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Abstract

This study assessed lead (Pb), cadmium (Cd) and zinc (Zn) concentrations reported for African catfish (*Clarias gariepinus*) associated with three markets in Maiduguri, Borno State, Nigeria: Custom, New Tashan Bama and Monday Market. Edible muscle samples were prepared, acid-digested and analysed using atomic absorption spectrophotometry. Pb was reported as not detected at all three locations. Cd concentrations were 0.813, 0.724 and 0.506 mg/kg, respectively, while Zn concentrations were 35.55, 37.54 and 22.92 mg/kg. Relative to the project-selected screening concentrations of 0.50 mg/kg for Cd and 40 mg/kg for Zn, all reported Cd values were above the selected comparison value, whereas all Zn values were below it. A scenario-based dietary assessment, using an assumed fish intake of 0.0324 kg/day and adult body mass of 70 kg, produced combined hazard indices of approximately 0.431, 0.393 and 0.270, respectively. These estimates are conditional on the assumed exposure parameters and reference doses; they are not measurements of individual or population risk. The findings identify Cd as the principal contaminant requiring follow-up, particularly in the Custom and New Tashan Bama entries. Interpretation is constrained by the absence of documented sample numbers, analytical detection limits, quality-control results and confirmation of the wet- or dry-weight basis. Larger, repeated sampling and analytical validation are required before broader food-safety conclusions can be drawn.

Keywords: cadmium; catfish; dietary exposure; food safety; lead; zinc

Introduction

Fish is an important source of dietary protein and essential nutrients in Nigeria, where fresh, frozen and processed fish are widely traded. African catfish (Clarias gariepinus) is particularly valued because of its suitability for aquaculture, availability and consumer acceptance. Its nutritional benefits make the safety of fish sold in urban markets a relevant public-health issue [1, 2]. Evidence from studies of fish marketing in Maiduguri also shows the importance of understanding local handling and distribution practices when considering the quality of fish reaching consumers [13].

Potentially toxic metals can enter aquatic systems through geological weathering, industrial effluent, municipal discharges, mining-related activities and agricultural runoff. Once present in water or sediments, these elements can be taken up by aquatic organisms and retained in tissues. Cadmium and lead are of particular concern because they have no established nutritional requirement, whereas zinc is an essential micronutrient that can cause adverse effects at sufficiently high exposure [3, 4]. Studies of industrial effluents and metal contamination in soils and vegetable crops in Nigeria further illustrate the potential for anthropogenic activities to introduce potentially toxic elements into environmental media and food pathways [14, 15].

The extent of metal accumulation in fish depends on environmental concentrations, chemical form, feeding habit, age and duration of exposure. Catfish feed near bottom sediments, where deposited contaminants may occur. Bioaccumulation provides a pathway through which contaminants present in environmental media can be retained in organisms, while muscle is of particular interest because it is a commonly consumed tissue [5, 6, 16]. However, tissue concentrations alone cannot establish whether contamination occurred in the rearing environment or during transport and marketing.

Studies in Nigeria have reported metal contamination in different fish species, including fish sold in Borno State [7]. Related assessments of heavy metals in edible animal products and in soil–crop systems in northern Nigeria provide further context for food-chain monitoring, although they do not substitute for fish-specific evidence [11, 12, 15]. Nevertheless, measurements from a limited number of market-associated samples should not be generalized to all fish sold at a market without adequate sample numbers, repeated sampling and source-tracing data. Screening of locally marketed catfish can help identify metals and distribution points that merit further monitoring.

This study therefore reports the available Pb, Cd and Zn concentrations for catfish associated with three Maiduguri market locations, compares the results with the screening concentrations used in the underlying student project, and presents a scenario-based estimate of dietary exposure and non-carcinogenic hazard indices. The exposure calculations follow the concentration–ingestion rate–body-weight approach used in food-contaminant studies [8–10].

Materials and Methods

Study setting and sample sources

The research was undertaken in Maiduguri metropolis, Borno State, northeastern Nigeria. Catfish associated with three market locations—Custom, New Tashan Bama and Monday Market—were assessed. The underlying project describes the purchase of catfish from selected markets and identifies these locations in its analytical results. It does not document the number of fish or independent biological replicates represented by each market-level result.

