Assessment of Heavy Metals in Water, Sediment and Fishes of Geidam River, Yobe State, Nigeria

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Abstract

Aquatic ecosystems face a significant environmental challenge with heavy metal pollution, which has adverse effects on human health, biodiversity, and the environment. This research examined the concentrations of heavy metals (such as Arsenic, Chromium, Cadmium, Copper, and Zinc) in both sediments and water of the Geidam River as well as two fish species (Catfish and Tilapia). The research covered the period from February to August 2020, during which five sampling stations were strategically placed based on both ecological and human impact on the river. Standard protocols were followed for field and laboratory investigations. The outcomes showed that fish contained As, Cr, Cd, Cu, and Zn in concentrations ranging from 0.000 mg/g to 0.930 mg/g; sediment concentrations ranged from 0.011 mg/g to 2.600 mg/g while water had concentrations varying between 0.04mg/L to 0.90mg/Significant variations ($P<0.05$) in Zn and Cd levels between seasons were observed specifically in the liver and gills of tilapia as well as catfish organs among others. In addition, significant findings ($p<0{\cdot}05$) included high levels of Zn and Cd detected in water samples. All heavy metals discovered exceeded USEP/FMH/WHO standards implying a pressing need for an ecosystem-based approach towards managing rivers aimed at reducing aquatic pollution thereby mitigating risks posed by consumption of contaminated aquatic resources containing toxic heavy metals.

Keywords: *Aquatic resources, Heavy metal, River, Sediment, Fish, pollution*

Introduction

The pollution of aquatic ecosystems by heavy metals is a significant environmental concern. Heavy metals persist in the environment, leading to pollution as they are deposited, assimilated, or taken up by water, sediments, and aquatic organisms. The transfer of pollutants from one trophic level to another is explained through the bioaccumulation of heavy metals in living organisms and biomagnification. Fish species are frequently used as bio-indicators of heavy metal contamination. According to Farkas et al., (2000) the presence of heavy metals in fish organs indicates environmental pollution. The chemical pollution caused by inorganic substances poses a serious threat to aquatic life, particularly fish species. Inorganic anions and heavy metals are introduced into water bodies and sediment through agricultural drainage water, which carries pesticides, fertilizers, industrial runoff, and sewage effluents. The accumulation of heavy metals in fish can have detrimental effects on their growth, physiology, and overall meat quality.The bioaccumulation of heavy metals poses a threat to human health, impacting blood cell production and causing issues with the liver, kidneys, circulatory system, and nerve signal transmission. Additionally, various types of cancer may be influenced by these toxic substances. Therefore, it is crucial to monitor and assess the levels of heavy metal pollution in aquatic ecosystems, particularly through the examination of fish species (Eroğlu et al., 2017).

In order to determine the significance of pollution in the aquatic environment, it is necessary to assess the water quality and potential ecological risk of heavy metals in the Geidam River (Kong et al., 2018) In aquatic ecosystem, heavy metals have received considerable attention due to their toxicity and accumulation in biota and fishes (Rahman et al., 2017). The presence of heavy metals in aquatic ecosystems, such as the Geidam River, has become a cause for concern due to their toxicity and ability to accumulate in fish and other biota . Heavy metals pollution in the Geidam River is a growing concern due to their potential toxicity and ability to accumulate in aquatic organisms, including fish. In order to fully understand and address the potential risks of heavy metal pollution in the Geidam River, it is important to consider the sources and factors contributing to the contamination, as well as the potential ecological and health impacts. To address the potential risks of heavy metal pollution in the Geidam , it is crucial to assess the water quality and ecological risk associated with the presence of heavy metals in the water and its impact on aquatic Therefore, the purpose of this study is to evaluate the bioaccumulation of heavy metals (Zn, Cd, Cu, and Pb) in various fish species from the Geidam River in Yobe State and to ascertain whether their levels (if any are present) are beyond the WHO-recommended limit.

MATERIALS AND METHODS

Study Area/Sites

The study was conducted in Geidam river, located in Geidam town, Geidam Local Government area of Yobe State, about 175 Km from the state capital. The river lies between longitude 8^0 31' to 8^0 45' E and latitude 20^0 13' to 12^0 10' N. It was impounded from the two major tributaries, River Yobe and River kamadugu. During a field reconnaissance, five sampling sites were identified from the river. Sampling was carried out once a month for six month in all the sampling sites in the river . The sampling sites are pointA1-A5

Collection and Preservation of Water sample

Water sampling was done according to the procedure described by Ndimele and Kumolu-Johnson (2012). Water samples from all five (5) sampling sites were collected at a depth of about 0.3m below water surface into 500 ml plastic bottles. Prior to sampling, the bottles were cleaned with 10% nitric acid and rinsed with distilled water. The bottles were rinsed three times with the dam water at the time of sampling. Samples were then collected by direct immersion of the sampling bottle into the reservoir. Immediately after sample collection, 2 ml nitric acid (AR grade) was added to the water samples. Sample bottles were then labeled to indicate date of sampling and the sampling site. Samples were transported in an ice-box to the laboratory and stored at 4^oC awaiting analysis.

Collection and Preparation of Sediment Sample

Sediment samples were taken from the bottom of the water using an Eckman grab as described by Osman and Kloas (2010). For each sample, three sediments grabs were randomly taken, and kept in clean polyethylene bags. The polythene bags were then labeled to indicate sampling station and date of sampling. Samples were then stored in ice box for transportation to the laboratory. In the laboratory, the samples were allowed to dry in hot air oven (model 30CG lab oven) and then ground into powder by using porcelain mortar and pestle, further more sieved through a 2mm mesh sieved to removed large particles and stored at – 20^0C until they were processed for heavy metal analysis.

