CURRENT STUDIES IN COMPARATIVE EDUCATION, SCIENCE AND TECHNOLOGY, VOLUME 3, NUMBER 2, 2016, PP. 136-147

Temporal Variation of Heavy Metal Concentrations in Periophthalmus SP Obtained from Azuabie Creek in the Upper Bonny Estuary, Nigeria

M. MOSLEN
Rivers State University of Science and Technology, Port Harcourt, Nigeria

C. A. MIEBAKA
Azuabie, Trans-Amadi Industrial layout, Port Harcourt, Nigeria

Abstract

The Azuabie creek receives both industrial and domestic waste input in the Trans-Amadi area of Port Harcourt, Nigeria. This study aims to assess the level of some heavy metals (Cr, Ni, Cu, Pb, Ag and Cd) in the tissue of mudskipper fish over time and compare with regulatory limits. Mudskipper (*Periophthalmus* sp) samples obtained from the creek were examined on a monthly basis for twelve months (January 2015 – December 2015). Samples were analysed following the method of ASTM and determined using Atomic Absorption Spectrophotometery. Temporal variations were observed in the heavy metal concentrations of mudskipper samples examined with mean values as follows; 3.16 μgg^{-1}, 2.91 μgg^{-1}, 1.92 μgg^{-1}, 3.09 μgg^{-1}, 2.57 μgg^{-1} and 0.51 μgg^{-1} for Cr, Ni, Cu, Pb, Ag and Cd respectively. Seasonal variations observed were not statistically significant ($p>0.05$) but the concentrations of Cr, Ni, Pb and Ag were above the limits in sea food set by WHO, FAO and FEPA. Conclusively, metal concentrations in the fish tissues above regulatory limits suggests the ability of mudskippers to bio-accumulate and bio-magnify the metal pollutants without physical distress irrespective of seasonal differences. This calls for concern and further studies in order to detect signs of biota and habitat changes.

Keywords: Heavy Metals, *Periophthalmus* sp, Azuabie creek, Bonny Estuary

Introduction

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms (Järup, 2003). Fergusson, (1990) defined heavy metals as metallic elements that have a relatively high density compared to water. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Jaishankar *et al.*, 2013; Nagajyoti *et al.*, 2010). Heavy metal pollution is one of the challenges of coastal waters as a result of human activities such as oil exploration and exploitation, construction and fabrication of marine boats, disposal of industrial and domestic wastes and sailing. Pollution of aquatic ecosystems by heavy metals is an important environmental problem, as heavy metals constitute some of the most dangerous toxicants that can be bioaccumulated in living tissues (Guo *et al*., 1997; Omoregie *et al*., 2002). Otitoju and Otitoju, (2013) stated that heavy metal pollution of terrestrial and aquatic environments in Niger-delta region of Nigeria is on the increase due to increased urbanization and crude oil exploration. Among the most alarming types of potential pollutants generated as a direct outcome of industrial and domestic waste disposal are toxic and heavy metal pollutants (Rauf *et al*., 2009). Heavy metals occur naturally in aquatic ecosystem, but deposits of anthropogenic origin increase their levels and create environmental problems in coastal zones and rivers (Dural *et al*., 2007). Fishes are sensitive indicators of heavy metals pollution (Adeyemi *et al.,* 1996). Heavy metals have been reported to exert negative effect on biological processes in general and may influence the nutritional and biological status of sea foods (Udosen *et al*., 2001). It was also recognized that the increased environmental burdens of metals and acids in lakes were potentially stressful to local fisheries (Kakulu and Osibanjo 1986). Hervey and Lee (1982) stressed the significance of the increased metal loadings that have been coincidental with acidification and concluded that the reproductive failure is a symptom of both acids and metal stresses. Regularly discharged pollutants have imminent detrimental effect on the flora and fauna of coastal ecosystems especially mangrove ecosystems and tropical mudflats (Ansari *et al*., 2014). Protecting and improving the state of coastal waters and mangrove forests ecosystems which are the natural habitat for mudskippers, mudskipper populations can be protected.