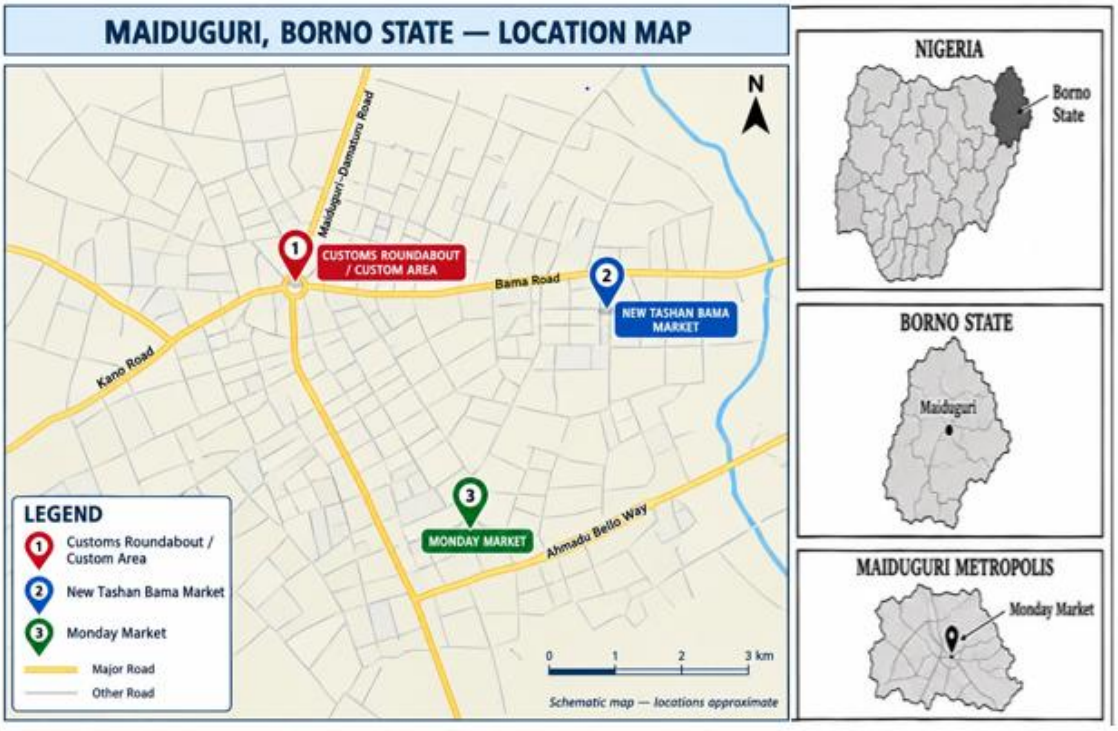


Fig. 1 Study-area map supplied with the original project. Monday Market is highlighted on the map; Custom and New Tashan Bama are identified in the analytical results but are not clearly plotted on this map

Sampling, tissue preparation and digestion

The original project describes the purchase and transport of catfish in clean packaging and an ice-packed container to reduce external contamination. In the laboratory, edible muscle tissue was washed, separated from non-edible portions, dried, ground and stored for analysis. A weighed subsample was described as being digested using nitric acid (HNO_3) and perchloric acid ($HClO_4$), followed by filtration and dilution to a known final volume. The project does not provide the exact digestion mass, reagent volumes, heating programme, recovery tests or sample-storage records; these details are therefore not inferred or reconstructed in this manuscript.

Determination of heavy metals

Lead, cadmium and zinc concentrations were reported from atomic absorption spectrophotometric analysis. Results are expressed as milligrams per kilogram (mg/kg) of fish material, as reported in the source project. The available records do not specify the instrument model, method detection or quantification limits, calibration performance, replicate precision, certified reference material results or whether concentrations are expressed on a wet- or dry-mass basis. Accordingly, “not detected” (ND) is retained as the reported analytical category and is not interpreted as zero concentration.

Concentration comparison and dietary exposure assessment

The underlying project used 0.50 mg/kg for Cd, 40 mg/kg for Zn and 0.50 mg/kg for Pb as comparison concentrations. Because the source records do not provide sufficient traceability to verify the regulatory instrument, commodity category or applicable standard, these values are treated in this manuscript as project-selected screening benchmarks rather than as independently verified, universally applicable legal limits. The concentration-to-benchmark ratio was calculated as the reported concentration divided by the corresponding selected value.

