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Assessment of Heavy Metals on African Catfish (*Clarias gariepinus*) from Some Fish Ponds in Emene, Enugu State, South-East Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The research was conducted to determine the presence and bioaccumulation pattern of some heavy metals in African catfish (*Clarias gariepinus*) from three fish ponds in Emene, Enugu State, South-East Nigeria. Fish samples used for the analysis were collected during the dry season from Tollex, Sopulu and Nduka pond farms. The analysis of heavy metals: lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), and iron (Fe), in *C. gariepinus* gills and muscles was carried out using atomic absorption spectrophotometer (AAS) after digestion with concentrated HCl. Results of the analysis show that the investigated heavy metal in the fish samples from the ponds on the basis of their average concentration followed the order: Sopulu pond > Nduka pond > Tollex pond with highest concentration (7.427 ppm of Fe) found in the gill of fish from Sopulu fish pond

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and lowest concentration (0.013 ppm of Cd) in the muscle of fish from Tollex fish farm. The study has shown that there was a considerable amount of heavy metals in the muscle and gills of catfish from Tollex, Nduka and Sopulu fish farms.

Keywords: Toxic metal; Clarias gariepinus; fish pond; atomic absorption spectrometry; Emene-Enugu.

1. INTRODUCTION

Pollution of the environmental media could be as a result of pollutants such as polycyclic aromatic hydrocarbons (PAHs) and toxic metals which are ubiquitous. Pollutants' contamination of air, soil, water, food, beverages etc. has been reported by several scholars. For example, the reports of PAHs and heavy metals in air [1-3], soil [4-7], water [8-12], food [13-16], beverages [17-20] are well documented.

The contamination of aquatic environment especially by heavy metals affects not only the water body but also the aquatic organisms inhabiting the environment. According to Alam *et al*. [21], metallic elements are easily dissolved in and transported by water as well as quickly ingested by aquatic creatures. They also appear to be everywhere or in many locations simultaneously. The density of heavy metals is at least five times that of water. Heavy metals typically do not degrade further into less dangerous components; instead, they build up where they are released and are hence stable and bio-accumulative [22]. They are sometimes passed up the food chain to humans [23]. At a certain amount of exposure, heavy metals are non-biodegradable and extremely damaging to aquatic life, vegetation, and people's health [24]. Some heavy metals, like copper or cobalt, are necessary for enzymatic function at low concentrations, but in greater quantities, they act as enzyme inhibitors.

At low levels, some heavy metals, such as copper or cobalt, are essential for enzymatic activity, but act as enzyme inhibitors at higher concentrations. Other metals, such as cadmium and lead, have no known essential role in living organisms and are toxic even at low concentrations [25]. In recent years, the need for a better understanding of heavy metal concentration and dispersion patterns in aquatic environments has been highlighted following the discovery of high levels of toxic heavy metals (particularly cadmium and lead) in fish and other living organisms [26,27] and even in water resources [12], beverages [28,29,18,19]. The most significant problem associated with heavy metals in the environment apart from accumulation through the food chain and persistence in nature is their toxicity [30].

Fishes, which are often at the top of the aquatic food chain absorb large amounts of these metals from both food chain and water [31]. Fishes have been considered good indicators of heavy metal contamination in aquatic systems because they occupy different trophic levels with different sizes and ages [32,33]. Fish is widely consumed in many parts of the world by humans, and polluted fish may endanger human health. Studies on heavy metals in fish [34-37] have been a major environmental focus, especially during the last decade because fishes are notorious for their ability to accumulate heavy metals in their gills and muscles as they play important role in human nutrition. Consequently, heavy metals need to be carefully screened to ensure that unnecessarily high levels of some toxic metals are not being transferred to man through fish consumption [38]. *C. gariepinus* is among the most commonly harvested and consumed fresh and pond water fish species and therefore a need for regular monitoring of the quality to prevent heavy metal contamination and bioaccumulation along the food chain.

In Enugu State, Emene is probably known to be an industrial area, thereby generating pollution by industrial activities by releasing pollutants especially heavy metals to the ecosystem each blessed day. Fish ponds in Emene have significant variations in the concentration of heavy metals due to untreated industrial and sewage wastes that are added to the pond water through one channel or the other. For the majority of the people living in Enugu and Emene in particular, their only source of fish for protein and other beneficial uses is the pond fish. And so, it becomes necessary to examine the heavy metals concentration in fish harvested in some fish ponds in Emene, Enugu State, South-East Nigeria.

Studies have shown that all over the world, ponds are contaminated with heavy metals [39–41] and as a result, fishes harvested from them are seriously affected. Fish ponds in Emene, Enugu State, Nigeria may not be an exception as the ponds are natural inhabitants of fishes that are used for human consumption in the area. Hence, the health risks associated with heavy metal poisoning in humans via consumption of fish harvested from ponds cannot be overemphasized and it was against this backdrop that this research was conducted since there remains little or no literature on the level of heavy metals in Tollex, Sopulu, and Nduka pond farms in Emene, Enugu State. The current study therefore examines six heavy metals (Pb, Cd, Cr, Zn, Cu and Fe) concentrations in the gills and muscles of the African catfish, *C. gariepinus*.

