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Bioaccumulation Pattern of Cadmium and Lead in the Head Capsule and Body Muscle of *Clarias gariepinus* [Burchell, 1822] Exposed to Paint Emulsion Effluent

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Abstract: The toxicity of Sub-lethal concentrations of effluents from a paint emulsion industry were investigated on African catfish *Clarias gariepinus* in order to determine the bioaccumulation pattern of two heavy metals i.e., Lead and Cadmium in the Head capsule and Body muscle using a renewable static bioassay. The trend of bioconcentration of metals in the head capsule and muscle of the test organisms differs significantly ($p<0.05$) and it followed the order, muscle>head capsule. In the muscle, the highest bioaccumulation of lead was 0.4680 mg/L while the least was 0.0660 mg/L. Cadmium bioaccumulation in the head had the highest value to be 2.0424 mg/L while the lowest value was 0.0101 mg/L. In the head capsule on the other hand, the highest accumulation of lead was found to be 0.3918 mg/L while its lowest value was 0.1677 mg/L. The highest value for cadmium in the head capsule was 2.0249 mg/L while its lowest was 0.0058 mg/L. It was revealed in the study that fish can bioaccumulate heavy metals from a polluted environment, which often result in reduction or impairment of natural population size and could be a veritable source of these metals to man. Therefore corrective measures should be taken to avoid pollution of this sort in the environment.

Key words: Bioaccumulation, concentration, effluent, emulsion, environment, heavy metals

INTRODUCTION

The contamination of fresh waters with a wide range of pollutants has become a matter of concern over the last few decades. Among the various toxic pollutants, heavy metals are particularly severe in their action due to persistence biological amplification through the food chain (Shah and Altindau, 2005). Heavy metals have long being recognised as serious pollutants of the aquatic ecosystem. The heavy metals that are toxic to many organisms at very low concentrations and are never beneficial to living beings are Hg, Cd, and Pb. Increase discharge of heavy metals into natural aquatic ecosystems can expose aquatic organisms to unnatural high levels of these metals (Van Dyk *et al*., 2007). It had been reported that heavy metals had a negative impact on all relevant parameters and caused histo-pathological changes in fish. Some heavy metals are essential elements while others are non-essential (Maity *et al*., 2008). Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Ashraj, 2005; Vosyliene and Jankaite, 2006; Farombi *et al*., 2007). The metals entering the aquatic ecosystem may not directly cause damage to organism but they can be deposited in aquatic organism through the effect of bioconcentration, bioaccumulation and other food chain processes thus gets to man in concentrations that poses threats to human health via consumption of seafoods (Adewoye and Fawole, 2002).

Transport of metals in fish occurs through the blood where the ions are usually bound to proteins. The metals are brought into contact with the organs and tissue of the fish and consequently accumulated to a different extent in different organs or tissues of the fish. Once heavy metals are accumulated by an aquatic organism, they can be transported through the upper class of the food chain (Ayandiran *et al*., 2009). Many researchers have been concerned with the physiological effects and bioconcentration patterns of individual metals in aquatic ecosystems. Akan *et al*. (2007), Abdullahi *et al.* (2008), Awode *et al*. (2008) and Babale *et al*. (2011) all worked on the total metal concentration of the sediment and farmland of the bank of the Challawa river. Senthil *et al*. (2008) reported that bioconcentration of zinc followed the order of liver> kidney> intestine> muscle of *Chanapunctatus* after chronic exposure to zinc. Trace metal like Cu. Fe, and Zn are readily concentrated in different fish tissues (Adewoye *et al*., 2005). Van Dyk *et al.* (2007) demonstrated that the harmful effect of heavy metal pollution of fish liver histology may however depend on the duration of the exposure (chronic or acute) and the concentration level of the specific metal. Ayandiran *et al.* (2009) found Cd and Hg to have low levels of bioaccumulation in the gut and muscle tissues of *C. gariepinus*. He also reported that these metals can remain in the body like other heavy metal for long period of time and can bioaccumulate for many years after exposure to low levels. Vindohini and Navayanan (2008) observed the trend of bioaccumulation of heavy metals

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in various organs of the fresh water fish; *Cyprinuscarpio* exposed to heavy metal contaminated water system. High concentration of Cu and Zn were observed in the body muscle of fish. They were found to mainly bioaccumulate in the skin, liver, gill, heart, kidney and muscle tissue of fish (Senthil *et al*., 2008). Factors affecting Hg levels includes exogenous (characteristics of the water as oxygen concentration, pH, hardness, temperature etc.) and endogenous (characteristics of the individuals or specie as habitat, food preference, metabolic rate, age etc), which may change the state of toxicity of chemical as Hg (Ebrahinpour *et al*., 2010; Hedayati and Safahieh, 2010). Hypoxic conditions, temperature and acidifications generally render the fish more sensitive to toxication whereas increase in mineral contents decrease metal toxicity (Abdullahi and Javed, 2006).

