant health implications. Determination of the levels of pollutants in aquatic environments is imperative so as to reduce the risk associated with the consumption of contaminated sea foods for healthy living. The results of the heavy metals concentrations in three species of

bentic and pelagic fish species; *Claria* spp., *Chana obscura* and *Tilapia zilli* revealed varying concentrations of the heavy metals investigated.

The analysis of the fish samples revealed low concentration of vanadium in three of the research stations investigated that is Andoni oil producing community in Rivers state, Ibeno in Cross River state and Oguta oil in Imo state. However, the investigation presented high content of vanadium in Sagbama in Bayelsa state and Uzere in Delta state. Low concentration of V recorded in the 3 research stations could be attributed to the type of petroleum found in the communities as well as the production techniques adopted by the oil exploitation companies. Human exposure to high V concentration results in stomach discomfort, kidney damage, loss of energy (Rashel, 2001; Dai and Sun, 2001; Wang and Wang, 2002). Low concentration of vanadium in fish speices has been reported (Suncar *et al.*, 2006; Meche, 2010).

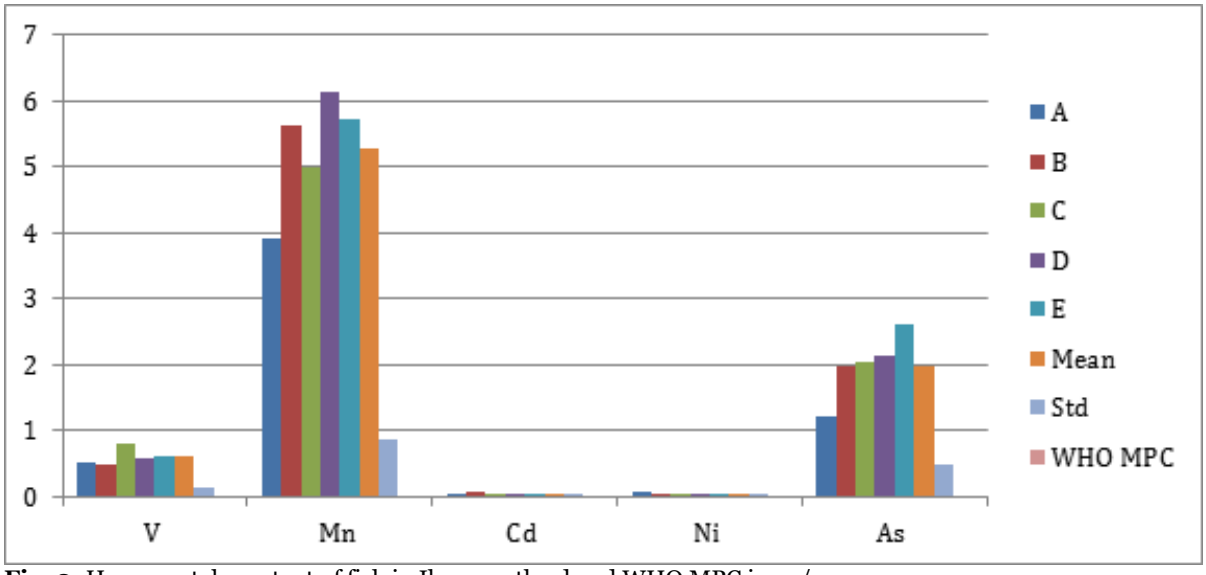

Fig. 2. Heavy metals content of fish in Ibeno wetland and WHO MPC in µg/g.

The heavy metals concentration in fishes in Ibeno wetlands in decreasing order are as follows: Mn > As > V > Cd = Ni.