Results obtained from this study would provide information on levels of heavy metals in the assessed fish species, thus contributing to the effective monitoring of the fish farms.

2. MATERIALS AND METHODS

2.1 Materials Procurement

The African catfish samples were collected from Tollex, Sopulu and Nduka fishponds from Emene in Enugu state. All reagents and chemicals used during analysis were of analytical grade and pre-tested for possible heavy metal contamination. All the glassware and plastics were soaked overnight in 10% nitric acid and rinsed twice with distilled water before use. The instruments used were all calibrated and standardized with standard solutions prepared from commercially procured chemicals.

2.2 Sample Preparation and Analysis

The samples were thawed at room temperature and then dissected for analysis using stainless steel scalpels. The gills and muscles on the dorsal surface of the fish were dried in an oven at 80°C for two hours. The samples were then removed from the oven and allowed to cool. Each dried sample was pulverized using a porcelain mortar and pestle. For each pulverized fish sample, 0.3g was weighed with a Mettler H10 sensitive weighing balance and poured into a beaker containing 20 mL of hydrochloric acid for digestion. Each digested sample was filtered using Whatman filter paper (0.45μm) and then transferred into a 50 mL Erlenmeyer flask and diluted to mark with distilled water. Heavy metals (Pb, Cd, Cu, Cr, Zn and Fe) were determined in the solution using Atomic Absorption Spectrophotometry as adopted from a study by Orakwue *et al*. [42] with little modifications. Procedural blanks were run alongside samples as the analysis was processed in triplicates to ensure the quality of the results obtained. Commercial standards (Buck scientific) containing known concentration were further diluted to provide working standards of the following concentrations in ppm (0,0.2, 0.4, 0.8 and 1.6) for each heavy metal and their corresponding absorbance recorded was used to plot the standard curve. From the standard curve, unknown concentrations of heavy metals in the samples were extrapolated. For each heavy metal, there is a specific hollow cathode lamp and an operational wavelength. The following: 283 nm, 228.9 nm, 357.9 nm, 213.9 nm, 325 nm and 385 nm are the wavelengths for lead, cadmium, chromium, zinc, copper and iron respectively.

3. RESULTS AND DISCUSSION

There is the presence of all the heavy metals investigated in both the gills and the muscles of catfish species in all three ponds as shown in Table 1. Lead content in the muscle of the fish samples from the three ponds is Sopulu (0.137 ppm) > Nduka (0.047 ppm) > Tollex (0.033 pm) while the order (Tollex (0.020 ppm) < Nduka and Sopulu (0.067 ppm) in the gills was observed. Pb concentrations in the muscle of catfish from Tollex and Sopulu ponds are higher than the metal concentration in the gills whereas the Pb concentration is higher in the gills than in the muscle of fish samples from Nduka pond. Lead poisoning in adults can affect the peripheral and central nervous systems, the kidneys, and blood pressure [43]. Hypertension has been associated with acute lead poisoning, along with renal failure. At lesser exposures, both experimental and epidemiological evidence of interference with renal function and elevations in blood pressure have been reported [44]. In children, exposure to Pb can cause acute symptomatic poisoning. Characteristics of this life-threatening syndrome are abdominal colic, constipation, fatigue, anemia, peripheral neuropathy, and in most cases, alteration of central nervous system function [45]. In severe cases, a full-blown acute encephalopathy with coma, convulsions, and papilledema may occur. In milder cases, only headache or personality changes may be evident. In many instances, persons who have suffered from acute lead encephalopathy are left with permanent neurologic and behavioral sequelae [46].

Cadmium content in the muscle of the fish samples followed the order: Sopulu > Tollex >

Nduka while that of the gills was of the order Tollex < Nduka < Sopulu. Cadmium induces tissue injury by creating oxidative stress [47–49], epigenetic changes in DNA [50-52], inhibition or upregulation of transport pathways [53–55] particularly in the proximal S1 segment of the kidney tubule [56].

Cu content in the muscle of the fish samples ranged between 1.197 ppm and 2.297 ppm with Tollex having the highest concentration while that of gills ranged from 1.180 ppm to 1.667 ppm with Nduka having the lowest concentration. Acute copper poisoning is rare. However, serious health problems from long-term exposure to copper can occur. Severe poisoning can cause liver failure and death [57]. In poisonings from a long-term buildup of copper in the body, the outcome depends on how much damage there is to the body's organs. Ingestion may lead to stricture formation throughout the gastrointestinal tract. Acute liver failure can occur due to direct copper toxicity-induced tissue necrosis [58].

Cr concentration in the muscles of the fish samples from the ponds indicated that Nduka > Sopulu > Tollex while that of the gills was of the pattern Sopulu > Nduka > Tollex. Chromium has been found to alter the epigenetic profile of cells at both the level of DNA methylation and histone modification [59-61].