A hypothetical adult body weight (BW) of 70 kg and fish ingestion rate (IR) of 0.0324 kg/day were used, equivalent to approximately 0.227 kg of fish per week. Estimated daily intake (EDI), target hazard quotient (THQ) and combined hazard index (HI) were calculated as follows:

EDI (mg/kg body weight/day) = [C (mg/kg) × IR (kg/day)] / BW (kg)

THQ = EDI / RfD

HI = THQ(Cd) + THQ(Zn)

where C is the metal concentration in fish, IR is the assumed fish ingestion rate, BW is the assumed consumer body weight and RfD is the oral reference dose. The RfD denominators required to reproduce the source project's reported THQ values were 0.001 mg/kg body weight/day for Cd and 0.3 mg/kg body weight/day for Zn. The source project does not identify the toxicological sources for these RfD values; they therefore require verification before regulatory, clinical or definitive risk interpretation. Pb was not included in numerical EDI/THQ calculations because its concentration was reported as ND and no detection limit was supplied.

The results are descriptive. Only one concentration entry per location is available in the project record; therefore, inferential statistical testing, sample-level standard deviations and claims of statistically significant differences among markets are not justified. The dietary estimates represent a hypothetical adult-consumption scenario, not a survey of consumption patterns among Maiduguri residents [9, 10].

Results and Discussion

Metal concentrations in market-associated catfish

Lead was reported as ND in the analytical entries for all three market locations (Table 1). Cd was detected at each location, with the highest reported concentration at Custom (0.813 mg/kg), followed by New Tashan Bama (0.724 mg/kg) and Monday Market (0.506 mg/kg). Zn concentrations ranged from 22.92 to 37.54 mg/kg; New Tashan Bama had the highest reported value and Monday Market the lowest.

Table 1. Reported heavy-metal concentrations in catfish associated with selected markets in Maiduguri

Sampling location	Lead, Pb (mg/kg)	Cadmium, Cd (mg/kg)	Zinc, Zn (mg/kg)
Custom	ND	0.813	35.55
New Tashan Bama	ND	0.724	37.54
Monday Market	ND	0.506	22.92

ND = not detected; the analytical detection limit was not stated in the source project.

The market-level entries are presented as reported. The underlying project also contains narrative references to small-, medium- and large-sized fish, but its final analytical table assigns the same concentration values to market locations. Because the mapping between fish-size categories and market locations is not consistently documented, this manuscript does not infer a relationship between fish size and metal concentration.

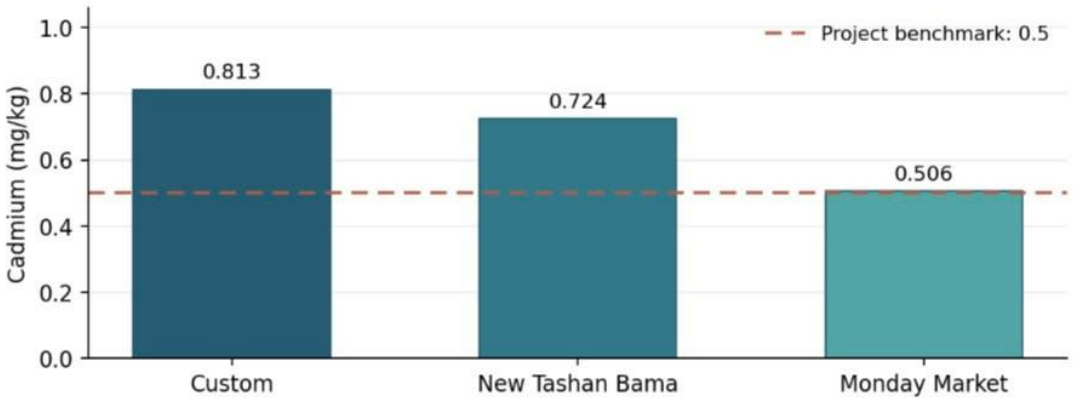


Fig. 2 Cadmium concentrations reported for catfish from the three market locations, shown against the project-selected screening concentration of 0.50 mg/kg

