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SHORT COMMUNICATION

Bioaccumulation of heavy metals in *Tilapia zillii* from Hadejia-Nguru Wetlands, Northern Nigeria

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Introduction

Fish are a vital source of protein globally, but contamination of water with heavy metals such as Pb and Cd threatens human health due to bioaccumulation (FAO, 2003). These metals originate from industrial discharges, agricultural runoffs, and inadequate environmental regulations (Hala *et al.*, 2015). Fish uptake heavy metals through water, food, and direct contact, with concentrations varying depending on environmental levels and the fish's physiology (Keziah *et al*., 2019). Fish also bioaccumulate heavy metals through food, water, suspended particles, and direct gill/skin absorption. The level of contamination in fish tissues depends on environmental exposure, uptake regulation, and elimination processes (Keziah *et al*., 2019).

This study examined *Tilapia zillii,* a globally introduced fish species used in aquaculture. While highly adaptable and successful, its herbivorous nature can negatively impact native plant communities (Katunzi *et al*., 2009). The permissible limits for Pb and Cd in fish flesh are 0.02 µg/g and 0.05 µg/g, respectively FAO (1983) and WHO (1985).

Materials and Methods

Study area

The Hadejia-Nguru wetlands (HNW) lie within Nigeria's Semi-arid Northwestern and Northeastern regions, spanning Kano, Bauchi, Jigawa, and Yobe states (Salako *et al*., 2016). Encompassing an area of approximately 3500 km², the wetlands are situated between latitudes 12°00'N and 13°15'N and longitudes 10°00'E and 11°12'E. This vital ecosystem supports over 7 million people, including migrants from neighboring Niger Republic (Salako *et al*., 2016).

Sample collection

Water and fish samples were collected biweekly from March to April 2021, representing the dry season. Twenty-one water samples were obtained from three designated sampling points, each at least 1 kilometer apart. These points included Dogon-Kuka, Gadar-Goriba, and Garbi, with seven samples collected from each location. Basic physicochemical parameters (pH and dissolved oxygen) were measured *in situ* using a mercury thermometer, pH meter, and DO meter.

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Sixty Tilapia spp. fish samples were purchased immediately after capture from local fishermen at the three sampling points. Both water and fish samples were transported in an ice chest to the Chemistry Laboratory of Yobe State University in Damaturu for heavy metal analysis and digestion.

Heavy metal analysis

Prior to and during experimentation, all equipment and instruments were thoroughly calibrated to ensure accurate measurements. Volumetric flasks, measuring cylinders, and digestion flasks were meticulously washed with detergents and tap water, followed by several rinses with deionized water. Furthermore, all glassware were cleaned with 10% concentrated nitric acid (HNO_3) to remove any residual heavy metals from surfaces and then rinsed thoroughly with distilled-deionized water. Digestion tubes were soaked for 24 hours in a solution of 1% (w/v) potassium dichromate in 98% (v/v) H_2SO_4, while volumetric flasks were soaked in 10% (v/v) HNO_3. Following this step, all glassware were rinsed with deionized water, oven-dried, and stored in a dust-free environment until analysis commenced. Before each use, the apparatus were soaked and rinsed again with deionized water.

Equipment and apparatus

i. Analytical Balance (OHAUS, PA214 Pioneer USA): 250-gram capacity, 0.0001 g resolution
ii. Borosilicate Glassware: Volumetric flasks (25, 50, 100, and 1000 ml), measuring cylinders Micropipettes (1-10 ml, 100-1000 ml)
iii. Atomic Absorption Spectrophotometer (Buck Scientific model 210VGP AAS, USA): Equipped with hollow cathode lamps and air-acetylene flame
iv. Microwave Digester (Master 40, serial no: 40G106M)

Sample pre-treatment/digestion (fish samples)

Fish samples were oven-dried (Model 30GC Lab Oven) and subsequently grounded into a fine powder using a clean mortar and pestle. Approximately 200mg of each sample was weighed into a thoroughly clean plastic container (microwave tube). Then, 6 ml of 65% HNO_3 and 2ml of H_2O_2 was added. For fish samples only, an additional 2ml of HF was included. The mixture was allowed to stand for a 1 – 5 minute before the container was covered and placed in the microwave digester (Master 40, serial no: 40G106M) for digestion (Perkin Elmer, 1997)

The digestion was done by heating the samples to 75°C for 10 minutes, followed by a rapid temperature increase of 100°C per minute to reach 950°C. This high temperature was maintained for 30 minutes. Afterwards, the samples were allowed to cool down to room temperature within the microwave.