Mudskippers are Gobies in the family Gobidae, subfamily Oxudercinae and tribe Periophthalmini (Murdy, 1989). They are amphibious fish that can use their pectoral fins to move on land (Swanson, and Gibb, 2004; Harris, 1960). This makes them major dwellers of the intertidal habitat, particularly on stretches of mudflats at low tide and on roots/bodies of aquatic plants during high tide. They also make holes/ burrows into muds as part of their main habitats. They feed and interact well during low tide on mudflats where they indicriminately ingest and accumulate toxic substances deposited into sediments. Mudskippers spend extensive periods of time out of water and have numerous physiological, morphological and behavioral specializations for amphibious life (Gordon *et al*., 1969; Clayton, 1993; Graham, 1997; Lee and Graham, 2002). Mudskippers are consumed by humans as food and this serve as potential for human exposure to toxicants therefore, regular monitoring is recommended. Mudskipper is usually cultured and studied ecologically because of their considerable tolerance to environmental stressors, organic and inorganic contaminants (Dabruzzi, *et al*., 2011).

Metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure (acute or chronic). This can lead to various disorders and can also result in excessive damage due to oxidative stress induced by free radical formation (Jaishankar, 2014). Target organs include skin, lung, liver, kidney bladder and others depending on the exposure and type of metal. Arsenic exposure is clearly linked to cancer of skin, lung, bladder, liver and kidney in human (Singh *et al*., 2007; Singh and Rana, 2007). Arsenic is known to exert some of its effects through interaction with glutathione - GST (Yoon *et al*., 2008) while Cd affects the transcription of genes and induces human genes which perform protective functions (Koizumi, 1997), and those coding for metallothioneins (Karin *et al*., 1984; Schmidt *et al*., 1985. Mercury can form a number of stable organic mercury compounds by attaching to one or two carbon compounds. Methyl mercury (CH3Hg+) is the most important organic form from human health point of view (Yoon *et al*., 2008). Methyl mercury undergoes biotransformation to divalent mercury compounds in tissues by cleavage of the carbon mercury bond. Within cells, mercury may bind to a variety of enzyme systems including those of microsomes and mitochondria producing nonspecific cell injury or cell death (Yoon *et al*., 2008). Toxic effects of chromium in human have been attributed to Cr (III) complexes with intracellular macromolecules (Yoon *et al*., 2008). The mechanism of toxicity of Cr at the biochemical level, cellular level –cell cycle arrest and genomic level has also been repoeted (Bridgewater *et al.,* 1998; Singh *et al*., 1998; Kaltreider *et al*., 1999; Dubrovskaya and Wetterhahn, 1998; Solis-Heredia *et al*., 2000) The Mechanisms of lead toxicity include damage to membranes, disturbances in metabolism and direct interference with neurotransmitter synthesis (Yoon *et al*., 2008). Molecular mechanisms of toxicity of copper leading to Wilson disease has also been reported by Bull *et al*. (1993). Heavy metals bind to protein substances and obstruct normal metabolic activities, reactions and cycle in the body.

Controlling garbage, untreated waste waters, pollutants, nutrients directly into the coastal waters will definitely help in protecting mudskippers (*Ansari, et al*., 2014). Several studies have been carried out to investigate the presence of heavy metal pollutants in aquatic ecosystems (Dambo, 1992, Dambo and Ekweozor, 2000, Calamari and Naeve, 1993; Obasohan and Oronsaye, 2000; Oguzie, 2000; Daka *et al*., 2007). However the concentrations of metals dissolved in water may give a highly misleading pictureof the degree of metal pollution and in some cases may significantly under-estimate the total metal concentration in the environment (Hameed and Raj 1990; Philips and Rainbow, 1993). Hence most researchers use benthic organisms as biomonitors of both the levels and long-term influences of pollutants within an ecosystem (Philips and Rainbow, 1993, Horsfall *et al*., 1998).The Azuabie creek receives industrial and domestic waste input from companies located along the Trans -Amadi industrial area and coastal settlements along the creek. Such anthropogenic activities could impact negative on the aquatic system in the creek. This study seek to assess the level of some heavy metals in the tissues of the mudskippers (*Periophthalmus* sp) obtained from the Azuabie creek..

Materials and method

Study site: The study location is the Azuabie creek. The Azuabie Creek located on the eastern part of Port Harcourt is part of the upper Bonny estuary of the Niger Delta (Fig. 1). The creek is tidal and drains into the Okpoka River that drains into the Bonny River. Mangrove and Nypa palm are dominant vegetation in the study area. At low tide, mudskippers are seen on exposed tidal mudflats during feeding.

