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Research Article

Ecological Risk Assessment of Heavy Metals in Fish Samples from Donga River, Taraba State, Nigeria

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Abstract

Background and Objective: Food items contaminated with heavy metals are unsafe for human consumption. Heavy metals are toxic to human health. The toxic nature of heavy metals could be teratogenic, carcinogenic, neurotoxic and osteotoxic. Inhabitants of the settlements along Donga River consume fishes sourced from Donga River. However, there is no available information on the heavy metals concentrations in these fishes concerning public health. This study was conducted to assess the concentrations of the heavy metals (Pb, As, Cd, Hg, Zn, Cu, Cr and Fe) in five fish species (*Synodontis membranaceus*, *Protopterus annectens*, *Clarias gariepinus*, *Heterotis niloticus* and *Tilapia zillii*) from Donga River in Donga, Taraba State, Nigeria. **Materials and Methods:** The tissue samples from the fishes, were analyzed for the heavy metals, Pb, As, Cd, Hg, Zn, Cu, Cr and Fe, using Atomic Absorption Spectrophotometer (AAS). **Results:** The result obtained indicated that with exception of Pb, all other heavy metals (As, Cd, Cr, Cu, Fe, Hg and Zn) are present in concentrations above the permissible limits as well as the Provisional Tolerable Week Intake (PTWI) (Cd: 0.007 mg kg⁻¹, As: 0.015 mg kg⁻¹, Hg: 0.004-0.0016 mg kg⁻¹ and Pb: 0.025 mg kg⁻¹) and Provisional Maximum Tolerable Daily Intake (PMTDI) (Zn: 0.3-1 mg kg⁻¹, Fe: 0.8 mg kg⁻¹, Cu: 0.05-0.5 and 0.06 mg kg⁻¹) recommended by FAO/WHO. **Conclusion:** Fish consumers who prefer fishes from Donga River are predisposed to As, Cd, Cr, Cu, Fe and Hg toxicities.

Key words: Heavy metals, risk assessment, fish, concentration, Donga River, bioaccumulation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In the last decades, contamination of water bodies by heavy metals has become a global problem. Heavy metals may enter aquatic systems from different natural and anthropogenic (human activities) sources, including industrial or domestic wastewater, application of pesticides and inorganic fertilizers, storm runoff, leaching from landfills, shipping and harbour activities, geological weathering of the earth crust and atmospheric deposition¹. Rapid industrialization has resulted in the discharge of potentially toxic trace metals such as mercury, cadmium, copper, chromium and nickel into the marine environment². Though heavy metals are natural constituents of the earth's crust, they are regarded as environmental pollutants because of their persistency, bioaccumulation problem and their toxic effects on health.

Most heavy metals are toxic to human health even at very low concentrations. However, few heavy metals have beneficial effects on human health and only become toxic at high concentrations.

Most heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts and most of them are extremely toxic because of their solubility in water. The nature of effects could be toxic (acute, chronic or subchronic), neurotoxic, carcinogenic, mutagenic or teratogenic³. Although individual metals exhibit specific signs of their toxicity, the following have been reported as general signs associated with cadmium, lead, arsenic, mercury, zinc, copper and aluminium poisoning: Gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremor, haemoglobinuria causing a rust-red colour to stool, ataxia, paralysis, vomiting and convulsion, depression and pneumonia when volatile vapours and fumes are inhaled³.

The major route for human exposure to heavy metals is through the food pathway⁴. Contamination of foods by heavy metals has become an inevitable challenge these days. Air, soil and water pollution are contributing to the presence of these harmful elements, such as cadmium, lead and mercury in food stuffs⁵. Because heavy metals are not degradable when present in the aquatic environment they are deposited or incorporated in sediments and aquatic animals like fishes and eventually get to humans through diet. Metals entering the aquatic ecosystem can be deposited in aquatic organisms through the effects of bioconcentration, bioaccumulation via the food chain process and become toxic when accumulation reaches a substantially high level⁶. In fish, which is often at the higher level of the aquatic food chain, substantial amounts of metals may accumulate in their soft and hard tissues⁴.

