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Bioaccumulation of Some Trace Metals in Wild and Farm-Raised African Catfish *Clarias gariepinus* in Kaduna, Nigeria

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Abstract: Bioaccumulation of some trace metals that occurred in juvenile and matured wild and farm-raised African catfish, *Clarias gariepinus* from River Kaduna and Fadama fish pond (Near NAF base, Kawo) was investigated by estimating trace metal concentration in the fish and water samples thereafter the transfer factor was evaluated. The concentration in (µg/g wet wt.) of Cu, Zn, Fe, Co, Ni, Cd and Pb for all fish samples ranged from 0.25-0.80, 0.42-0.61, ND-0.5, 0.10-0.75, 0.18-0.85, 1.25-3.2 and 0.1-0.7, that of water samples was 0.18-0.34, 0.45-0.73, 3.0-7.2, 0.53-0.93, 0.13-0.41, 1.5-4.5 and 0.1-1.25. while the transfer factors had a range of 0.658-2.353, 0.575-0.980, 0.058-0.1, 0.139-1.0, 0.04-02.0, 0.560-1.50 and 0.278-1.196, respectively. There were little variation in concentration of trace metals in the juvenile and matured catfishes from the wild except in Cadmium. In the farmed fish Iron was present in the matured fishes but was not detected in the juvenile fishes and there were no significant variations in other trace metals. This study showed that wild and farm-raised catfish can be exposed to minerals (metals) in one form or the other, therefore water quality should be maintained and monitored closely for sustainability of fish human health.

Key words: Bioaccumulation, trace metals, wild and farmed, *Clarias gariepinus*, Kaduna, Nigeria

INTRODUCTION

Fish muscles which is the most consumed portion of fish accumulates substantial amounts of metals in their tissues and these tissue represent a major dietary source of these metals to humans (Tariq and Jaffar, 1993; Kalay *et al.*, 1999; Rose *et al.*, 1999). These metals could exceed acceptable levels in the muscle of some fish in polluted regions. Fish accumulate different amounts of metals depending on many factors such as physiological needs, feeding habits, genetic composition, sex of each fish species and the biochemical role of each metal (Huang, 2003) (a high transfer factor indicates that metals are transferred to fish tissues from any environmental source Rashed, 2001). Metal accumulation in fish has also been employed as an impact assessment tool with regard to fish health (Deviller *et al.*, 2005; Shah and Altindag, 2005), fish community structure (Bervoets *et al.*, 2005; Allert *et al.*, 2009) and aquatic ecosystem health (Birungi *et al.*, 2007; Nesto *et al.*, 2007; Prasath and Khan, 2008; Shinn *et al.*, 2009). Biomagnification of trace metals is an indicators of long-term metal pollution exposure (Woelfl *et al.*, 2008; Retief *et al.*, 2009; Oyoo-Okoth *et al.*, 2010). Metals entering the aquatic ecosystem can be deposited in aquatic organisms through the effects of bioconcentration through the food chain and fish is at the higher level of the aquatic food chain (Huang, 2003). In the last two decades there has been a growing interest in assessing the levels of heavy metals in food including fish, such interest is aimed at ensuring the safety of the food supply and minimizing the potential hazardous effect on human health. Cultured fishes may absorb dissolved elements and trace metals from its feeding diets, pesticides, antibiotics and the surrounding water leading to their accumulation in various tissues in significant amounts thereby exhibit eliciting toxicological effects at target organs (Ali and Abdel star, 2005).

Variability in tissue metal concentrations in *C. gariepinus* may either result in positive effects when the metals present are essential for life and taken in low concentrations, or result in negative toxicologically and undesirable effects (Galvin, 1996). Toxicity of metals is dependent on the availability of the metal in the ionized form (Sorensen, 1991). This in turn is influenced by factors such as hardness, pH, dissolved oxygen, temperature, salinity, interactions with heavy metal salts and other particles such as suspended solid (Wang, 1987).

