# ACCUMULATION OF CADMIUM AND THE MODIFYING EFFECTS OF COPPER AND LEAD IN TISSUES OF AFRICAN SNAKEHEAD, *Parachanna obscura*

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**Abstract:** The chronic accumulation profile of cadmium was determined by analyzing the tissues of *Parachanna obscura* exposed to cadmium and the interactive effects of copper and lead by exposing the same fish specimens to combined metals using mixtures of 0.2 mg/L cadmium with 0.2 mg/L copper and 0.2 mg/L cadmium with two different concentrations of 0.2 mg/L and 0.4 mg/L of lead. Following 40 days of exposure, the highest concentrations of cadmium consistently accumulated in the liver of the fish. The intestine and caudal muscle accumulated low levels of cadmium, while the gill accumulated the lowest levels of cadmium. Correlation between cadmium and copper concentrations indicates that cadmium accumulation was increased by co-exposure to copper. Lead however, impaired the uptake of cadmium. This study provides an insight to cellular accumulation of metals caused by single and combined dose of metal exposure, and hence can serve as a useful tool in identifying prior exposure to metals.

**Keywords:** Cadmium, copper, gill, intestine, lead, liver, *Parachanna obscura*

## Introduction

In recent times, human activities have led to the introduction of many potentially hazardous inorganic compounds, heavy metals into our environment particularly as a result of industrial attributable point sources (Monday and Nsikak, 2007). Heavy metal contamination has been reported in aquatic organisms (Adham *et al*., 2002; Olojo *et al*., 2005). These pollutants build up in the food chain and are responsible for adverse effects and death in the aquatic organisms (Farkas *et al.*, 2002; Figueiredo-Fernandes *et al.*, 2007). Contaminants change water quality and can cause serious damages to the organisms, including fish (Jemal *et al.*, 2002; van der Oost *et al.*, 2003; Sirimongkolvorakul *et al*., 2012). The toxicity of these metals varies depending on the chemical nature of the metal, point of exposure and degree of exposure to the metal (WHO, 1992). Some of these metals are trace elements, essential for healthy growth and physiological wellbeing of living organisms, and both shortage and excesses could be detrimental to organisms (Kalay and Canli, 1999).

Most studies of the effects of metals on fish concern exposure to a single metal. Polluted water bodies, however, usually contain elevated levels of various metals. The effect of mixtures of two or more chemicals may be additive, synergistic or antagonistic. The data obtained by many authors presented in the review by Jezierska and Witeska 2001 indicate various interactions of various metals, and therefore the effects of their mixtures on fish may also differ from the effect of single elements (Sarnowski and Witeska, 2008). The frequent presence of lead, cadmium and copper in industrial wastes and its high toxicity along with considerable bioaccumulation in fresh water fishes makes them toxicants that should be given due consideration in aquatic toxicology (Gbem *et al.*, 2001). The effects of copper and cadmium in single exposure or co-exposure on growth of common carp (*Cyprinus Carpio* L.) larvae was studied by Sarnowski and Witeska (2008). They discovered that copper was more toxic to the fish compared to cadmium and a mixture of both metals indicated a possible antagonism of cadmium against copper toxicity. Thus, in this study, the fish, *Parachanna obscura* was used to assess the interaction of lead and copper with cadmium and the impact of their exposure to water bodies containing aquatic fauna which indirectly affects humans when the fishes or other edible organisms from the contaminated water bodies are ingested.

## Materials and Methods

Fifty (50) African snakeheads (*Parachanna obscura*) with average weight of 65 ± 4 g and length of 18±2 cm were obtained and reared in tanks with dechlorinated tap water and aerated using electronic air pumps for a period of 7 days. During the acclimatization period, they were fed with fish flakes. At the end of the acclimatization period, *P. obscura* specimens were exposed to very low, sub-lethal concentrations of the different heavy metals, at the desired pH (7.0). The 50 fishes were shared into four treatment tanks each stocked with 10 fish. Tank A was the control. Tanks B, C, D, and E represented the experimental treatment tanks. Tank B fish were exposed to 0.2 mg/L of Cd. Fish in tank C were exposed to a mixture of 0.2 mg/L of Cd and 0.2 mg/L of Cu. Fish in Tank D were exposed to 0.2 mg/L of Cd and 0.2 mg/L of Pb, while tank E specimens were exposed to a mixture of 0.2 mg/L of Cd and 0.4 mg/L of Pb. The test solution was renewed periodically (constant intervals) by transferring the organisms to a fresh test chamber with the same concentration of toxicant. The bioassay used in this study is the renewal system. The fishes were exposed for duration of 40 days.