This study focuses on the bioaccumulation of heavy metals in the body muscle and head capsule of African catfish *Clarias gariepinus* exposed to chronic concentrations of paint emulsion effluent.

MATERIALS AND METHODS

The test chemical: The effluent used for the toxicity test was collected from the discharge point of a company that specializes in chemicals production. The collections were made bi-monthly between June 2010 to July 2011 and between the hours of 8.00 am to 9.00 am on the days of sample collection. The samples were kept in the refrigerator to avoid further activities of microorganisms. The waste waters (effluents) were then pooled together to avoid variability in concentration. Further analysis of samples was carried out in the Research Laboratory of the Biological Sciences Department, Covenant University, Nigeria.

The test organism: Since variability in size may lead to different responses to the effluent of the same concentration, the test organism; *Clarias gariepinus* of Standard length between 21-24 cm and 130-140 g body weight were purchased from a commercial Agricultural farms, and transported in a big bowl to the Laboratory. The organisms were kept in a large plastic container that has already been washed and rinsed with 5% potassium trioxonitrate to remove any adhered metals and there after acclimatized for a period of fourteen days. During this period of acclimatization, renewal bioassay was employed and fish were fed twice daily (12 hourly) with an already formulated fish feed with about 40% crude protein content.

The physico-chemical analysis: The physico-chemical analysis of the effluent was carried out prior to the laboratory experiment and it is to quantify the concentrations of the metals and other parameters in the effluent of study using the APHA/AWWA/WEF (1995) Standard method for examination of water and waste waters.

Toxicity test: After the acclimatization period, range finding test using the (ASTM, 2007) method was carried out to determine the definitive concentrations to be used for the evaluation. Renewal bioassay test was employed in the experimental set up. Ten *C. gariepinus* was placed in each of five different plastic containers containing well aerated bore-hole water. The fishes were then exposed to paint emulsion effluent at sub-lethal concentrations of 0.00 (control), 0.30, 0.40, 0.50, and 0.60 mg/L for 42 days. All the experiments were set up in replicates. Careful observations were then made to note the number of mortalities of the test organisms.

Digestion of specimen: The specimens were sacrificed and the head and muscle were separated, which were then kept in the freezer prior to analysis. The parts were oven dried at 70-73ºC until constant weight was obtained. The specimens were then grounded to fine powder and stored in desiccators in order to avoid moisture accumulation before digestion. The digestion procedure was then carried out as described by (Kotze *et al.*, 2006). The heavy metals were analyzed using PYE UNICAM Atomic Absorption Spectrophotometer (AAS).

Statistical analysis: The obtained data were statistically analyzed by using one way analysis of variance (ANOVA) followed by Duncan multiple range tests as a post-hoc test, with the aid of SPSS 10 computer statistical software package.

RESULTS

The physicochemical analysis parameters of the paint emulsion effluent used in this research are shown in Table1. The result of the analysis showed that the effluent

Table 1: Physicochemical parameters of paint emulsion effluent

Parameters	Paint emulsion effluent	FEPA (1991) specification
Ph	6.7	6.9
DO mg/L	2.6	5.0
BOD mg/L	0.4	5.0
Total suspended Solid mg/L	72	30
Iron μg/L	0.6	1.0
Cadmium μg/L	7.5	<1.0
Cyanide μg/L	32	20
Lead μg/L	9.6	<1.0
Total hardness mg/L	52.0	-
Magnesium μg/L	0.59	-
Nickel μg/L	0.10	-
Copper μg/L	0.08	<1.0

Table 2: Levels of bioaccumulation of metals in the head capsule of *Clarias gareipinus* at sub-lethal concentration (±se)

Effluent conc. (mg/L)	Metals lead (µg/L)	Cadmium (µg/L)
Control (0.00)	ND	ND
0.30	0.2536±0.1815^{a}	0.9217±0.0215^{a}
0.40	0.1677±0.1507^{a}	1.0158±0.015^{a}
0.50	0.3918±0.1685^{a}	2.0067±0.016^{a}
0.60	0.2253±0.1059^{a}	2.0249±0.011^{a}

Means within column having the same alphabet(s) are not significantly different (p>0.05), S. E: Standard error; ND: not detected

Table 3: Levels of bioaccumulation of metals in the body muscle of C*lariasgareipinus* at sub-lethal concentration (±se)

Effluent conc. (mg/L)	Metals lead (µg/L)	Cadmium (µg/L)
Control (0.00)	ND	ND
0.30	0.1671±0.1671^{a}	0.0173±0.0173^{b}
0.40	0.1272±0.0104^{a}	0.0101±0.0097^{b}
0.50	0.3364±0.2784^{a}	1.0152±0.0152^{b}
0.60	0.4680±0.3964^{a}	2.0424±0.0039^{a}

Means within column having the same alphabet(s) are not significantly different (p>0.05), S.E: Standard error; ND: Not detected

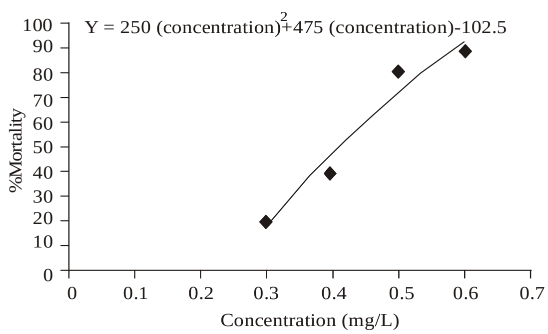

Fig. 1: Mortality response of *Clarias gareipinus* to paint emulsion effluent

is unsafe and deleterious to aquatic organisms when compared with Federal Environmental Protection Agency (FEPA, 1991) standard specification for effluent discharge into the aquatic environment.

