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ASSESSMENT OF HEAVY METAL BIOACCUMULATION IN THE GILLS AND TISSUE OF THE JUVENILE *CLARIAS GARIEPINUS (CATFISH)*

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ABSTRACT
The Assessment of heavy metal Bioaccumulation as well as the rate of excretion of the bioaccumulated metals in the Gills and Tissue of the juvenile *Clarias gariepinus (catfish)* when placed in pollution-free aquatic environment (artificial environment) was determined. *Clarias gariepinu* (catfish) samples of about ten weeks old were collected from fish tanks in the Department of Environmental Zoology of the Delta State University, Abraka and held in bulk container filled with chlorine-free water for five days at 28 ± 2^0C. While preparing the stock and test solutions for the metals, the nitrate form of lead, chloride of cadmium and the zinc sulphate ($ZnSO_4.7H_20$) were chosen because of its moderate toxicity. Bioassay test method was adopted with three different concentrations of the test solutions (10 mg/kg, 5 mg/kg and 2 mg/kg of lead, 8 mg/kg, 5 mg/kg and 2 mg/kg of cadmium and 8 mg/kg, 5 mg/kg and 2 mg/kg of zinc) of the metals under investigation were prepared. The Cappon (1987) Static method was used in digesting the fish sample and metal concentration in the gills and tissues of the fish samples were determined using Atomic Absorption Spectrophotometer. Results from this study revealed that Pb had a higher mortality rate (20%) than cadmium (10%) and zinc (0%) at the same concentration of 5mg/kg. The study further revealed that the bioaccumulation of heavy metals in the different parts of the fish was not uniform but could thus, be concluded that the determination of bioaccumulation can be used to monitor the health of aquatic environment as data from the study revealed that the degree of contamination was directly proportional to bioaccumulation. Results obtained from this work also indicated that if fish exposed to contaminated environment are able to migrate to safe unpolluted environment, they can, over a period of time naturally eliminate significant amount of ingested toxicants such as heavy metals.

KEYWORDS: bioaccumulation, bioaccumulation factor (baf), heavy metals**,** clarias gariepinu, juvenile**,** catfish

INTRODUCTION
The accumulation of heavy metals in an aquatic environment has direct consequences to man and to the ecosystem. This is so because it has been observed to be a major environmental concern because this portion of the environment is the final destination of contaminants released from domestic, industrial and other anthropological activities (Nwokedi and Obodo, 1993). Heavy metals could enter the aquatic environment from both natural and anthropogenic sources. Natural sources include weathering of minerals and soils (Merian, 1991). Anthropogenic inputs are mainly from industrial effluents, domestic effluents, rural and urban storm water runoff and spoil heaps (Agbozu and Ekweozor, 2001).

Anthropogenic source is disposed indiscriminately either directly into surface water bodies or on surface where they are either washed into surface water or permeate into ground water (Okoh *et. al.*, 2015). The aquatic ecosystem becomes polluted and consequently aquatic organisms become contaminated. Heavy metals are dangerous because they tend to bioaccumulate in organisms over time, as compared to the concentration of other chemicals in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are metabolized or excreted. As a result of food chain/web, heavy metals that may have bioaccumulated in fish get into man either through direct consumption of fish or organisms that feed on fish. Man is therefore exposed to pollution related health problems through consumption of contaminated food. The effect of contaminated food on man can be very critical if children are involved. At such tender age when growth is rapid any adverse effect on the biochemistry of their vital organs can have serious health implications during their adult life. Meanwhile, it is well known that our diet is largely deficient of protein as most foods consumed in our locality are mainly carbohydrate. Of all sources of protein, fish is a veritable source. However, when fish is exposed to heavy metals in their aquatic ecosystem, they may die or bioaccumulate the heavy metals. The level of bioaccumulation of heavy metals cannot only be used to determine the mortality rate of the catfish juvenile exposed to toxic environment, but also to determine the critical concentration of heavy metal in fish that is