Blanks were included in each digestion batch to assess potential metal contamination from the chemicals used. To ensure analytical accuracy, the digested samples were diluted with deionized water to a final volume of 100ml.

Water samples were filtered using Whatman No. 1 filter paper. Approximately 1 mL of HNO_3 was added to each 90 mL of the sample to achieve a 1.0% acid concentration. The presence of heavy metals in the samples was determined using atomic absorption spectrometry (AAS). As with fish samples, blanks were employed in each analytical batch to verify the analytical quality.

Determination of metal content in fish and water samples

The concentration of metal ions in each sample was determined by measuring their absorbance using the atomic absorption spectrophotometer (AAS) and comparing it to the corresponding standard calibration curve. Triplicate analyses were performed for each sample. The AAS operated in absorption/concentration mode, with manual recording of instrument readouts for each solution. This analytical procedure was also used for analyzing metal content in digested blank solutions and spiked samples (Perkin Elmer. 1997).

Data analysis

Statistical analyses were performed using IBM SPSS Statistics version 25 to generate descriptive statistics (Field, 2018). Significance difference was determined at $p < 0.05$. One way ANOVA were employed to compare the levels of cadmium (Cd) and lead (Pb) between fish tissues and water samples.

Results

Physical and chemical parameters of water

The physical and chemical parameters of water in Hadeja-Nguru wetlands are shown in Table 1. There was no significant difference ($p>0.05$) between the water parameters studied in the three locations.

Table 1: Physical and chemical parameters of water in Hadeja-Nguru wetlands

Sampling locations Parameters	Dogon-Kuka	Gadar-Goruba	Garbi	LOS	FEPA (1991) Standard limit	NESREA (2011) Standard limit
Temperature(ºC)	26.75±0.34	27.71±0.40	27.85±0.23	NS	<40	25
pH	7.12±0.16	7.01±0.10	7.39±0.34	NS	6-9	6-8.5
Dissolved oxygen (mg/L)	7.05±0.40	6.38±0.27	6.68±0.25	NS	Nil	8-10

LOS = level of significance, NS = not significant at $P>0.05$.

Concentrations of heavy metals in water samples from Hadejia-Nguru wetlands

Table 2 shows the concentration of heavy metals in water samples from Hadejia-Nguru wetlands. The levels of lead and cadmium were significantly different at ($p<0.05$) in Dogon-Kuka, Gadar-Goruba and Garbi water sampling points respectively. The level of lead was higher in Garbi (0.30±0.12mg/L), followed by Gadar-Goruba (0.11±0.04mg/L) and lower in Dogon-Kuka (0.09±0.01mg/L) whereas, the level of cadmium was higher in Gadar-Goruba (0.16±0.06mg/L) in lower in both Dogon-Kuka and Garbi (0.04±0.01 mg/L each).

Table 2: Concentration of heavy metals in water sample from Hadejia-Nguru wetlands

Sampling locations Parameters	Dogon-Kuka	Gadar-Goruba	Garbi	LOS	FEPA 2003 mg/L	WHO 2003 mg/L
Lead (mg/L)	0.09±0.01[c]	0.11±0.04[b]	0.30±0.12[a]	*	<1.0	0.05
Cadmium (mg/L)	0.04±0.01[b]	0.16±0.06[a]	0.04±0.01[b]	*	<1.0	0.01

Values are mean±SEM of 21 water samples, LOS = level of significance, * significant at P>0.05.

Concentration of heavy metals in fish samples (Tilapia zilli)

Table 3 shows the concentration of heavy metals in fish samples from Hadejia-Nguru wetlands. There was no significant difference (p>0.05) in both the levels of lead and cadmium at the three fish sampling points.