Fish is prevalently consumed by the populace of most river settlements in various countries. Previous studies have shown heavy metals contamination of fishes harvested from certain rivers of various countries.

Zrnčić *et al.*⁷ reported Pb concentrations ranging from 0.015 μg^{-1} dry weight in planktivorous to 0.039 μg^{-1} dry weight in herbivorous fish in Danube River, Croatia. Edward *et al.*⁸ reported Mn concentrations of 0.49, 0.93 and 1.13 mg kg^{-1} in the muscles, kidneys and gills, respectively of fish from Odo-Ayo River, Nigeria.

Therefore, the need to assess the levels of heavy metals in fishes harvested from the river is of public health and toxicological importance.

MATERIALS AND METHODS

Study area: The study was carried out at the Central Research Laboratory the University of Ibadan, Oyo State, from January to April, 2016.

Sample collection and treatment: Five different samples of fishes, *Synodontis membranaceus*, *Protopterus annectens*, *Clarias gariepinus*, *Heterotis niloticus* and *Tilapia zillii* were purchased from the fishermen at the bank of Donga River and was packaged into different polythene bags.

The fish samples were transported to the Biochemistry Laboratory Federal University Wukari in a cold box with ice on the same day. All fish samples were kept in the freezer at 0-4°C until analysis. The fish samples were then washed with de-ionized water and were allowed to thaw at room temperature. The fish samples were dissected and filleted to obtain the fish flesh. The fillets were dried at ambient room temperature. About 20 g of the dried samples were each homogenized using pestle and mortar and then sieved with a mesh of size 0.5 m. Then 1 g of the sample homogenates each were weighed into round bottom flasks, followed by the addition of 2-3 Spatula of anti-bump granules and 50 mL of 2 M HNO_3 to the respective flasks. The round bottom flasks were placed into an electro-thermal heater and allowed to concentrate for 30 min and 1 hr. After the period, the samples were each transferred into 100 mL volumetric flasks and were diluted with distilled water to the 100 mL mark. The sample was taken to the UNICAM 939 Atomic Absorption Spectrophotometer (AAS) for heavy metal determination. The heavy metals (Pb, As, Cd, Hg, Cr, Cu, Fe and Zn) concentrations in the samples were measured using a UNICAM 939 Atomic Absorption Spectrophotometer (AAS).

Statistical analysis: Statistical analysis of the results was carried out using SPSS (Statistical Package for Social Sciences)

Table 1: Result of heavy metal analysis (mg kg⁻¹)

	Pb	Cd	As	Hg	Zn	Cr	Fe	Cu
<i>Tilapia zillii</i>	0.001	0.018	0.059	0.033	97.482	0.042	75.081	54.439
<i>Protopterus annectens</i>	0.001	0.015	0.036	0.035	78.396	0.043	65.761	28.943
<i>Synodontis membranaceus</i>	0.001	0.016	0.17	0.038	92.933	0.05	81.504	39.141
<i>Clarias gariepinus</i>	0.001	0.017	0.181	0.054	86.102	0.019	73.776	59.538
<i>Heterotis niloticus</i>	0.001	0.016	0.116	0.154	115.728	0.133	68.606	13.645
Mean±SD error mean	0.0010±0.0001	0.0200±0.0100	0.1100±0.2900	0.6300±0.2300	94.1300±6.2900	0.0600±0.0200	72.9500±2.7300	39.1400±8.3800

statistical software (version 21). The results were analyzed through a t-test. The means and standard deviations were calculated.

RESULTS

The result of heavy metals analysis of the fishes harvested from Donga River is presented in Table 1. The result showed that mercury concentrations range from 0.033-0.153 mg kg⁻¹, with *Heterotis niloticus* having the highest concentration while *Tilapia zillii* having the lowest concentration.

Concentrations of arsenic range from 0.036-0.181 mg kg⁻¹, with *Clarias gariepinus* having the highest concentration while *Protopterus annectens* has the lowest arsenic concentration.