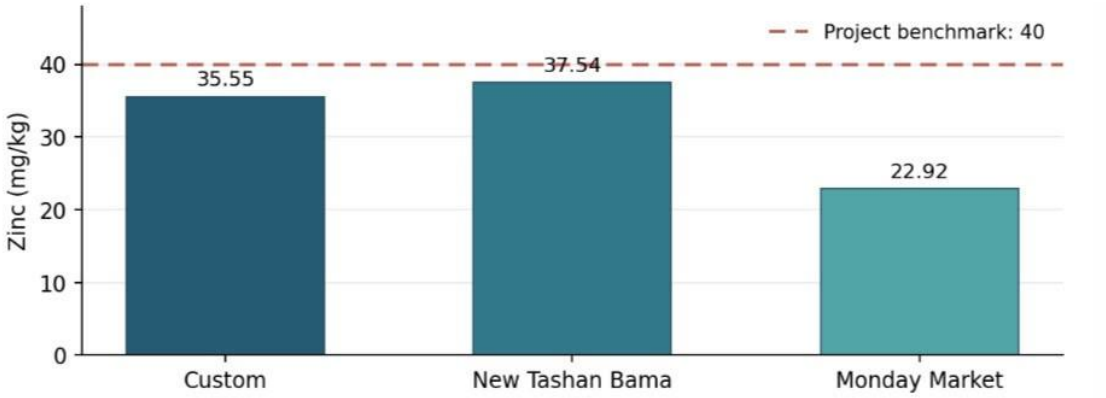


Fig. 3 Zinc concentrations reported for catfish from the three market locations, shown against the project-selected screening concentration of 40 mg/kg

Comparison with the project-selected screening concentrations

The reported Cd concentrations exceeded the project-selected comparison value by approximately 62.6% at Custom, 44.8% at New Tashan Bama and 1.2% at Monday Market. The corresponding concentration-to-benchmark ratios were 1.626, 1.448 and 1.012. In contrast, all reported Zn values were below the selected 40 mg/kg comparison value (Table 2). These comparisons identify Cd for further investigation but do not, by themselves, establish the magnitude of risk to consumers.

Table 2. Comparison of reported concentrations with the screening benchmarks adopted in the source project

Sampling location	Cd (mg/kg)	Cd / 0.50	Zn (mg/kg)	Zn / 40	Screening observation
Custom	0.813	1.626	35.55	0.889	Cd above benchmark
New Tashan Bama	0.724	1.448	37.54	0.939	Cd above benchmark
Monday Market	0.506	1.012	22.92	0.573	Cd above benchmark

A ratio greater than 1 indicates a concentration above the project-selected comparison value. These ratios are screening comparisons and are not substitutes for a validated dietary exposure assessment.

Scenario-based dietary intake and non-carcinogenic screening

Using the assumed fish ingestion rate of 0.0324 kg/day and adult body weight of 70 kg, the recalculated Cd EDI values were approximately 0.000376, 0.000335 and 0.000234 mg/kg body weight/day for Custom, New Tashan Bama and Monday Market, respectively. The corresponding Zn EDI values were approximately 0.01645, 0.01738 and 0.01061 mg/kg body weight/day. Using the RfD inputs described above to reproduce the source project's calculations, all single-metal THQ values and combined HI values were below 1 (Table 3).

Table 3. Estimated daily intake and hazard indices under the stated hypothetical adult exposure assumptions

Sampling location	Cd EDI	Cd THQ	Zn EDI	Zn THQ	HI
Custom	0.000376	0.376	0.01645	0.055	0.431
New Tashan Bama	0.000335	0.335	0.01738	0.058	0.393
Monday Market	0.000234	0.234	0.01061	0.035	0.270

EDI is expressed in mg/kg body weight/day; THQ and HI are dimensionless. Values are recalculated from the reported concentrations and stated scenario assumptions. Minor differences from the source project's original values reflect rounding or transcription inconsistencies.