After 40 days of exposure in the renewal system, one fish from each group of the experimental and control tanks was removed and dissected for tissue collection. The tissues collected included the liver, gills, caudal muscle and intestine. The tissues were essentially removed promptly to avoid postmortem degeneration (Carson and Christa 2009). The pretreatment method used in the digestion of tissues for atomic absorption spectrometry (AAS) is the mixed acid procedure. 0.25 g of different soft tissues excised from the fish was put in a 50 ml Kdeldahl flask. 2.5 ml of trioxonitrate (V) acid was added and allowed to stand for 30 min. Later, 0.5 ml of 70% perchloric acid and

0.25 ml tetraoxosulphate (VI) acid was added. This mixture was swirled gently and allowed to digest slowly at moderate heat under a fume chamber.

**Table 1: Tissue concentration of heavy metals of the control fish**

| Groups | Cadmium (mg/L) | Copper (mg/L) | Lead (mg/L) |
|---|---|---|---|
| AL (Control liver) | <0.001 | <0.001 | <0.001 |
| AG (Control gill) | <0.001 | <0.001 | <0.001 |
| AM (Control muscle) | <0.001 | <0.001 | <0.001 |
| AINT (Control intestine) | <0.001 | <0.001 | <0.001 |

***Statistics***

Data were subjected to analysis of variance (ANOVA) and significant differences were determined. The criterion for significance was set at $p<0.05$.

**Result and Discussion**

Cadmium and copper showed a consistent synergic relationship in liver as shown in Table 2. The tissue concentration of cadmium at single dose was 0.447 mg/L. However, in the presence of 0.047 mg/L of copper in the tissue, the value of cadmium significantly increased to 0.628 mg/L. Cadmium accumulation values was observed to decrease with the absence of copper even with the presence of lead at 0.2 mg/L and 0.4 mg/L of lead respectively. Tissue concentration of heavy metals for gills is shown in Table 3.

**Table 2: Tissue concentration of heavy metals of the experimental group for liver**

| Groups | Cadmium (mg/L) | Copper (mg/L) | Lead (mg/L) |
|---|---|---|---|
| BL (Cd in liver) | 0.471 | <0.001 | <0.001 |
| CL (Cd + Cu in liver) | 0.628 | 0.047 | <0.001 |
| DL (Cd+Pb in liver/Conc. A) | 0.482 | <0.001 | 0.002 |
| EL (Cd+Pb in liver/Conc. B) | 0.510 | <0.001 | 0.022 |

*Significance from control (p<0.05)

**Table 3: Tissue concentration of heavy metals of the experimental group for gills**

| Greeoups | Cadmium (mg/L) | Copper (mg/L) | Lead (mg/L) |
|---|---|---|---|
| BG (Cd in gill) | 0.026 | <0.001 | <0.001 |
| CG (Cd + Cu in gill) | 0.030 | 0.003 | <0.001 |
| DG (Cd+Pb in gill/Conc. A) | 0.028 | <0.001 | <0.001 |
| EG (Cd+Pb in gill/Conc. B) | 0.029 | <0.001 | <0.001 |

*Significance from control (p<0.05)

Gill filament of fish exposed to 0.2 mg/L of cadmium accumulated 0.026 mg/L of the metal. However, co-exposure with copper increased cadmium accumulated values to 0.03 mg/L. Thus, increase in tissue copper tends to increase the availability of cadmium in the gills. Lead values in the gill were low (less than 0.01 mg/L) and showed no synergic relationship with cadmium. The intestine revealed a synergic relationship between cadmium with copper and cadmium with lead as shown in Table 4. In the muscle tissue, increasing concentration of cadmium with increase in copper concentration was observed (Table 5). Increased availability of lead in tissue did not show any correlation with cadmium.