Water quality variables and chemical elements are important determinants of metal availability and toxicity. A large number of biological variables also play a significant role with regard to metal accumulation. These include interspecies variations (Giesy and Wiener, 1977), life stages present (Mance, 1987) as well as orientation of the sediment and behaviour (Kligour, 1991; Kidwell *et al.*, 1995). Metal accumulation is affected by some of the same parameters that affect toxicity (water chemistry and particulate matter). As such it is potentially one of the most valuable tools for identifying and quantifying the impact of metals in

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aquatic environments (Birungi *et al*., 2007; Shinn *et al*., 2009; Allert *et al*., 2009; Otero-Muras *et al*., 2010). It has been found that nonessential elements, on the other hand, tend to accumulate in fish year to year in a stepwise manner, since fish are not able to eliminate the metals completely (Kock *et al*., 1995). There is great concern of trace metals in foods, which has prompted several bodies such as World Health organization [WHO] to establish maximum allowable concentrations of these metals in food (WHO, 1993). Therefore, this work aims at ascertain the level of biomagnifications that can take place in fish tissue.

MATERIALS AND METHODS

Study area: Kaduna metropolitan city is the state capital of Kaduna State in North-central Nigeria. It is located in Nigeria at Latitude 10.9^0 and 10.15^0N and 7.5^0 and 7.9^0 E with an area of 46,053 Km^2. It is a River (class H-Hydrographic) in Nigeria with an elevation of 55 meters above sea level. Its coordinates are 8°45'0" N and 5°48'0" E. Kaduna River is a main tributary of the Niger River in Nigeria. Fadama fish farm is located in the agricultural area of Nigeria Air force base, in Kawo, Kaduna.

Collection and preservation of specimens: Live specimens of *Clarias gariepinus* and water were purchased from local fishermen in River Kaduna and Fadama Fish Farm(Near NAF base, Kawo) in Kaduna and stored in a plastic bucket before it was conveyed to the chemistry laboratory, Nigerian Defense Academy, Kaduna. Water samples was collected at a depth of 20 cm below the River and pond water at four different locations to form a composite sample in 2-liter pre-cleaned polythene plastic containers.. The samples were kept in a refrigerator preset at 4°C, a temperature where the bacteria were inactivated (Ademoroti, 1996, APHA, 1995). Water samples obtained from the different points was pre-treated by repeated evaporation before carrying out AAS analysis in Chemistry laboratory, Nigerian Defense Academy, Kaduna.

Analytical methods: Water samples were collected in clean plastic bottles, with cap securely tightened and were analyzed for pH, temperature, electrical conductivity and dissolved oxygen (DO) in-situ using a portable multi-parameter water quality monitor (Hanna Instrument C99 and 200 series, model H1-991301 multi-parameter Bench Photometers having a light Source of Tungsten lamp with narrow band interference filter at 525 nm) (Ademoroti, 1996; APHA, 1995).

The water samples were digested by transferring 100 mL portion of the sample into a beaker followed by the addition of 5 mL conc. HNO_3. The beaker containing the acid mixture was placed on a hot plate for 3 h at 110°C. The mixture was heated vigorously until the volume reduced to 20 mL. The sample was allowed to cool and another 5 mL conc. HNO_3 was added. The beaker was covered with watch glass and returned to the hot plate. The heating was continued and small portion of HNO_3 was added until the solution appeared light coloured and clear. The beaker wall and the watch glass were washed with water and the sample was filtered. The volume was adjusted to 100 mL with water. Triplicate digestion of each sample together with blank was carried out.

Statistical analysis: Statistical analyses used included student t test, least significant difference LSD.

RESULTS AND DISCUSSION

The study of mineral elements present in living organisms is of biological importance. Many of such elements take part in some metabolic processes and are known to be indispensable to all living things (Mills, 1980). The most important minerals are that of iron, Zinc and copper etc while many others are also needed in trace amounts. The deficiency of these principal nutritional mineral elements induces a lot of malfunctioning including reduced productivity, inability of blood to clot, osteoporosis and anemia (Mills and Beamish, 1980). While the essential trace metals play a vital role in many physiological processes, they can potentially have a toxic effect when present in high concentrations. Determining tissue concentrations of these metals may allow possible effects on the health of fish (and humans that consume them) to be inferred.