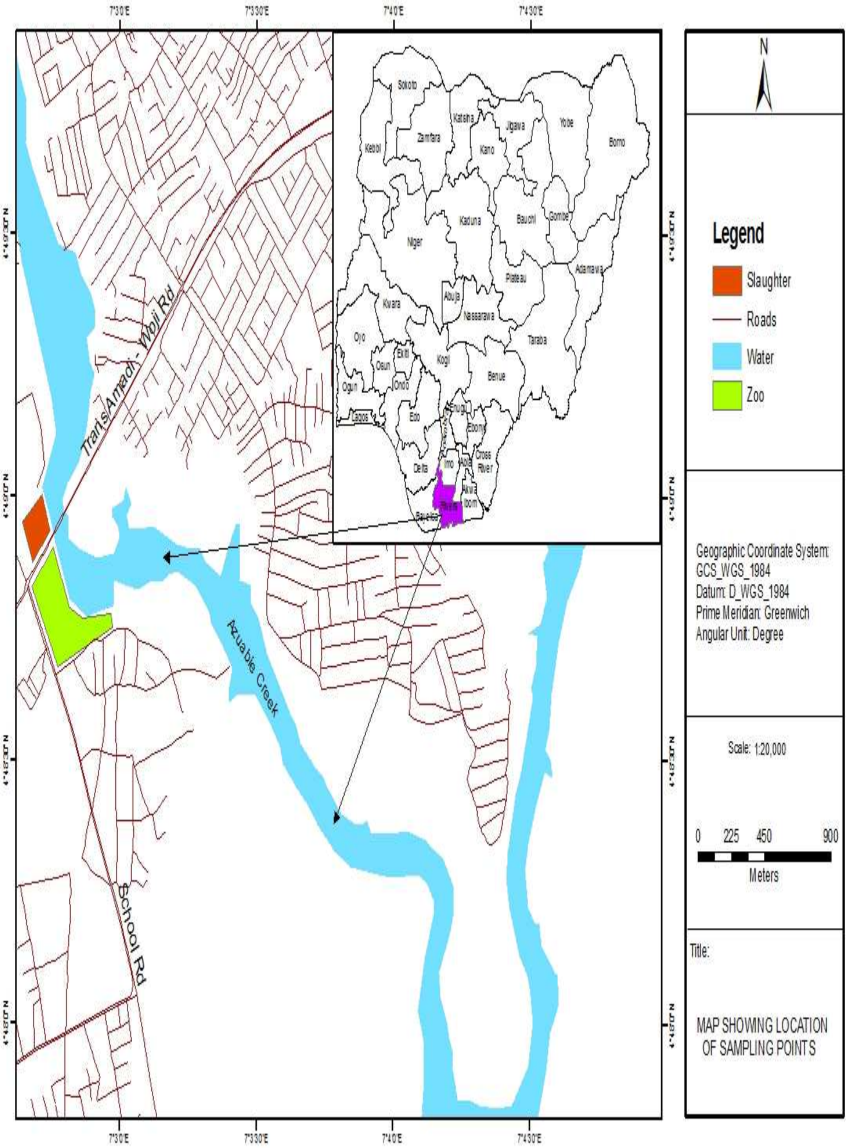


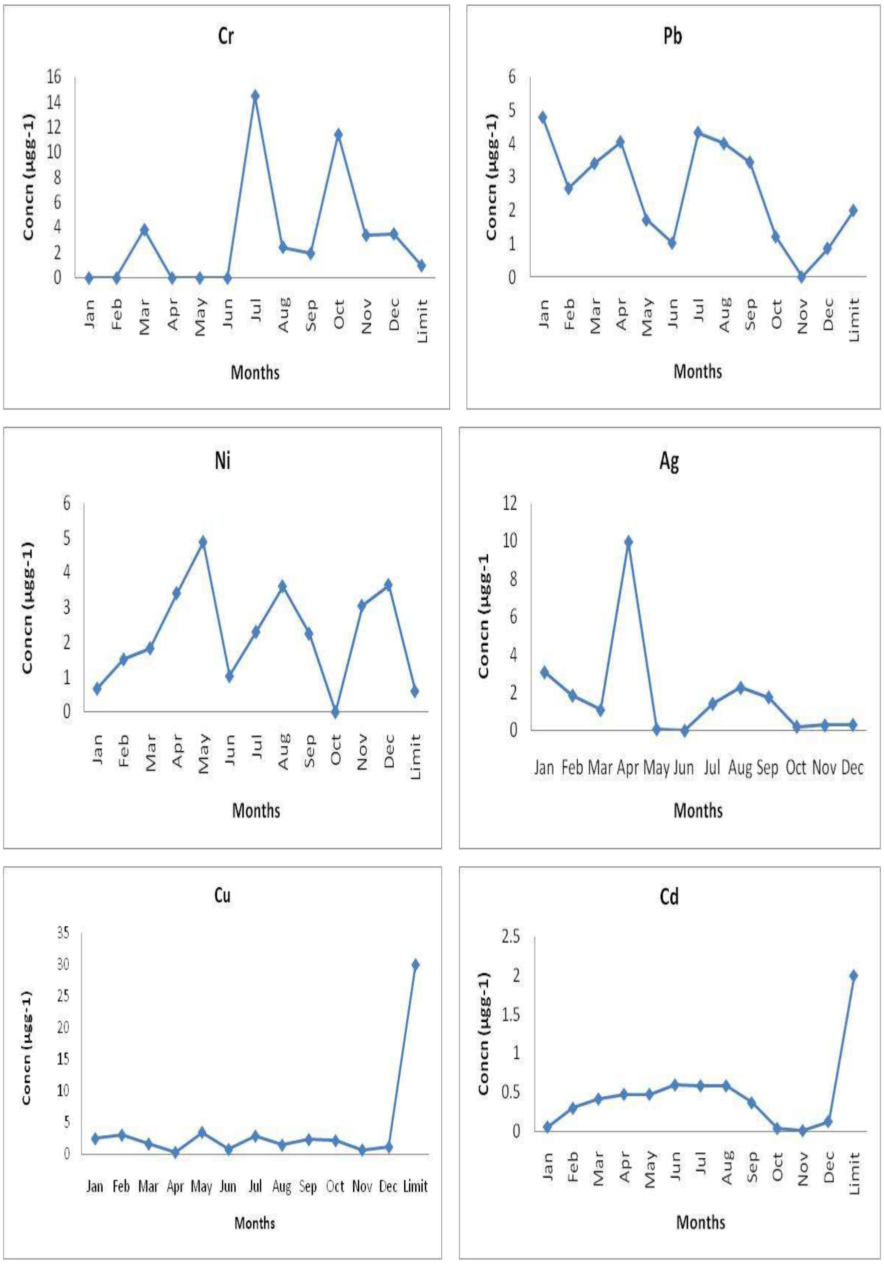
Fig. 1: Location of Azuabie Creek

Sample Collection and Analysis

Mudskipper samples were collected on a monthly basis for a period of 12 months (January – December, 2015). The rationale for the choice of the sampling period was to incorporate both dry and wet season periods for purposes of seasonal differences. Mudskippers were obtained by fishermen at low tide using non-destructive manual methods. Five samples were obtained and used as composite sample for each month. Samples were immediately preserved in ice packs and transported to the laboratory where they were frozen before analysis. Whole samples were dried and digested using HCl/HNO_3 following the method of the American Society for Testingand Materials (ASTM, 1986). The concentrations of heavy metals were determined using an Atomic Absorption Spectrophotometer (GB Avanta PM AAS, S/N A6600). The concentrations were blank-corrected and expressed as μgg^{-1}dry weight of sample. Significant differences in metal concentrations between months were tested by Analysis of Variance (ANOVA) of log (x+1) transformed concentrations while the t-Test was used for test for significant difference between seasons. Analyses were performed using MS Excel.

