BIOACCUMULATION AND TOXIC EFFECTS OF SOME HEAVY METALS IN FRESHWATER FISHES

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ABSTRACT

The contamination of the aquatic systems with heavy metals from natural anthropogenic sources has become a global problem which poses threats to ecosystems and natural communities. Hence this study reviews the effects of heavy metals in freshwater fishes. Fishes bioaccumulate heavy metals (including cadmium, zinc, lead and copper) through various organs such as gills, liver, stomach and intestine. The effects of these heavy metals are highlighted.

Keywords: Bioaccumulation, Toxicity, Heavy metals, Cadmium, Zinc, Lead, Copper, Freshwater fish

INTRODUCTION

Heavy metal according to Dianne and William (1999) embraces any metal exposure to which is clinically undesirable and which constitute a potential hazard. The presence of heavy metals in the aquatic environment is a major concern because of their toxicity and threat to plant and animal life, thus disturbing the natural ecological balance (Bhattacharya *et al*., 2008). The rate at which heavy metals gain entry into the aquatic systems is alarming. The occurrence of heavy metals in aquatic ecosystems in excess of natural loads has become a wide spread problem and a matter of concern over the last few decades (Voegborlo *et al.,* 1999; Canli *et al.,* 1998; Dirilgen, 2001; Vutukuru, 2005). The sources of toxic heavy metals in aquatic environment could be traced to both natural and anthropogenic sources for changes arising from anthropogenic activities have taken place in aquatic ecosystem affecting the aquatic habitat (Olomukoro and Ezemonye, 2011) and fish, the major component of the food chain leading to humans (Mason, 1996). Through human activities such as industrialization, urbanization and agriculture, effluents are discharged into water systems either directly or through run-of, leaching or seepage (Ezemonye and Kadiri, 2000). Heavy metals and organic compounds can bioaccumulate in aquatic biota (USEPA, 1991) and biomagnify in food chains. Bioaccumulation is the net build-up of substances from water in an aquatic organism as a result of enhanced uptake and slow elimination of such substance (Bhattacharya *et al.,* 2009). Heavy metals are conservative pollutants in that they are broken down over such a long time scale that they effectively become permanent additions to the aquatic environment (Mason, 1996). Since heavy metals bioaccumulate and have deleterious effects on the aquatic ecosystems (Roux, 1994; Ezemonye *et al.,* 2006) bioaccumulation measurements are necessary. Bioaccumulation measurements refer to studies on methods of monitoring the uptake and retention of pollutants like metals or pesticides in organs or tissues of organisms such as fish (Roux, 1994). Hence Olaifa *et al.* (2004) and Vinodhini and Narayanan (2008) reported that among aquatic animal species, fishes cannot escape from the detrimental effects of these pollutants. Thus fish health, growth, development and survival is affected. The characteristic feature of heavy metals is their strong attraction to biological tissues and in general their slow elimination from biological systems (Nwani *et al.,* 2009). The uptake of heavy metals in fish was found to occur through absorption across the gill surface or through the gut wall tract (Obasohan, 2007; Nwani *et al.,* 2009). Diffusion facilitated transport or absorption in gills and surface mucus are the mechanisms of uptake from water (Oguzie, 2003). Bioaccumulation of metals reflects the amount ingested by the organisms, the way in which the metals were distributed among the different tissues and the extent to which the metals is retained in each tissue type (Murugan, *et al.,* 2008). In light of the above this study seeks to address issues pertaining to the bioaccumulation of some heavy metals in fish.

MATERIALS AND METHODS

A comprehensive literature search was made from the internet and serial materials of University of Nigeria, Nsukka. Different journal articles, proceedings of learned societies of fisheries and hydrobiology and textbooks were consulted in relation to heavy metals and their effects on freshwater fishes.

RESULTS AND DISCUSSION

Cadmium: Cadmium, the most toxic and non-essential heavy metal has wide distribution in the earth's crust and aquatic environments (Muthukumaravel *et al.,* 2007). Cadmium occurs naturally in some phosphate rock and this may account for the high concentration of cadmium in some phosphate fertilizers (Geisy, 1978; Oronsaye, 2001) such as super phosphate fertilizer. With increased urbanization and industrialization (Akan *et al.,* 2009) there has been rapid and persistent increase in the manufacture and utilization of cadmium over the years. It is to be expected that run off from agricultural land treated with cadmium bearing fertilizers can enrich the aquatic environment with the metal (Oronsaye, 2001). Cadmium has many industrial applications and measurable amounts of the metal may be discharged as effluents to surface water (Onuoha *et al.,* 1996; Oronsaye, 2001).

Cadmium, a heavy metal commonly used in environmental studies, is highly toxic and widely distributed in the environment (Ghiasi *et al.,* 2010). Cadmium is highly toxic to some aquatic life (Mason, 1996) particularly fishes (Suresh *et al.,* 1993). Fish bioaccumulate heavy metals including cadmium through various gateways. Fish accumulation of chemicals especially those with poor water solubility occurs because of the very intimate contact with the medium that carries the chemicals in solution or suspension and also because fish have to extract oxygen from the medium by passing enormous volumes of water over the gills (Akan *et al.,* 2009). The gills, skin and digestive tract are potential sites of absorption of water borne chemicals (Vinodhini and Narayanan, 2008; Akan *et al.,* 2009). The chemicals once absorbed are transported by the blood to either a storage point such as bone, or to the liver for transportation (Akan *et al.,* 2009). Cadmium has deleterious effects on fish (Table 1).