Zn content in the muscle of the fishes showed a range of 2.050 ppm to 3.580 ppm in the order Sopulu > Tollex > Nduka while the concentration in the gills indicated a range between 3. 587 ppm and 4.923 ppm in the order Sopulu > Nduka > Tollex. There is a very low probability of zinc toxicity being fatal; however, the prognosis largely depends on how quickly the patient receives treatment. Large intentional ingestions are most likely to cause significant toxicity [62]. Severe toxicity may also mimic many other pathologies and rarely present with acute kidney injury, pancreatic injury, liver failure, and hemodynamic instability [63].

Table 1. Concentration of the investigated heavy metals (ppm) in muscles and gills of catfish in the selected fish ponds

	Tollex Pond		Nduka Pond		Sopulu Pond	
	Muscle	**Gill**	**Muscle**	**Gill**	**Muscle**	**Gill**
Lead	0.04	0.01	0.04	0.06	0.15	0.07
	0.03	0.03	0.05	0.06	0.1	0.08
	0.03	0.02	0.05	0.08	0.16	0.05
Average	**0.033**	**0.020**	**0.047**	**0.067**	**0.137**	**0.067**
STD	**0.006**	**0.010**	**0.006**	**0.012**	**0.032**	**0.015**
Cadmium	0.01	0.04	0.03	0.05	0.06	0.07
	0.02	0.06	0.03	0.06	0.08	0.09
	0.01	0.05	0.03	0.05	0.1	0.08
Average	**0.013**	**0.050**	**0.030**	**0.053**	**0.080**	**0.080**
STD	**0.006**	**0.010**	**0.000**	**0.006**	**0.020**	**0.010**
Cupper	2.13	1.32	1.25	1.65	1.16	1.19
	2.11	1.44	1.22	1.66	1.19	1.18
	2.65	1.26	1.2	1.69	1.24	1.17
Average	**2.297**	**1.340**	**1.223**	**1.667**	**1.197**	**1.180**
STD	**0.306**	**0.092**	**0.025**	**0.021**	**0.040**	**0.010**
Chromium	0.07	0.05	0.08	0.07	0.06	0.07
	0.04	0.08	0.09	0.07	0.06	0.08
	0.05	0.06	0.09	0.06	0.05	0.07
Average	**0.053**	**0.063**	**0.087**	**0.067**	**0.057**	**0.073**
STD	**0.015**	**0.015**	**0.006**	**0.006**	**0.006**	**0.006**
Zinc	3.54	3.76	2.01	4.16	3.54	5.01
	2.97	3.35	2	4.22	3.44	4.98
	3.89	3.65	2.14	4.17	3.76	4.78
Average	**3.467**	**3.587**	**2.050**	**4.183**	**3.580**	**4.923**
STD	**0.464**	**0.212**	**0.078**	**0.032**	**0.164**	**0.125**
Iron	5.15	4.69	5.21	6.12	7.18	7.29
	5.22	5.02	5.29	6.22	7.19	7.43
	5.44	5.11	5.22	6.17	7.23	7.56
Average	**5.270**	**4.940**	**5.240**	**6.170**	**7.200**	**7.427**
STD	**0.151**	**0.221**	**0.044**	**0.050**	**0.026**	**0.135**

Ingested iron can cause direct caustic injury to the gastrointestinal mucosa, resulting in nausea, vomiting, abdominal pain, and diarrhea. Significant fluid and blood loss can lead to hypovolemia. Hemorrhagic necrosis of gastrointestinal mucosa can lead to hematemesis, perforation, and peritonitis [64]. At the cellular level, iron impairs cellular metabolism in the heart, liver, and central nervous system. Free iron enters cells and concentrates in the mitochondria. This disrupts oxidative phosphorylation, catalyzes lipid peroxidation, forms free radicals, and ultimately leads to cell death [65]. Fe concentration was of the order Sopulu > Tollex > Nduka in the muscle of the fish samples while, in the gills, it was Sopulu > Nduka > Tollex. The concentration ranged between 4. 940 ppm in the gill of fish from Tollex to 7.427 in the gill of the fish from Sopulu.

4. CONCLUSION

Present research reveals significant variations in the concentration of the investigated heavy metals in the fish samples from the ponds which may be as a result of untreated industrial and sewage wastes that leach into the pond water. The study has shown that there was a considerable amount of heavy metals in the fish tissues from Tollex, Nduka and Sopulu fish farms. In most cases, Sopulu pond showed higher levels of heavy metals than the other sources. Nduka pond likewise showed higher levels of heavy metals than Tollex pond which showed the lowest levels of heavy metals in the entire sources. In general, catfish tissue samples showed higher levels of heavy metal in the gills than in the muscles from the three fish pond sources when compared to catfish tissue samples. Heavy metal concentrations in the fish samples from the ponds on the basis of their average followed the order: Sopulu pond > Nduka pond > Tollex pond. Further study is recommended for levels of toxic metals including silver (Ag), Arsenic (As), mercury (Hg), nickel (Ni) and their exposure risks from the fish harvested from the ponds. Again, the levels of heavy metals in the ponds should be continuously monitored to check on their levels in order to maintain standard recommended by appropriate authorities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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