Catfish are particularly suited to bioaccumulation studies as they are bottom feeders and are readily exposed to metals that accumulate in a wide variety of prey including small fish (Skelton, 2001). As predators they may thus also accumulate metals from surrounding water or from feeding on other fish (Kidwell *et al*., 1995). Meanwhile, water quality is also one of the most important limiting factors in aquatic ecosystem, it is the most difficult factor to understand, predict and manage. P^H is one important quality parameter which indicate the aesthetic quality of water (Ogamba, 2004). A look at the physicochemical parameters showed that Water sample obtained from River Kaduna (Angwa Rimi area) was slightly alkaline, although high pH has been reported for most fluvial (Beecroft *et al*., 1987; Emere, 2000) and Lacustrine ecosystems (Ufodike and Garba, 1992; Kemdirim, 2005) in Northern Nigeria This may be due to the granite, which forms the basement rock of these water bodies. The pH of water sample from the ponds were slightly acidic. Low pH of pond water seems to indicates that ammonia a byproduct of fish excretion is present in its ionized form. Ammonia occurs in two forms depending on the acidity of the water. The unionized form of ammonia (NH_3) is more dominant when the water is alkaline and the ionized form of

Table 1: Physico-chemical parameter of water samples

Water samples	pH	TEMP (°C)	EC (mS/cm)	DO (mg/L)
W_R	7.38	25.3	18.5	2.4
W_{P1}	6.69	25.2	59.7	4.3
WP_2	6.93	24.9	45.9	3.2
Range	6.69-7.38	24.9-25.3	18.5-59.7	2.4-4.3
Coefficient of Variation(CV)	5.0	0.82	50.7	28.9
WHO LIMITS(2005)	6.5-8.5	30-35	250	73.0

W_R = Water sample from River Kaduna
W_{P1} = Water sample from pond 1 (juvenile catfish)
W_{P2} = Water sample from pond 2 (matured catfish)

Table 2: Trace metal concentrations in wild and farm-raised catfish

Fish sample		Cu	Zn	Fe	Co	Ni	Cd	Pb
Wild catfish	RCF_{ju}	0.25±0.03	0.61±0.04	0.4±0.03	0.20±0.05	0.85±0.1	1.25±0.09	0.70±0.04
	RCF_{ma}	0.80±0.09	0.42±0.06	0.5±0.04	0.13±0.02	0.17±0.03	3.2±0.6	0.19±0.02
Farmed catfish	PCF_{ju}	0.28±0.07	0.44±0.07	ND	0.10±0.01	0.26±0.03	1.45±0.04	0.13±0.01
	PCF_{ma}	0.64±0.05	0.50±0.05	0.3±0.06	0.75±0.08	0.18±0.02	2.75±0.3	0.15±0.05
Range		(0.25-0.80)	(0.42-0.61)	(ND-0.5)	(0.10-0.75)	(0.18-.85)	(1.25-3.2)	(0.15-0.7)
WHO 1989		30	1.0	-	-	0.5-1.0	1.00	2.00
WHO 1996		30	-	-	-		-	2.00
EC 2005		-	-	-	-		0.05	0.20

RCF_{ju} = Juvenile river catfish
RCF_{ma} = Matured River catfish
PCF_{ju} = Juvenile pond catfish
PCF_{ma} = Matured pond catfish

Table 3: Trace Metal Concentration of water samples

Water sample	Cu	Zn	Fe	Co	Ni	Cd	Pb
W_R	0.38±0.05	0.73±0.04	7.20±1.08	0.93±0.06	4.1±0.46	4.5±0.46	1.25±0.03
WP_1	0.18±0.03	0.45±0.03	3.60±0.17	0.53±0.03	0.13±0.1	3.40±0.52	0.11±0.01
WP_2	0.34±0.05	0.51±0.03	3.0±0.06	0.75±0.6	2.3±0.95	1.5±0.30	0.10±0.03
Range	(0.18-0.38)	(0.45-0.73)	(3.0-7.20)	(0.53-0.93)	(0.13-4.1)	(1.5-4.5)	(0.10-1.25)
SON 2007	0.005	-	-	-	0.02	0.005	0.01
WHO 1993	2.0	3.0	-	-	0.02	0.003	0.01
WHO 2005	2.0	3.0	0.2	-	0.02	0.005	0.01