safe for consumption, the indirect monitoring of the level of heavy metals in an aquatic environment-there is a relationship between the concentration of toxicant in an aquatic environment and the amount of toxicant ingested by aquatic organisms, and the determination of the rate of excretion when fishes are placed in a pollution-free environment are immerse benefit as it will assist in understanding the migration pattern of fish in their natural environment. Fish juvenile are more susceptible to death when exposed to toxic environment than adult fish. This can lead to reduced availability of fish. In realization of both domestic and commercial advantages derived from pollution – free aquatic ecosystem as well as healthy aquatic organisms, especially fish, a veritable source of food for mankind, there is need to monitor levels of pollution in our environment on regular basis. This will afford the opportunity to eliminate sources of pollution, where practically possible, or apply remedial measures to ameliorate the effect of pollution. Fishes were considered as better specimens for use in the investigation of pollutant loads than water samples because of the significant levels of metals they bioaccumulate. Significant heavy metal levels were recorded in fishes of the Warri River (Atuma and Egborge, 1986; Ezemonye and Egborge, 1992); fish and shellfish of the Niger Delta (Kakulu *et. al.,* 1987), the physiological activities and biochemical parameters in organs, tissues and blood (Nriagu, 1986), accumulation of heavy metal in fresh water fish (Akporhonor *et. al.,* 2007).

The characteristic feature of heavy metals is their strong attraction to biological tissues and in general, their slow elimination from biological systems. The uptake of heavy metals in fish was found to occur through absorption across the gill surface or through the gut wall tract. Diffusion facilitated transport or absorption in gills and surface mucus are the mechanisms of uptake from water. 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 are retained in each tissue type. Thus, the aim of this work is to determine the level of bioaccumulation of some heavy metals in catfish juvenile in their artificial environment as well as the rate of excretion of bioaccumulated heavy metals in catfish juvenile when placed in pollution-free aquatic environment (pure water). This work is poised to specifically evaluate the LC_{50} of the toxicant in the fish, assess the concentration of the toxicant on some of the fish organs (gills and muscle), and determine the rate of excretion of ingested heavy metals and to Investigate the bioaccumulation factor of the heavy metals.

MATERIALS AND METHODS

Sample Preparation

Sample organisms (catfish juvenile of about ten weeks old) were collected from fish tanks in the Department of Environmental Zoology of the Delta State University, Abraka and held in bulk container filled with chlorine-free water for five days at 28 ± 2^0C. The water was analyzed to be free from metals to be investigated. The fish were fed daily during the period of acclimatization with fish meal (also analyzed to be free from metals to be investigated) to avoid starvation. The water in the tank was changed every day to prevent accumulation of metabolites. The fish were considered acclimatized when no mortality was recorded within the five days period.

Preparation of Stock and Test Solution of Heavy Metals

Lead: the nitrate form was chosen because of its moderate toxicity (Wayne and Mingdto, 2003) and high solubility. 1.299 g of $Pb(NO_3)_2$ was weighed and added to about 750ml of de-ionized water and after dissolving it, the solution was made up to 1 litre mark with de-ionized water to give 1000 mg/kg of lead ions.

Calcium: The chloride of cadmium was preferred to other salts, being less toxic (Wayne and Mingdto, 2003). 1.631g of $CdCl_2$ was weighed on top loading electronic balance with accuracy of 10mg, added to about 750ml of de-ionized water, and after dissolving it, the solution was made up to 1 litre mark with de-ionized water to give 1000 mg/kg of cadmium ions.

Zinc: Zinc sulphate ($ZnSO_4.7H_20$) was chosen because of its solubility and moderate toxicity (Wayne and Mingdto, 2003). 4.396g of $ZnSO_4.7H_20$ was weighed and added to about 750ml of de-ionized water and after dissolving it, the solution was made up to 1 litre mark with de-ionized water to give 1000 mg/kg of zinc ions.