The result also showed that copper and iron concentrations in the fish species range from 13.645-59.538 and 65.761-75.081 mg kg⁻¹ respectively, with *Clarias gariepinus* having the highest (59.538 mg kg⁻¹) concentration of copper while *Synodontis membranaceus* has the highest (81.504 mg kg⁻¹) concentration of iron.

Clarias gariepinus has the highest (0.017 mg kg⁻¹) value for cadmium concentration while *Heterotis niloticus* has the highest (0.133 mg kg⁻¹) value for chromium concentration.

All the fish species have the same value for lead concentration (0.001 mg kg⁻¹). The result also indicated that zinc concentration was highest (115.728 mg kg⁻¹) in *Heterotis niloticus* and lowest (78.396 mg kg⁻¹) in *Protopterus annectens*.

DISCUSSION

Anthropogenically, the aquatic systems are being polluted with pollutants from industrial, domestic and agricultural wastes, which are ultimately absorbed by aquatic animals and plants⁹. These pollutants range from fertilizer, pesticides and industrial effluents to heavy metals. Heavy metals are among the most dangerous environmental pollutants which can bio-accumulate living tissues. The consumption of fish which is a prevalent aquatic organism is very common in Donga and its environment due to its

closeness to Donga River. However, the safety of the Donga River which is the source of these fishes gives reasons to worry.

The result obtained from this study indicated that the heavy metals, Pb, As, Hg, Cd, Zn, Cu, Cr and Fe were present in the fish samples from Donga River. All the metals occur in concentrations above their Food and Agriculture Organization/World Health Organization (FAO/WHO) stipulated permissible limits as well as the Provisional Tolerable Week Intake (PTWI) (Cd: 0.007 mg kg⁻¹, As: 0.015 mg kg⁻¹, Hg: 0.004-0.0016 mg kg⁻¹, Pb: 0.025 mg kg⁻¹) and Provisional Maximum Tolerable Daily Intake PMTDI (Zn: 0.3-1 mg kg⁻¹, Fe: 0.8 mg kg⁻¹, Cu: 0.05-0.5 mg kg⁻¹ and Cr: 0.06 mg kg⁻¹) with exception of lead (Pb).

Mercury is a dangerous heavy metal whose poisoning (or excessive intake) can result in numerous health conditions. Mercury is known to be a latent neurotoxin compared to other metals like lead, cadmium, copper and arsenic. A high dietary intake of mercury (organic) that is concentrated above 1.0 mg g⁻¹ from the consumption of fish has been hypothesized to increase the risk of coronary heart disease¹⁰. The Food and Agriculture Organization and the World Health Organization (2011) stipulated the PTWI for inorganic Hg and methyl mercury at 4 µg kg⁻¹ (0.004 mg kg⁻¹) b.wt. and 0.0016 mg kg⁻¹ b.wt., respectively¹¹. In this study, the concentrations of Hg in the fish samples range from 0.033-0.154 mg kg⁻¹. These concentrations are higher than the FAO/WHO (2011) stipulated PTWI. The consumption of these fishes could result in health problems related to Hg. Hence, the consumers of the fishes from Donga River are at great risk of Hg toxicity.

Arsenic (As) concentrations in all the fish species examined in this study ranged from 0.036-0.181 mg kg⁻¹. This value is above the FAO/WHO (2011) stipulated PTWI for As at 15 µg kg⁻¹ (0.015 mg kg⁻¹). Consumption of these fishes could predispose the consumers to As-induced health problems.

Cadmium (Cd) poisoning can result in several health conditions in humans and even in animals. In man, Cd poisoning could lead to anaemia, renal damage, bone disorder and cancer of the lungs. The Cd concentrations (0.015 and 0.018 mg kg⁻¹) recorded in fish samples from this study were higher than the FAO/WHO (2011) PTWI of

7 $\mu\text{g kg}^{-1}$ (0.007 mg kg^{-1}) for Cd. Consumption of fish from Donga River could pose Cd related health problems.