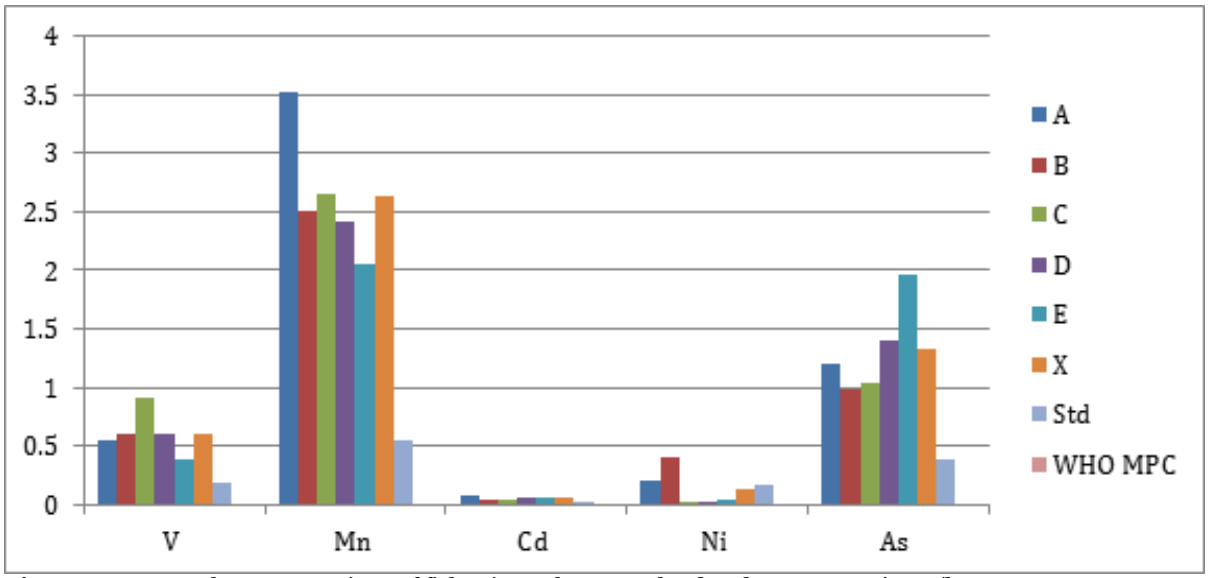

Fig. 3. Heavy metals concentartions of fishes in Sagbama wetland and WHO MPC in µg/l.

The heavy metals concentration in fishes in Sagbama wetlands in decreasing order are as follows: Mn > As > V > Ni > Cd.

The result of the investigation of the heavy metals concentration of fish species harvested in the wetland of Niger Delta oil producing communities revealed high concentration of Mn in oil producing communities investigated and this can be associated with oil extraction activities in the environment. High concentration of Mn in aquatic organisms has been reported (Al-Busaidi, 2011, Voeghorlo *et al.*, 2012, Bawuro *et al.*, 2018). Prolonged exposure to Mn by human results in varying health implications such as Parkinson disease and osteoporosis (Mustapha and Guluza, 2003), hallucination, respiratory problem (Dural *et al.*, 2007).