Range Finding Bioassay

Test solutions were set up in triplicate and the number of death for each test solution was averaged. A control in triplicate was set up with the same number of test organisms (7 per container) in same volume of diluting medium (4 litres). The number of living and dead fish in each test series and triplicate were recorded after 96 hours. The 96 hours mortality data was used to calculate the LC_{50} for each replicate series. The Arithmetic graphic method which, according to Donald and Philip (1987), is the easiest and quickest way to determining 96 LC_{50} was used. The method involved the calculation of the average number of deaths at 96 hours in the replicates and converting to percent mortality. The concentration of the various test solution including the control was recorded and their respective logarithm determined. A plot of concentration and percent mortality was made. To obtain 50, a horizontal line drawn from 50 mortality point to intersect the graph and the point of intersection was extrapolated on the abscissa by dropping a vertical line on it. This gave the LC_{50} concentration.

Bioassay Procedure

Static bioassay test method was adopted for this study as described by Wayne and Mingdto, (2003). Seven fish of fairly average length and weight, 12cm and 93g respectively were selected randomly and placed in bioassay containers made up of plastic of dimension 42 cm length by 25 cm height and 30 cm width. The outer walls of the container were covered with black polythene to reduce light penetration. The tanks were initially washed with detergent, rinsed with tap water and thoroughly dried. The cleaning was done to prevent contamination and growth of mould. Three different concentrations of the test solution (10 mg/kg, 5 mg/kg and 2 mg/kg of lead, 8 mg/kg, 5 mg/kg and 2 mg/kg of cadmium and 8 mg/kg, 5 mg/kg and 2 mg/kg of zinc) of heavy metals were prepared. The highest concentration in each case was 20 below the $LC_{50,}$ previously determined. This sub – lethal concentration was used to ensure the survival of more than 50 of the fish. Each concentration as well as the control was prepared in triplicate. This gave a total of 12 containers per concentration series. The volumes of the standard solution were 4 litres. The dead fish in each container were harvested after 96 hours exposure and the heavy metal concentration in various organs and tissue were determined. The percent mortality was also recorded.

Pre -Treatment and Analysis of Samples

Each fish samples were carefully opened using plastic knife in order to remove the organs and tissue. The organs/tissue harvested was gills and flesh. It was dried for a period of 36 hours before pulverized in a clean dry mortar. The pulverized fish samples were again dried for another 1 hour and finally preserved in a clean dry polythene bottle. The Cappon, (1987) method was used in digesting the fish samples. 1g of dried fish was weighed and put in a 200 ml kjeldehl flask. 20ml of the digested mixture made up of 10 ml $HClO_4$ and 100 ml of Conc. HNO_3 was added to the flask. It was carefully swirled and digestion started in a fume cupboard at increasing temperatures. This process continued until the complete disappearance of brown fumes of NO_2. The final digestate was poured into a 50ml volumetric flask, cooled and made to the mark with 0.7M HNO_3 solution. Metal concentration in the various Gills and tissues were determined using Atomic Absorption Spectrophotometer.

Bioaccumulation Factor (BAF)

Bio-accumulation factor refers to the ratio between the concentration of a chemical measured in an organism and the concentration of the same in water. The ratio is usually derived from field – collected samples and water (Asthana and Asthana, 2003).

$$\mathbf{BAF} = \frac{\mathbf{C_B}}{\mathbf{C_W}}$$

Where C_B = Chemical concentration in organism

C_w = Chemical concentration in water

Determination of Rate of Excretion

The fishes that survived after 96 hours exposure to different stated concentrations of the heavy metals solution were harvested. The harvested fishes were transferred to potable water to determine the rate of natural excretion of the bioaccumulated heavy metals. Meanwhile, the dissolved oxygen (DO) and pH of the water used were also determined. Fish samples were harvested on weekly basis for a period of five weeks and the concentration of the heavy metals in the tissue and various organs were analyzed with AAS.

Determination of Dissolved Oxygen (DO)

It is the amount of oxygen (O_2) in milligram per litre in a given water sample solution. In the determination of DO, the electrode of the DO meter was inserted into the beaker containing the water and the result read out. The purpose of this determination is to ensure that the dissolved oxygen is within the recommended level for fresh water organisms.