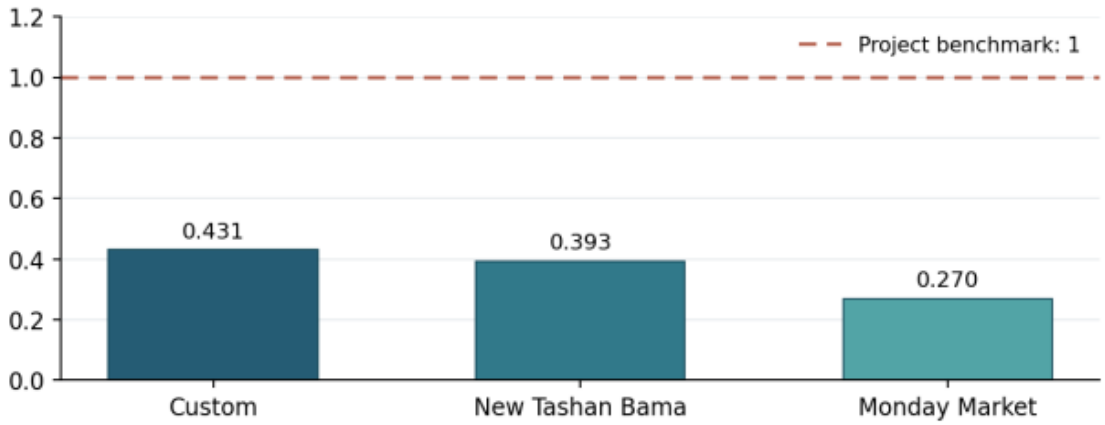


Fig. 4 Combined hazard index (HI) for Cd and Zn at each market under the modelled adult-intake scenario; the dashed line represents HI = 1

The scenario-specific HI estimates (approximately 0.431, 0.393 and 0.270) were below 1. This does not negate the concentration-screening concern because the two approaches address different questions. Concentration comparison indicates whether a reported value exceeds a selected food benchmark, whereas HI incorporates assumptions about consumption and toxicological reference doses. Health-risk interpretation is therefore sensitive to food-intake and body-weight assumptions, which require local justification [9].

Interpretation and study limitations

Cadmium was the principal screening concern in the reported catfish entries. Research on fish from polluted aquatic environments has shown that metal burdens can vary with contamination sources, environmental media and fish characteristics [8, 6]. Studies of metals in edible cattle hides from Yobe North and toxic metals in soils and crops from the Sharada industrial zone offer relevant regional evidence that food products and food-producing environments warrant monitoring; however, those studies concern different matrices and cannot be used to infer concentrations in catfish [11, 12, 15]. The Maiduguri results cannot identify the stage of the supply chain at which Cd may have entered the fish. Confirmatory investigation would require paired sampling of production water, feed, sediments, fish tissues and relevant handling environments.

All reported Zn concentrations were below the project-selected comparison value. Zinc is an essential trace element, but its significance in the diet depends on the amount consumed and the wider dietary context. The Pb non-detections cannot establish absolute absence without the method detection limit and analytical quality-control records. Similarly, the uncertainty associated with the reported concentrations cannot be quantified without independent sample and replicate results. Local evidence on fish marketing practices in Maiduguri also supports the need to consider post-harvest handling and distribution as part of a broader food-quality investigation [13].

Several limitations constrain interpretation and generalisation. First, the source project reports three location-associated concentration entries but does not clearly document the number of fish or independent subsamples represented by each entry. Second, its narrative alternates between market locations and fish-size categories; the final analytical table was used as the basis for the market-level presentation because the mapping of size categories to markets is not consistently documented. Third, the moisture basis of the reported concentrations, analytical detection limits, calibration performance and recovery data are unavailable. Fourth, the selected comparison concentrations and RfD inputs require verification against authoritative standards and toxicological sources. Finally, the consumption rate and body weight are assumptions rather than locally measured exposure parameters. Accordingly, these data do not support population-level risk estimates, child-specific exposure estimates or definitive regulatory-compliance conclusions.

Conclusion

The available analytical entries for catfish associated with Custom, New Tashan Bama and Monday Market in Maiduguri showed detectable cadmium (Cd) and zinc (Zn), while lead (Pb) was reported as not detected. Reported Cd concentrations were 0.813, 0.724 and 0.506 mg/kg, respectively, each exceeding the project-selected comparison value of 0.50 mg/kg. In contrast, reported Zn concentrations ranged from 22.92 to 37.54 mg/kg and remained below the project-selected comparison value of 40 mg/kg. These preliminary findings identify Cd as the principal element requiring confirmatory investigation.

The scenario-based adult dietary assessment produced combined hazard indices below 1 for all three market entries (0.431, 0.393 and 0.270). However, these estimates depend on assumed fish intake and body weight, as well as toxicological reference doses whose sources were not documented in the project records; they therefore do not establish that consumption is risk-free. The absence of documented sample numbers, analytical detection limits, quality-control results and wet- or dry-weight confirmation further limits interpretation. The results should consequently be regarded as preliminary market-associated screening evidence, not a definitive assessment of catfish safety across Maiduguri. Repeated sampling, validated laboratory analysis, verification of applicable food standards and investigation of potential cadmium sources along the fish supply chain are recommended.

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