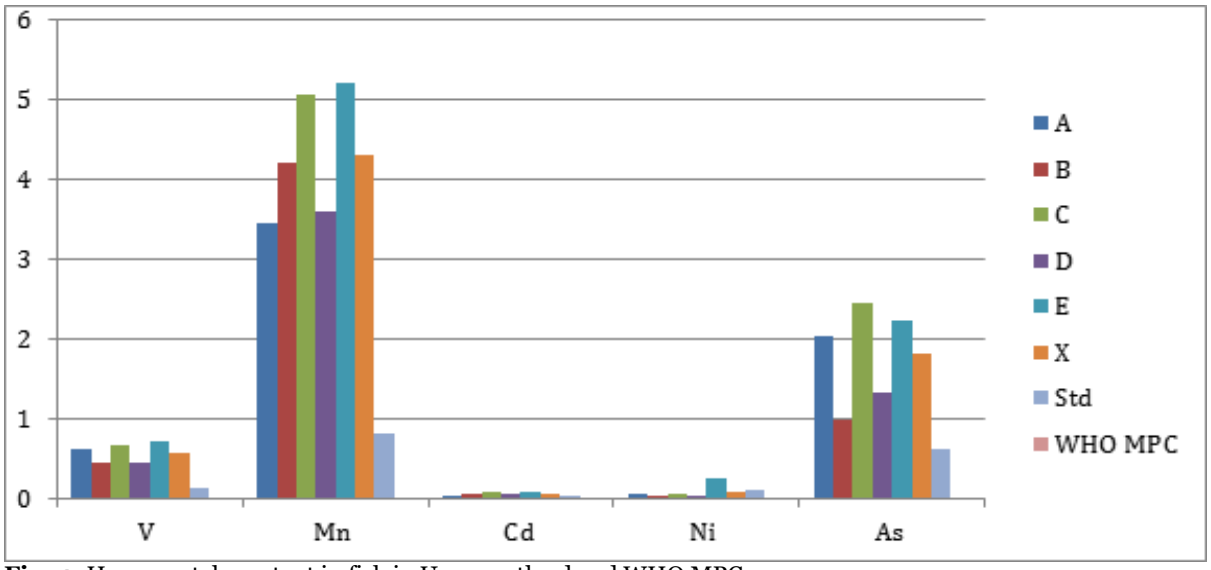

Fig. 4. Heavy metals content in fish in Uzere wetland and WHO MPC.

The heavy metals concentration in fishes in Uzere wetlands in decreasing order are as follows: Mn > As > V > Ni > Cd.

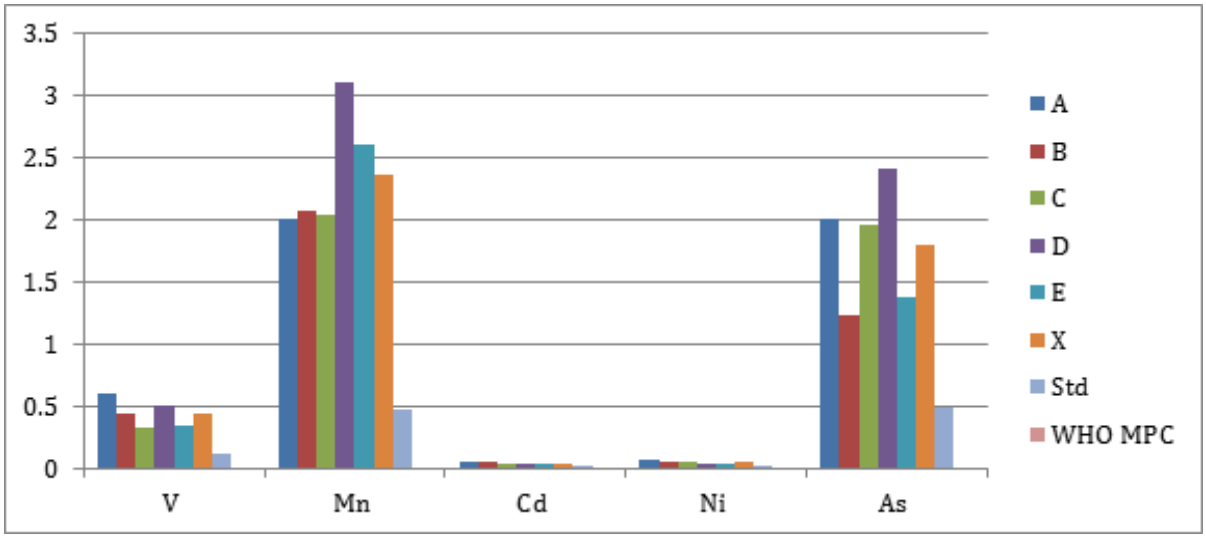

Fig. 5. Heavy metals of fish in Oguta wetland and WHO MPC in µg/g.

The heavy metals concentration in fishes in Oguta wetlands in decreasing order are as follows: Mn > As > V > NI > Cd.