Zinc: Zinc, an essential element is one of the most common heavy metal pollutants (Kori-Siakpere *et al.,* 2008). Zinc is an essential element acting as structural component and having properties indispensable for life (Bengari and Patil, 1986; Murugan *et al.,* 2008). The sources of zinc and other heavy metals in natural waters may be from geological rock weathering or from human activities such as industrial and domestic waste water discharges and animals where it forms constituent functions in maintaining cytoplasmic integrity (Weatherly *et al.,* 1980; Kori-Siakpere *et al.,* 2008). Since zinc is an unnatural substance, it may persist for years without decomposition. Zinc is toxic to fish and macroinvertebrates at sublethal concentration (Folorunsho and Oronsaye, 1990; Ajiwe *et al.,* 2000; Nsofor *et al.,* 2007). Although zinc is an essential element (Dimari *et al.,* 2008) it is a potential toxicant to fish (Everall *et al.,* 1989; Murugan *et al.,* 2008) with adverse effects (Table 2). Liver and kidney are the primary sites of zinc accumulation (Murugan *et al.,* 2008).

Table 1: Effects of cadmium on freshwater fish

Fish	Effects	Sources
Gasterosteus aculeatus	Formation of vacuoles, and sloughing of the epithelial layer from the secondary lamellae and the enlarged subepithelial spaces reduce the amount of oxygen diffusing into fish by increasing the water to blood distance; severe constriction of the blood spaces and the enlarged red blood spaces and the enlarged red blood cells reduce blood flow and make oxygen transport less efficient. Many of the chloride cells degenerate.	Eller (1971) Oronsaye (1997) Oronsaye and Brafield (1984)
Fundulus heteroclutus	Increase in the number of chloride cells	Gardner and Yevich (1970) Oronsaye (1997)
Oreochromis mossambicus	Reduction of proteins due to the impact on the protein synthetic pathway.	Muthukumaravel *et al.* (2007)
Cyprinus carpio	Enhance susceptibility to disease due to decrease in innate immune response.	Ghiasi *et al*. (2010)

Table 2: Effects of zinc on freshwater fish

Fish	Effects	Sources
***Heteroclarias* sp.**	Affects tissue respiration leading to death by hypoxia, induce changes in vein and heart physiology, and causes a significant decrease in haemoglobin and haematocrit. Decreases plasma protein.	Kori-Siakpere *et al.* (2008)
Oreochromis niloticus ***Salmo gaidneri***	Result in several dysfunctions in fish. Exerts adverse effects by accruing structural damage which affects the growth, development and survival.	Tuurala and Soivio (1982) Kori-Siakpere *et al.* (2008)
Clarias ischeriensis	Decrease in plasma protein attributed to renal excretion or impaired protein synthesis or due to liver disorder.	Kori-Siakpere *et al.* (1995) Kori-Siakpere *et al.* (2008)
Salmo gardnerii	Cause toxic changes in ventilatory and heart physiology	Hughes and Tort (1975) Kori-Siakpere *et al.* (2008)
Clarias gariepinus	Sublethal levels adversely affect hatchability, survival and haematological parameters of fish	Cardeihac *et al.* (1981) Kori-Siakpere *et al.,* (2008)

Table 3: Effects of lead on freshwater fish

Fish	Effects	Sources
Tilapia galillilaeus ***Clarias lazera***	Delay embryonic development, suppress reproduction, and inhibit growth, increase mucus formation, neurological problem, enzyme inhalation and kidney dysfunction.	Al-kahtani (2009)
Clarias gariepinus	Lamella shrinkage, degeneracy of epithelium, branchial arterial rupture and ischemia, reduction in growth rate and loss in body weight, degenerates liver cells synctial arrangement.	Olojo *et al.* (2005)
Salmo gardnerii* and *Salvelinus namaycush	Inhibits egg hatching, excessive mucus secretion, hypertrophy and deformation of gill.	Weber *e al.* (1997)
Poecilia latipinna	Filaments and hyperplasila of epithelial cells hence lamellae fuses and gill lamellae curls at the tips, increases secretion of mucus from gills and skin, dilation of bile canaliculi and liver sinusoids, extravasation of blood and necrosis/pyknosis cell nuclei in liver.	Mobarak *et al.* (2010)
Auratus auratus	Genotoxic and cytotoxic damage in both gill and fin epithelia cells.	Cavas (2007)

Lead: Lead residues according to Mason (1996) are rich in heavy metals resulting in considerable contamination of freshwater systems. Lead is released into the environment mainly through exhaust pipes of automobiles as a result of its presence in gasoline (Nsofor *et al.,* 2007). Fishes bioaccumulate lead through various organs including gills, stomach, liver and intestine. The biological effects of sublethal concentrations of lead on fish are presented (Table 3).

Copper: Copper is among the heavy metals enrichment of Lagos lagoon reported by Okoye (1991) in which he implicated inland based urban and industrial wastes. The gill is an important site (Vinodhini and Narayanan, 2008) for the entry of copper. Other sites include liver, stomach and intestine. Copper contamination affects fish adversely. Woodward *et al.* (1994) have reported that high concentrations in fish can experience toxicity. Copper can combine with other contaminants such as ammonia, mercury and zinc to produce additive toxic effect on fish (Herbert and Vandyke, 1964; Rompala *et al.,* 1984).

Conclusion: Heavy metals are diffuse and conservative pollutants that bioaccumulate and biomagnify along the food chain with deleterious effects on the aquatic ecosystems. Although cadmium, zinc, lead and copper are vital in metabolic processes, efforts should be made to ensure that they and other heavy metals do not exceed the prescribed world Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) acceptable limits. All environmental policy should be enhanced and campaigns carried out to educate the public on the importance to protect and preserve aquatic systems and their resident biota.

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