W_R = water sample from River Kaduna, W_{P1} = water sample from pond 1 (juvenile catfish), W_{P2} = water sample from pond 2 (matured catfish)

Table 4: Calculated transfer factor

Fish sample	Cu	Zn	Fe	Co	Ni	Cd	pb
RCF_{ju}	0.658	0.835	0.056	0.215	0.207	0.278	0.560
RCF_{ma}	1.684	0.575	0.0694	0.139	0.040	0.711	0.152
PCF_{ju}	1.556	0.978	-	0.189	2.000	0.426	1.182
PCF_{ma}	2.353	0.980	0.1	1.0	0.078	1.196	1.500

RCF_{ju} = Juvenile River Catfish
RCF_{ma} = Matured River Catfish
PCF_{ju} = Juvenile pond Catfish
PCF_{ma} = Matured pond Catfish

ammonium (NH_4^+) when the water is acidic. P^H result agrees with that of Mendie (2005) which reported that the large majority of public water supplies may register a pH range between 6.9-7.4. Pond water was slightly acidic, this could trigger high mortality of fishes as young fish and insect larvae are sensitive to a low pH (acid). Extreme values on either end of the scale can be lethal to most organisms (LCRA, 2012).

Temperature affects the rate of metabolism, feeding pattern, breeding and rate of enzymatic activities is directly influenced by temperature, the recommended temperature in °C for catfish is 26 to 32. The temperature of all the water samples was lower than the recommended range and that reported by WHO (2005). Low temperature for water sample could be attributed to the season when the sample was collected. Water sample was collected in January during the harmattan when the temperature was low. The low conductivity in River Kaduna (W_R) (Angwa Rimi area) places it in class 1 of Talling and Talling's (1965) classification of African waters (the most dilute waters of conductivity<600 mhoscm-1). This class of water is said to be poor in nutrients. Pond water have a higher conductivity than that obtained from River Kaduna and this could be attributed to the fact that water used for aquaculture are treated by farmers. Dissolved Oxygen concentration recorded in River Kaduna (Angwa rimi area) agreed with values reported for some Nigerian waters (Ofojekwu *et al.*, 1996). Dissolved oxygen values in juvenile pond catfish water sample (W_{P1}) and matured pond catfish water sample (W_{P2}) revealed anoxic or septic condition within the study period. Deposition of waste that generate aerobic organism in the aquatic environment could be a major cause of low dissolved Oxygen, although such low oxygen saturation has been reported in River Kaduna in dry season months when there was little or no flow (Beecroft *et al.*, 1987; Emere, 2000).

The accumulation measurements refer to studies or methods monitoring the uptake and retention of pollutants such as metals in organs and tissues of organisms, such as fish (Obasohan, 2008). The accumulation factor consists of ratios of the concentration of a given contaminant in biota (a particular metal concentration in fish muscle) to that in an abiotic media (water, sediment and food). Having a good understanding of the accumulation factor is important in predicting the relative contributions of abiotic media as a source of heavy metals accumulation in fish and the accumulation efficiency for any particular pollutant in any fish organ. In addition, such information is crucial in making accurate risk assessment for seafood safety purposes and its possible health consequences to humans.

The calculated transfer factor in all fish samples indicated the level of biomagnification that has occurred in this fish. Calculated transfer factor is calculated by dividing the concentration of trace metal in fish sample by that present in the water sample, a transfer factor of 1 and above indicates that the metals is biomagnified. Matured pond Cat Fish (PCF_{ma}) had the highest transfer factor, this is because of the high amount of metal present in the aquatic environment. This implies that water quality should be maintained such that these trace metal that can cause pollution and bioaccumulate in biota can be eliminated. Although, both wild and farm-raised catfish are exposed to minerals (metals) in one form or the other, catfish from the wild was observed to have essential trace metals present in their tissues when compared with their counterpart. This is probably because of their exposure to these metals in their environment. However, transfer factor indicated that biomagnification of metal was highest in the matured farm-raised catfish.

Conclusion: Periodical monitoring of aquatic environment should not be neglected as fishes are sensitive biological indicators of long-term pollution exposure. They still remain an impact assessment tool with reference to human health, fish community, structure and aquatic ecosystem health.

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