Table 2 Show the bioaccumulation of heavy metal in the head capsule of the fish after exposure to sub-lethal concentrations of the emulsion effluent for a period of 42 days. Heavy metals bioaccumulation in the head capsule was found not to be significantly different (p>0.05).

Table 3 shows the bioaccumulation of heavy metals in the body tissue of the test organisms at sub-lethal concentrations, there are variations in the bioaccumulation pattern of Lead, and Cadmium. In cadmium the 1st, 2nd, 3rd concentrations were found not to be significantly different (p>0.05) except in 0.60 mg/L.

Figure 1 reveals that at higher concentrations of effluent C*larias gareipinus* mortality rate response are higher compared to marginal increase of death rate at lower concentrations.

DISCUSSION

The physico-chemical characteristics of the effluent revealed that there were high total suspended solids, high pH level and low dissolve oxygen content. This might have resulted from the organic loads in the effluent, which serves as a suitable medium for microorganisms that competes with the test organisms for the utility of the limited available oxygen. Most of the parameters investigated in the physico-chemical characteristics of the effluent showed deviation from the Federal Environmental Protection Agency (FEPA, 1991) safe limit for waste discharge into water bodies, thus the discharge of the effluent into water bodies over time might lead to the bioaccumulation of metals in fish tissues and organisms in such water bodies.

In this study, the fish exposed to emulsion effluent were observed to be highly irritable and they displayed several abnormal behaviours, this could be attributed to response in the toxic effect of the effluent and to the depletion of the oxygen content of the medium. Abnormal reactions observed in the test organisms include erratic swimming and frequent surfacing in the test containers. Activities of test organisms like swimming and feeding reduced drastically and they grew weaker as the exposure time was prolonged. This is especially noticed in fishes in higher concentrations. Colour change from black to pale black with mucus covering the entire body in response to the toxic effect of the effluent was also observed.

Increased metals bioaccumulation was observed with increase in effluent concentration, bioaccumulation of the analyzed metals was significantly higher in the body muscle at higher concentrations than the head capsule. This finding agrees closely with the studies done by Kotze *et al*. (2006) and Senthil *et al*. (2008). The high concentration of the analyzed metals in the body muscle investigated could be due to the storage role played by the body muscle of fish. Accumulation of heavy metals in the body muscle and head capsule followed the order Pb > Cd. The result conformed closely with the work done by Vindohini and Navayanan (2008) where they carefully observed the trend of bioaccumulation of heavy metals in various organs of the fresh water fish *Cyprinuscarpio* (common carp) exposed to heavy metal contaminated water system. Cadmium was found in this study to have low levels of bioaccumulation in the head capsule and body muscle investigated. Cadmium is considered in other works to have the highest concentration in liver. Ivan *et al*. (2011) reported that it reached 40 to 100 times greater concentrations in muscle than those found by Agusa *et al*. (2004) in five Caspian sturgeon species. An increased Cd levels in sterlet are worrying, especially considering the fact that it could be very hazardous for fish genetic material (Alibabic *et al*., 2007) and it is one of the most toxic heavy metals, even at relatively low concentrations (Dural *et al*., 2006; Fianko *et al*., 2007; Yilmaz *et al*., 2007). These metals can remain in the body like other heavy metals for long period of time and can bioaccumulate for many years after exposure to low levels (Groundwork, 2002). A fish contaminated with these metalscan finds its way into man's food chain, resulting inbiomagnifications of such heavy metal and this becomes harmful to man's health. The pattern of Lead bioaccumulation in this study reveals that the metal has some level of variations in the different concentrations used and this could be as a result of the individual test organism's physiological response to pollutants. The result indicates that the effluent contamination definitely affected the aquatic life of the fresh water fish. Hence, a scientific method of detoxification is essential to improve the health of these economic fish in any stressed environmental conditions.

The recorded significant differences in the bioconcentration of metals in the fish under study may be attributed to the observed differences in the behavioral and metabolic responses of the fish to the effluent; these differences can also be attributed to the differences in the physiological role of each tissue. It can be conclusively deduced from this study that fish has the tendency to bioaccumulate heavy metals in a polluted environment. Thus the indiscriminate consumption of fish from a polluted water body should be discouraged. Federal government should enact laws that will ensure industries make use of standard waste treatment plants for the treatment of their wastes.

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