Determination of pH

In determining the pH of the fresh water, pH meter was used. The pH electrode was inserted into the water in a trough and the result from the meter monitor or screen was read. Again, the purpose of this determination is to ensure that the pH is within the recommended level for fresh water organisms.

RESULTS AND DISCUSSIONS

The analysis of water and rate of mortality of the Fish is shown in table 1 – 4. The results of ingestion of the heavy metals by the test species after 96 hour exposure to the toxicant and rate of excretion (for 5 weeks) after transferring the test species from the toxic environment into potable water are presented in Tables 5 – 13

Table 1: Parameters of Water Used

Parameter	Value
Dissolved Oxygen	7.8 mg/l
pH	7.2

Table 2: Mortality Rate at 96hr Exposure to Pb^{2+}

Concentration (ppm)	No. of Fish used	No. of live Fish	No. of dead Fish	Percentage mortality
8	10	8	2	20
5	10	9	1	10
2	10	10	Nil	Nil

Table 3: Mortality Rate at 96h Exposure to Cd^{2+}

Concentration (ppm)	No. of Fish used	No. of live Fish	No. of dead Fish	Percentage mortality
10	10	7	3	30
	10			20
5		8	2	
	10			10
2		9	1	

Table 4: Mortality Rate at 96h Exposure Zn^{2+}

Concentration (ppm)	No. of Fish used	No. of live Fish	No. of dead Fish	Percentage mortality
8	10	8	2	20
5	10	10	Nil	Nil
2	10	10	Nil	Nil

Table 5: Excretion Results for Pb at 10 mg/Kg Concentration in mg/Kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.592	3.730±0.10	2.111±0.07	1.949±0.04	1.877±0.03	1.801±0.02	1.799±0.01
Gills	0.414	3.106±0.09	1.787±0.06	2.008±0.08	1.703±0.01	1.680±0.04	1.601±0.02

Table 6: Excretion Results for Pb at 5 mg/Kg Concentration in mg/kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.592	1.287±0.14	1.280±0.08	1.256±0.05	1.195±0.06	1.190±0.01	1.189±0.01
Gills	0.414	1.307±0.014	1.350±0.06	1.240±0.11	1.220±0.12	1.200±0.14	1.195±0.09

Table 7: Excretion Results for Pb at 2 mg/Kg Concentration in mg/kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.592	0.753±0.01	0.701±0.01	0.680±0.02	0.670±0.02	0.655±0.03	0.650±0.03
Gills	0.414	0.831±0.03	0.800±0.07	0.751±0.04	0.700±0.05	0.700±0.04	0.665±0.03

Table 8: Excretion Results for Cd at 8mg/kg Concentration in mg/kg

Fish Part	Control	96 h	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.340	3.78±0.01	3.010±0.12	2.890±0.06	2.400±0.06	2.060±0.06	2.000±0.07
Gills	0.235	2.12±0.02	2.115±0.02	1.850±0.04	1.680±0.02	1.595±0.07	1.590±0.01

Table 9: Excretion Results for Cd at 5 mg/kg Concentration in mg/kg

Fish Part	Control	96 h	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.340	1.41±0.01	1.410±0.01	1.115±0.01	0.955±0.01	0.910±0.01	0.890±0.01
Gills	0.235	0.485±0.01	0.410±0.02	0.395±0.02	0.381±0.01	0.291±0.01	0.290±0.01

Table 10: Excretion Results for Cd at 2 mg/kg Concentration in mg/kg

Fish Part	Control	96 h	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.340	0.651±0.02	0.600±0.02	0.581±0.02	0.542±0.01	0.540±0.01	0.501±0.01
Gills	0.235	0.701±0.01	0.544±0.03	0.535±0.02	0.530±0.02	0.520±0.01	0.501±0.01