The Zn and Fe are metals of major importance to the body. They are required in a certain amount for the proper functioning of the body but excess concentrations can cause serious health conditions. The concentrations of Zn and Fe in the fish sample were high and are above the FAO/WHO stipulated PMTDI (Provisional Maximum Tolerable Daily Intake) value of 0.3-1 mg kg^{-1} for Zn and 0.8 mg kg^{-1} for Fe. The concentrations of Zn and Fe in the fish samples range from 78.396-115.728 mg kg^{-1} and 65.761-81.504 mg kg^{-1} , respectively. This implies all the fishes examined could predispose the consumers to Zn and Fe toxicities. The trend in the zinc (Zn) concentration of the samples followed the sequence *Heterotis niloticus* > *Tilapia zillii* > *Synodontis membranaceus* > *Clarias gariepinus* > *Protopterus annectens*.

Copper (Cu) is one of the essential metals for human health. It is necessary for the synthesis of haemoglobin and combines with certain proteins to produce certain enzymes that act as a catalyst to help in the body functions. The concentrations of copper (Cu) in this study ranged from 13.645-59.539 mg kg^{-1} which is above FAO/WHO stipulated PMTDI value for Cu (0.05-0.5 mg kg^{-1}) this implies that all the fishes examined pose Cu-induced health problems to consumers. The level of Cu recorded in this study was generally high when compared to the report by Edward *et al.*⁸ in which the Cu levels in fishes from Odo-Ayo River in Ado-Ekiti, Ekiti-State, Nigeria was less than 3.00 mg kg^{-1} .

The speciation of chromium is of great importance for its toxicity. Chromium III (Cr (III)), the most stable form of Cr in biological materials, is an essential element for normal glucose metabolism, while Cr (VI) is highly toxic. The Cr (III) has low toxicity due to low absorption (about 0.5%)⁹. The FAO/WHO stipulated PMTDI values for Cr is (0.06 mg kg^{-1}). While the Cr concentrations in this study ranged from 0.019-0.133 mg kg^{-1} . The concentration of Cr in *Heterotis niloticus* (0.133 mg kg^{-1}) being above the FAO/WHO stipulated PMTDI value (0.06 mg kg^{-1}). This implies that consumers who prefer *Heterotis niloticus* from Donga River are predisposed to Cr-induced health conditions.

It has been reported that cognitive development, intellectual performance in children, increased blood pressure and cardiovascular disease in adults can be reduced by lead¹⁰. The FAO/WHO stipulated maximum level of Pb in fish is 0.03 mg kg^{-1} and PTWI 0.025 mg kg^{-1} . From the result of this study, Pb concentration is very low at 0.001 mg kg^{-1} in all fish samples which is the stipulated FAO/WHO maximum permitted level and the PTWI. Thus, Pb may not pose serious health consequences to consumers of the fish in the short

term of exposure but could be in the long run. The values obtained for Pb in this study is not in line with the report of Zrnčić *et al.*⁷, who obtained a Pb concentration ranging from 0.015 μg^{-1} dry weight in planktivorous to 0.039 μg^{-1} dry weight in herbivorous fish in Danube River, Croatia.

CONCLUSION

The result of this study has shown that the heavy metals As, Cd, Cr, Cu, Fe, Hg, Pb and Zn are present in all the five fish species from Donga River. It was observed that with exception of Pb, all other heavy metals (As, Cd, Hg, Cr, Fe, Zn and Cu) analyzed were present in concentrations above the FAO/WHO recommended limit. The consumption of the fishes from Donga River, predispose the consumers to the toxicities associated with these heavy metals, As, Cd, Hg, Cr, Fe, Zn and Cu. Hence, it is essential for agricultural activities and other human activities that may increase heavy metal contamination of foodstuff around river Donga to be controlled.

SIGNIFICANCE STATEMENT

This study discovered the presence of certain heavy metals (As, Cd, Cr, Cu, Fe and Hg) in the five fish species from Donga River which were above the FAO/WHO recommended limit, suggesting that the consumers of fishes harvested from Donga river are predisposed to the toxicity of the mentioned heavy metals. This study will help the researcher to uncover the critical area of heavy metal risk assessment of fishes in Donga River that many researchers were not able to explore. Thus, new information on heavy metals contamination of fish species in Donga River could be used to sensitize consumers to the toxic effects of heavy metals on human health.

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