The result of the heavy metals analysis of fish harvested in the wetlands showed that Cd concentration was high in 3 out of the 5 states, Andoni, Sagbama and Uzere with low concentrations recorded in Ibeno and Oguta. Low concentration recorded in Ibeno and Oguta could be associated with

the extraction methods employed by the oil exploitation company or the variant of crude oil found in the two communities. Human prolonged exposure to Cd results in damaged lungs (Agency for Toxic Substances and Disease Registry (ATSDR), 2012). Kidney problem and bone disease (Rahman *et al.*, 2012). High concentration of Cd in fish species in oil producing area have been reported (Zhang, 2001). Low concentration of Cd in fish species was equally reported (Qadir and Malik, 2011).

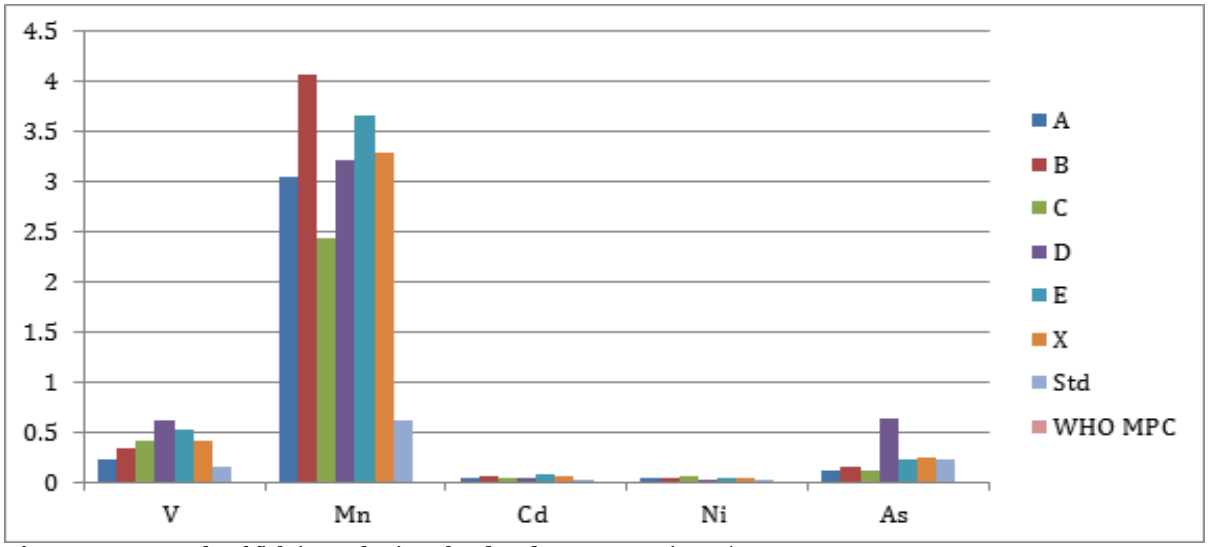

Fig. 6. Heavy meals of fish in Andoni wetland and WHO MPC in µg/g.

The heavy metals concentration in fishes in Andoni wetlands in decreasing order are as follows: Mn > V > As > Cd. > Ni.