Table 11: Excretion Results for Zn at 8 mg/Kg Concentration in mg/kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.354	3.450±0.01	2.910±0.12	2.514±0.06	2.495±0.06	2.490±0.05	2.490±0.070
Gills	0.244	2.000±0.02	1.505±0.02	1.415±0.04	1.300±0.02	1.315±0.07	1.300±0.01

Table 12: Excretion Results for Zn at 5 mg/kg Concentration in mg/kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.354	2.115±0.02	2.01±0.02	1.915±0.02	1.900±0.01	1.910±0.01	1.890±0.01
Gills	0.244	0.94±0.01	0.89±0.02	0.814±0.02	0.800±0.02	0.740±0.08	0.710±0.01

Table 13: Excretion Results for Zn at 2 mg/kg Concentration in mg/kg

Fish Part	Control	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	0.354	0.641±0.01	0.580±0.01	0.540±0.02	0.538±0.02	0.535±0.03	0.641±0.03
Gills	0.244	0.610±0.03	0.525±0.02	0.520±0.04	0.515±0.01	0.500±0.04	0.610±0.01

Determination of Bioaccumulation Factor (BAF)

The results of the determination of bioaccumulation factor (BAF) of the test species for the 5 weeks duration during when the rate of excretion was determined are presented in Tables 14-22.

Table 14: BAF of Pb at 10 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	37.30	21.10	19.50	18.80	18.00	17.90
Gills	31.10	17.80	20.10	17.10	16.80	16.00

Table 15: BAF of Pb at 5 mg/Kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	25.70	25.60	25.10	23.90	23.80	23.80
Gills	26.20	27.00	24.80	24.40	24.00	23.90

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Table 16: BAF of Pb at 2 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	37.70	35.10	34.00	33.50	32.80	32.50
Gills	41.60	40.00	37.50	35.00	35.00	33.30

Table 17: BAF of Cd at 8 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	47.30	37.60	36.10	30.00	25.80	25.00
Gills	26.40	26.40	23.10	21.00	19.90	19.80

Table 18: BAF of Cd at 5 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	28.20	28.20	22.30	19.10	18.20	17.80
Gills	9.70	8.20	7.90	7.60	5.80	5.80

Table 19: BAF OF Cd at 2 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	32.60	30.00	29.00	27.10	27.00	25.00
Gills	35.50	27.30	26.70	26.50	26.00	25.10

Table 20: BAF of Zn at 8 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	43.13	36.38	31.14	31.18	31.12	31.12
Gills	25.00	18.80	17.69	16.25	16.44	16.25

Table 21: BAF of Zn at 5 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	42.30	40.20	38.30	38.00	38.20	37.80
Gills	18.80	17.80	16.20	16.00	14.80	14.20

Table 22: BAF of Zn at 2 mg/kg Concentration in mg/kg

Fish Part	96 hrs	1st Week	2nd Week	3rd Week	4th Week	5th Week
Muscle	32.05	30.70	29.00	27.00	26.90	26.75
Gills	30.50	27.20	26.25	26.00	25.75	25.00

Comparison of Uptake of Heavy Metal Ions by Various Organs and Tissues

Tables 23 – 25 compare the results of tissue uptake of heavy metals with various metal ion concentrations