Table 3: Concentration of heavy metals in fish samples (*Tilapia zilli)* from Hadejia-Nguru wetlands

Parameter	Dogon-kuka	Gadar-goruba	Katuzu	LOS	NAFDAC 2016 mg/kg	FAO 1983 mg/Kg	WHO 1985 mg/Kg
Lead	1.41±0.45	1.24±0.33	1.81±0.52	NS	0.1	0.50	2.00
Cadmium	0.13±0.04	0.06±0.01	0.10±0.03	NS	2.00	0.05	2.00

Values are Mean ± SEM of 21 water samples, LOS = level of significance, NS = not significant at P>0.05.

Discussion

This study found minimal variation in the physical and chemical parameters (temperature, pH, and dissolved oxygen) across the three sampling locations within the Hadejia-Nguru wetlands. These results suggest a relatively uniform water quality profile throughout the wetlands. While temperature values were within the recommended limit of <40°C set by FEPA (1991), they fall within the range reported by NESREA (2011). Similarly, pH values remained within the acceptable range established by both FEPA (1991) and NESREA (2011). Dissolved oxygen concentrations also adhered to the standard of 8-10 mg/L outlined by NESREA (2011).

Water temperature plays a crucial role in aquatic ecosystems, influencing factors like metabolic rates, photosynthetic production, and the solubility of dissolved gases. Warmer temperatures can decrease dissolved oxygen (DO) levels, potentially impacting aquatic life.

Temperature has a large impact on the biological activity of aquatic organisms. It affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviors of aquatic organisms (Suski *et al*., 2006).

The DO concentration within the Hadejia-Nguru wetlands suggests the water can support aquatic life, although continued monitoring of temperature remains essential. Survival of aquatic organisms, especially fishes depend upon the level of DO. DO provides a source of oxygen needed for the oxidation of organic matter; when the concentration is high, very low or lacking, it causes the water body to become dead or devoid of aquatic life (Chukwu, 2008).

Significant differences were observed in the lead (Pb) and cadmium (Cd) concentrations between the three sampling points. While these levels fell below the critical threshold of 1.0 mg/L established by FEPA (2003), they exceeded the WHO (2003) guidelines of 0.05 mg/L for Pb and 0.01 mg/L for Cd. These findings suggest potential anthropogenic activities, such as industrial waste disposal, mining operations, or agricultural practices using fertilizers and agrochemicals, may be contributing to heavy metal contamination in the wetlands (Okachukwu, 2012).

Although no significant differences were detected in Pb and Cd concentrations across the fish sampling points, Pb levels surpassed the safety limits set by NAFDAC (2016) 0.1 mg/kg and FAO (1983) 0.50 mg/kg. Conversely, Cd levels remained below the maximum permissible limits established by NAFDAC (2016) and WHO (1985) of 2.00 mg/kg, but exceeded the FAO (1983) guideline of 0.05 mg/kg. These variations compared to previous reports could be attributed to geographical differences.

The high Pb concentrations in fish highlight the potential health risks associated with consuming fish from the Hadejia-Nguru wetlands. Continued monitoring efforts are crucial to ensure consumer safety and inform appropriate management strategies.

Heavy metal pollution in aquatic ecosystems is a significant environmental concern due to the bio-accumulative nature of these contaminants. As organisms ingest contaminated water or food, heavy metals accumulate within their tissues, potentially reaching harmful levels at higher trophic levels. This bioaccumulation poses a threat to the health of not only aquatic life but also humans who consume these organisms.

The Hadejia-Nguru wetlands serve as a vital economic and domestic resource for the Nigeria and West African region. Heavy metal contamination within this ecosystem necessitates further investigation to understand the potential ecological and economic ramifications. Implementing effective pollution control measures and sustainable management practices is critical to safeguarding the ecological integrity and economic viability of this vital wetland system

Conclusion

From the results obtained in this study, it can be concluded that the concentration of heavy metals was found within the standard permissible limit of NASREA, FAO and WHO. However, the fish within the wetlands are said to be wholesome for human consumption, there is need for caution as they have the potential to bio-accumulate some of these heavy metals in food chain over time.

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