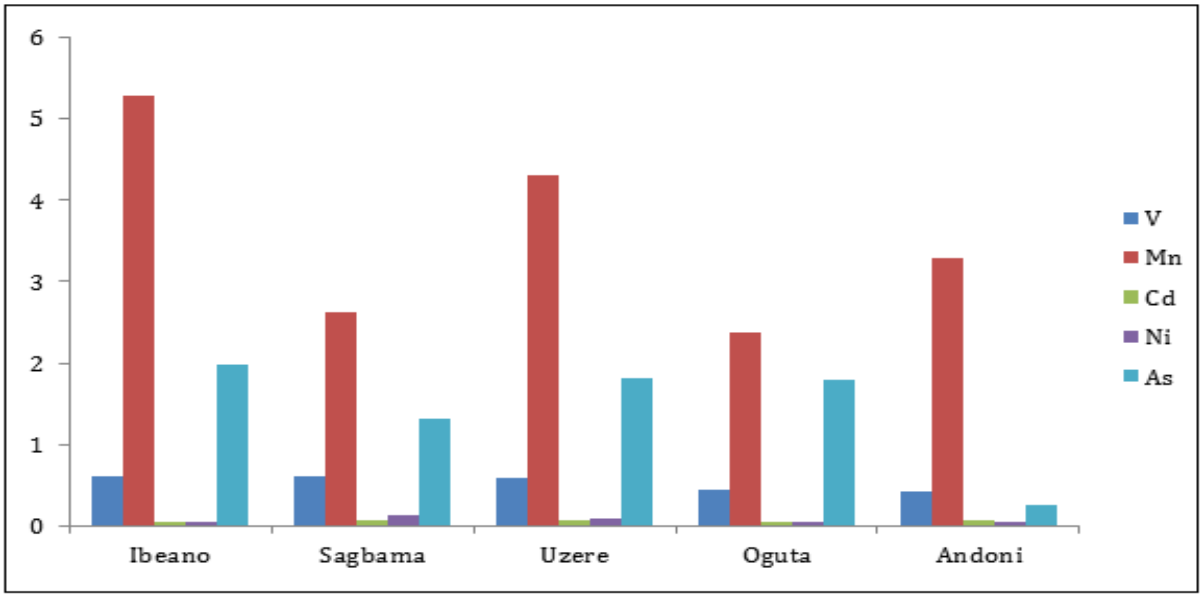

Fig. 7. The aggregate mean of heavy metals in fishes in the Niger Delta wetlands and WHO MPC in µg/g.

The aggregate concentration of heavy metals in fishes in the Niger Delta wetlands in decreasing order are as follows: Mn > V > As > Ni > Cd.

The concentration of Ni in the areas investigated revealed low concentration in all the states except Uzere in Delta state. The increased concentration of Ni in Uzere may not be unconnected with long history of oil extraction as Uzere rank second to Olobiri in history of oil exploitation in Nigeria which begun in 1958 (Okecha 2003, Braku, 2009). Low Ni concentration in fish species in oil bearing wetland

have been documented (Rahman *et al*., 2012; Eislev, 210). High concentration of Ni in fish species has also been reported (Avenont and Maix 2010). Prolonged human exposure to Ni results in various health problems such cancer, kidney failure and lung problem (International Agency for Research in Cancer, 2012, Agency for Toxic Substances and Disease Registry, 2013).

It also results in nose sinuses, and dermatitis (Genche, 2020). Nickel exposure equally results in headache, blisters with draining fluid (dhancesh, 2012). The result of the investigation showed that as was high in the fish samples investigated in four out of the 5 states oil producing communities investigated. High concentration of as in these oil producing communities are the resultant effect of oil exploitation. High content of as in fish species investigated in oil producing environment have been reported (Khalid, 2004, Gonzalez and Amenta, 2008, Ploetz and Rice, 2007) and human exposure to as in high concentration results in angiosarcoma lung, skin and bladder cancer (IARC, 2004, ATSDR, 2012). Prolonged exposure to as also results in nervous and cadioscular disorder (Yan *et al*., 2004; Verol, 2013; Zhao, 2012).

Conclusion

The results of the heavy metals V, Mn, Cd, Ni and as the content of three fish species sampled from selected wetlands of Niger Delta oil-producing communities showed that most of the areas investigated presented elevated concentrations of the heavy metals in the fish species. This shows that world best practices are not adopted by the oil mining companies operating in the Niger Delta. They are enjoined to operate within the ethical standards set for operations in the oil industry for the sustainability of the environment. Against this backdrop of the result of this investigation, it is recommended that fishing and aquaculture in these areas investigated be suspended forthwith until remediation is carried out. The environment monitoring agencies in Nigeria should live up to their billing by constantly monitoring the oil exploiting companies operating in the Niger Delta to ensure their compliance with the world's best practices in the oil industry. Clean-up exercise is highly recommended so as to allow the fisheries and aquaculture to be implemented in the wetlands for zero hunger, food security and economic growth and development in Nigeria.

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