Table 23: BAF of Pb at 96 hrs in Various Concentrations

Fish Part	10ppm	5ppm	2ppm
Muscle	37.30	25.70	37.70
Gills	31.10	26.20	41.60

Table 24: BAF of Cd at 96 hrs in Various Concentrations

Fish Part	8ppm	5ppm	2ppm
Muscle	47.30	28.20	32.60
Gills	26.40	9.70	35.50

Table 25: BAF of Zn at 96 hrs in Various Concentrations

Fish Part	8ppm	5ppm	2ppm
Muscle	36.38	42.30	32.05
Gills	18.80	18.80	30.50

Statistical analysis of the range findings showed that lead was slightly more toxic than cadmium. Lead had a higher mortality rate (20%) than cadmium (10%) and zinc (0%) at the same concentration of 5mg/kg. This observation agreed with the finding of Wayne and Mingdto, (2003). Cadmium, the most toxic and nonessential heavy metal has wide distribution in the earth's crust and aquatic environments (Muthukumaravel and Paulay, 2007). 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 absorb oxygen from the medium by passing enormous volumes of water over the gills (Akan et. *al.*, 2009). Zinc is an essential element acting as structural component and having properties indispensable for life. 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. Ibemenuga, (2013) reported that Zn bioaccumulation in fish species could results to the adversely affect of hatchability, survival and haematological parameters of fish. He further reported that Pb bioaccumulation results to lamella shrinkage, degeneracy of epithelium, branchial arterial rupture and ischemia, reduction in growth rate and loss in body weight, degenerates liver cells synctial arrangement. The concentration of Pb in the juvenile fish sample could be attributed to the possibility of adsorption of particulate or organic Pb to fish gills. The lower pH at the gills surface could be attributed to respired CO_2, and may dissolve Pb to a soluble form, and this could diffuse into the gill tissues. Consequently, the highest concentration of lead solution used was 10mg/kg while that of cadmium and zinc was each 8 mg/kg. The result of Tables 4 to 12 showed that when the test species were exposed to different concentrations of lead, cadmium and zinc solutions for 96 hr, reasonable amount of the metals investigated were ingested and deposited in different parts of the fish. Pb witness a higher bioaccumulation of 3.730 ± 0.10mg/kg in the muscle and it is lower at 3.106±0.09 mg/kg in the gill when the fish was exposed to 10 mg/kg of the toxicant. In the fifth week, the value was reduced to 1.799±0.01 mg/kg for muscles and 1.601±0.02mg/kg for gills. The excretion result for the 5mg/kg of Pb reveals that at 96hr, bioaccumulation of the same metal in the muscle was 1.287±0.14 and 1.307±0.014 for the gills. In the fifth week, the values was reduced to 1.189±0.01mg/kg for muscles and 1.195±0.09 mg/kg for the gills. The bioaccumulation factor of Pb at 10mg/kg concentration in mg/kg for muscles is 37.30 at 96hr and 17.90 at the fifth week. The BAF of the same metal in mg/kg for gills is 31.10 at 96hr and 16.00 at the fifth week. The results from this study reveal that the bioaccumulation of heavy metals in the different parts of the fish is not uniform. A close observation of the rate of excretion of the ingested metals shows that the metals under investigation were excreted by the fish when placed in pure water. In other words, when the fish species were removed from contaminated environment, the body system naturally excreted the ingested metals. For instance, the amount of bioaccumulated cadmium decreased from 3.780±0.01mg/kg after 96hr exposure to 2.000±0.07mg/kg after five weeks in potable water. Again, the excretion rate decreased with time. After the fourth week in virtually all cases investigated there was insignificant excretion. It can therefore be concluded that the rate of excretion is not infinite. For lead solution, the rate of excretion at the first week was sharp. For instance, it decreased from 3.730±0.10mg/kg (in 10mg/kg) at 96hr exposure to 2.111± 0.07mg/kg after one week in potable water. It was not so in the other two concentrations. In the 5mg/kg and 2mg/kg solutions the decrease in rate of excretion with time was not as high as in cadmium. It can be generally concluded that the fish excreted cadmium more than lead. It therefore stands to reason that the rate of bioaccumulation is directly proportional to the rate of excretion. Although, there were sharp decrease in the value of the BAF in the 10ppm Pb solution after one week of excretion in pure water, the BAF of Pb for the fish part analyzed remained fairly constant.

CONCLUSION

It can be concluded that the determination of bioaccumulation can be used to monitor the health of aquatic environment as the degree of contamination was observed to be directly proportional to bioaccumulation. Results obtained from this work also indicated that if fish exposed to contaminated environment are able to migrate to safe unpolluted environment, they can, over a period of time naturally eliminate significant amount of ingested toxicants such as heavy metals. Hence, due to deleterious effects of metals on aquatic ecosystem and their implications on human health, it is necessary to monitor heavy metals values in fish species to understand and control the hazard levels of pollution.

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