Metal accumulations in fish bodies appear as site specific, corresponding with the metallic toxicity of three aquatic components via water, plankton and sediments (Javed, 2003). The high tissue concentration values reported for liver could be attributed to the fact that the liver receives a major supply of blood from veins from the digestive system, pancreas and spleen via hepatic portal vein in addition to a supply of arterial blood from the hepatic artery. The liver is therefore situated directly in the way of the blood vessels that convey substances absorbed from the digestive system. This position gives the liver the first chance to metabolize these substances making it to be the first organ to be exposed to toxic compounds that have been ingested. The routes of uptake of cadmium by fish are mainly through ingestion of food and water or both (Kumada *et al.*, 1980). Cadmium has also been found to accumulate in specific sites in the body rather than being distributed throughout (Tawari-Fufeyin *et al.*, 2006). This suggest the possible high level of cadmium accumulation recorded in the intestinal and gill tissues as a result of the ingestion of food substances and water consumed, which may contain some trace of the contaminant. Oner *et al*. (1995) reported that cadmium accumulates in the mucosa of the gastrointestinal tracts.

Since the gills is a possible route for a toxicant to enter a fish via contaminated water (Nussey, 1998), it also suggest the possibility of tissue damage due to the contaminant. Thiyagarajal *et al.* (2000) also reported a high prevalence of gill lesions in two species of buffalo fish collected from a contaminated swamp. According to Kraemer *et al.* (2005), copper and cadmium first show affinity to gill which is main uptake site of waterborne elements, then they are transported via blood to liver and kidney. Metal ions usually accumulated less in gills since they are a temporary target organ of accumulation, and then Cd is transferred to other organs (Wu *et al*., 2007) and was same for this study.

**Table 4: Tissue concentration of heavy metals of the experimental group for intestines**

| Groups | Cadmium (mg/L) | Copper (mg/L) | Lead (mg/L) |
|---|---|---|---|
| BINT (Cd in intestine) | 0.052 | <0.001 | <0.001 |
| CINT (Cd in Cu in intestine) | 0.078 | 0.002 | <0.001 |
| DINT (Cd+Pb in intestine/Conc. A) | 0.062 | <0.001 | <0.001 |
| EINT (Cd+Pb in intestine/Conc. B) | 0.070 | <0.001 | 0.029 |

*Significance from control (p<0.05)

**Table 5: Tissue concentration of heavy metals of the experimental group for muscle**

| Groups | Cadmium (mg/L) | Copper (mg/L) | Lead (mg/L) |
|---|---|---|---|
| BM (Cd in muscle) | 0.026 | <0.001 | <0.001 |
| CM (Cd + Cu in muscle) | 0.524 | 0.139 | <0.001 |
| DM (Cd + Pb in muscle/Conc. A) | 0.326 | <0.001 | 0.121 |
| EM (Cd + Pb in muscle/Conc. B) | 0.471 | <0.001 | 0.208 |

*Significance from control (p<0.05)

The availability of cadmium in the muscle tissues could be attributed to dermal absorption and bioaccumulation in the muscle. Results from this study also revealed a correlation in the accumulation profiles of cadmium in the organs of specimens exposed to cadmium with copper and lead. According to Haslam (2010), it is very rare for rivers to receive single pollutants. It is therefore more likely that various pollutants will interact with each other and thereby alter the bioavailability of one another. Both copper and lead seem to increase the bioavailability of cadmium. This resulted to higher accumulation values of cadmium in almost all the organs of the specimens exposed to either cadmium with copper or cadmium with lead. George, (1992) reported that non-essential metals often exert their actions through their chemical similarity to essential elements. In this study, Cu tends to have a stronger positive correlation with cadmium than lead in this study. Cu can combine with other contaminants such as mercury and ammonia to produce an additive toxic effect on fish (Bolawa *et al.*, 2012) and was not different from the report of this study. Sarnowski and Witeska (2008) study on the effect of single exposure or co-exposure of metals on the growth of common carp (*Cyprinus Carpio* L.) larvae indicated an interaction between Cu and Cd in mixture and suggest that the presence of Cd reduces the toxic effect of Cu. Thus, it seems that Cd is an antagonist to Cu. Interaction of copper and cadmium toxicity can be related to the interaction of these metals in accumulation in various tissues in which they disturb metabolic processes related to growth. Reduction of toxicity of one metal by another could result from competitive uptake and accumulation by the tissues (Calamari *et al.*, 1982; Protasowicki and Chodyniecki, 1988; Allen 1995).

## Conclusion

There are reports that non-essential metals often exert their actions through their chemical similarity to essential elements. In this study, Copper tends to have a stronger positive correlation with cadmium than lead; therefore, Lead impaired the uptake of cadmium by *P. obscura*. This study provides an insight to cellular accumulation of metals caused by single and combined dose of metal exposure, and hence can serve as a useful tool in identifying prior exposure to metals

## Refererence


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