Results

Temporal variations were observed in the heavy metal concentrations of the mudskipper fish samples examined (Fig 2). The concentrations of Cr in samples differed across months with lowest value of <0.001 μgg^{-1} observed in the months of January, February, April, May and June and highest value of 14.54 μgg^{-1} observed during the month of July. There was no significant difference ($p>0.05$) between dry and wet seasons in the levels of Cr but observed values were generally higher than the 1.0 ppm limit in fish food (WHO,1985; FEPA, 2003 and FAO,1983). The concentration of Ni in mudskipper samples also varied across periods of study with the least value (<0.001μgg^{-1}) observed during the month of October and the highest value (4.88 μgg^{-1}) noticed during the month of May. These values were not significantly different ($p>0.05$) between seasons but were generally higher than the 0.6 ppm limit in fish food (WHO, 1985; FEPA, 2003 and FAO, 1983). Temporal differences were also recorded in the concentrations of copper in mudskipper samples examined without seasonally significant difference ($p>0.05$). Cu levels in fish samples ranged from 0.36μgg^{-1} in April to3.53 μgg^{-1} in May with such values below the limit in fish food (WHO, 1985; FEPA, 2003 and FAO, 1983). Seasonal differences were not significant but temporal variations were observed in the concentrations of Pb in fish samples with values varying between <0.001 μgg^{-1} (November) and 4.80 μgg^{-1} (January). The concentrations of Pb were observed to be less than the limit in fish food (WHO, 1985; FEPA, 2003 and FAO, 1983) for five different months while the other seven months had values higher than the limit. Ag concentrations in fish samples was highest (9.95 μgg^{-1}) in April and least (<0.001 μgg^{-1}) during the month of June while those of Cd was found to be least (<0.001 μgg^{-1}) during the month of November and highest (0.59 μgg-1) during the month of June 2015. Values of Cd found in fish samples were all less than the 2ppm limit in fish food (WHO, 1985; FEPA, 2003 and FAO, 1983).



Limit = WHO, FAO and FEPA Limits.

Fig. 2: Temporal variation in heavy metal concentrations of *Periophthalmus* sp

Discussions

Mudskippers are important for their biological and eco-toxicological studies and recognized as potential bio-indicators in environmental monitoring and assessments of coastal waters and tropical or subtropical soft bottom intertidal systems (Aligaen and Mangao, 2011). Mudskippers are very sensitive to ambient environment and this potential would be beneficial for new researches on this species especially its ecological importance in detecting pollution levels in coastal water ecosystems (Ansari *et al*., 2014). The results from this study were generally above the limits in fish food (WHO, 1985; FEPA, 2003 and FAO, 1983) showing elevated levels of heavy metals in mudskipper samples examined except for Cu and Cd. This suggests bioaccumulation of certain metals in the organisms obtained from Azuabie creek. The implication here is that the mudskipper fish could accumulate elevated levels of heavy metals in their tissues over time without physical signs of distress. This may constitute potential health harm to consumers of the fish from presumed polluted areas, hence the need to carry out regular monitoring studies. Heavy metals input into the Azuabie creek are traceable to anthropogenic activities from industrial and domestic discharges into the creek. Such heavy metal pollutants are indiscriminately taken in during feeding by benthic feeders such as mudskippers and this has the tendency for bioaccumulation in the tissues of the fish. In polluted coastal areas mudskippers are the potential bioindicators and bio-accumulators of pollutants and directly or indirectly related with human health issues, as they are consumed in different regions (Aligaen and Mangao, 2011). It has been found that mudskippers can accumulate very high concentrations of toxic compounds in their tissues (Polgar *et al*., 2010). Their robustness to environmental stressors and tolerance against many contaminants give them the capacity to be exposed to toxicants without significant effects, and to biomagnifying toxicants in their body tissues (Polgar *et al*., 2010). This in tandem with the findings of this study where mudskippers used were observed to be healthy looking in spite of the high concentrations of metals found in the fish tissues. Barium was not examined in this study but Nwakanma and Hart (2013) reported high concentrations (22 – 510 µgg-1) of the metal in the Niger Delta mudskipper in a bioaccumulation study of the area. This also agrees with the findings of this study that mudskippers could actually bioaccumulate elevated concentrations of heavy metals and bio-magnify it along the food chain.

Conclusion

Heavy metal contamination in the aquatic environment is a measure challenge with regards to industrialization in view of the fact that industrial and domestic wastes containing such pollutants are regularly channeled into nearby water bodies. Mudskipper samples from Azuabie creek had elevated concentrations of Cr, Ni, Pb and Ag in their tissues suggesting metal inputs into the creek. The tendency to bioaccumulate such heavy metals in the tissues of *Periophthalmus* sp without any physical sign call for serious concern of potential health risk. Treatment of industrial wastes and regulation of domestic waste discharge directly into the creek are key control measures. Regular aquatic monitoring studies are also important in order to detect sings of environmental fluctuations and degradations.

Correspondence
Dr. Miebaka Moslen
Department of Applied and Environmental Biology
Rivers State University of Science and Technology
Port Harcourt, Nigeria
Email: moslen4c@yahoo.com

Dr. (Mrs) Calista Adamma Miebaka
Azuabie, Trans-Amadi Industrial layout
Port Harcourt, Nigeria
Email: ekehcalista@yahoo.com

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