Collection and Preparation of Fish Samples

Tilapia *Oreochromis niloticus* and African Cat fish *Clarias gariepinus* , were obtained from local fisher men at all five sampling sites. A total of 157 Tilapia and 165 Common Cat fish samples were caught during the study period. Fish samples obtained were immediately kept in pre-cleaned polythene bags, sealed, labeled and kept in ice boxes for transportation to the Biological Science Laboratory, Bayero University Kano. The samples were dissected into gills, liver and muscles followed by oven dry at 105^oC for 24 hour and then powdered using motor and pestle.

Digestion of Water Samples for Metal Analysis

Digestion of the water samples were done in triplicates using concentrated nitric acid (Analytical Grade) according to method described by Zhang (2007). Concentrated acid (5 ml) was added to 50 ml of sample water in a 100 ml beaker, and then heated on a hot plate to boil until its volume reduced to 20 ml. Another 5ml of concentrated HNO_3 was added and then heated for 10 minutes and allowed to cool. About 5 ml of nitric acid was used to rinse the sides of the beaker and the solution filtered using Whatman 0.42μm filter paper into a 50 ml volumetric flask and topped up to the mark with distilled water. A blank solution was similarly prepared. Heavy metal analysis was done using Varian Atomic Absorption Spectrometer (model 210GP).

Processing and Digestion of Fish and Sediments Sample for Metal Analysis

Fish Tissue and sediment samples were digested using 4G106M (CEM, Matthews, USA) microwave accelerated system. Around 100 g of an oven-dried fish sample and powdered sediment samples were weighed accurately to four decimal places in a Teflon vessel. A total of 6 ml of 65% conc. HNO_3 (AR, Sigma) and H_2O_2 was added and allowed to stand for 15 min in a fume hood for pre-digestion. Then, the Teflon vessel was connected to a microwave digester and digestion was carried out (at 75 °C for 10min then ramped at 10^oC per min to 95^oC and hold to 30 min). The digested tissue and Sediment samples were transferred to 50 mL volumetric flasks and made up to the mark with deionized water.

Determination of Heavy Metal Contents

Concentration of the Heavy metal (Cadnium Arsenic, Cromium, Copper, Lead and Zinc) present in the sample was determined using AAS (Buck scientific model 210GP) . The Machine was set up at specific wave length of each metal to be determined. Deionized water was aspirated between each analysis. Reading of each metal metal was taken and recorded by taking using the standard calibration curve.

Data Analysis

Data analysis was done using a computerized statistical program (SPSS 20.0). The data were subjected to student T-Test and one way analysis of variance (ANOVA) and significant differences accepted at $p \leq 0.05$.

RESULTS

Heavy Metals in *Clarias gariepenus* Sampled in Geidam River

Table 1 shows the average concentration of heavy metals in Clarias samples taken from the Geidam River. The fish's body parts exhibited variations in the bioaccumulation of heavy metals. The content of zinc (Zn) was found to be lowest in the flesh (36.68 ppm) and highest in the liver (113.99 ppm). Only the liver (1.68 ppm) contained cadmium (Cd), which was absent from the gills and flesh of every sample of fishes reported. The liver had a notably high concentration of copper (Cu) (145.50 ppm), although the flesh and gills had lower concentrations (0.09 ppm and 0.32 ppm, respectively). On the other hand, lead (Pb) was exclusively detected in the gills, where it had an average value of 21.45 ppm. Although there is no chromium (Cr) or arsenic (As) in any of the fish parts, the results showed that the distribution of heavy metals in the Clarias fish species was Zn > Cu > Pb > Cd, whereas the parts that were analyzed showed the following distribution of heavy metals: Flesh > Gills > Liver.

Heavy Metals in Tilapia Fish Sampled in Geidam River

Table 1 shows the average concentration of heavy metals in tilapia fish, with variations in the bioaccumulation of heavy metals seen in the fish's different organs. With a mean concentration of 69.69 ppm, zinc was found to be highest in the liver and lowest in the flesh (34.5 ppm). The fish's gills were the only organ where cadmium was detected, albeit there, at a very low concentration of 0.12 parts per million. Cu was discovered to be most concentrated (1.74 ppm) in the liver and least concentrated (0.08 ppm) in the meat. Only the liver contained trace quantities of lead, with an average concentration of 0.95 ppm. Only Cr and As were found. Using an independent sample t-test to compare the metal concentrations in fish samples from the Geidam River, it became apparent that only the concentrations of Zn and Cu, which are found in the gills and livers of tilapia and clarias, respectively, showed a significant difference ($p>0.05$).

Concentration of the Different Metals in Fish Samples

Table 2 shows the total concentration of the various metals in fish samples from the two distinct species, regardless of the body parts. The total concentration of all elements in the fish samples from Clarias and Tilapias showed no significant difference ($p>0.05$), with the corresponding p-values for zinc being 0.650, copper being 0.370, copper being 0.155, and lead being 0.356.

Seasonal Comparative Analysis of Heavy Metals Concentration in Water at Geidam River

The Geidam River's seasonal comparative study of the concentration of heavy metals is presented in Table 2, along with the allowable limits from several sample sites. Zinc concentrations in Geidam were 0.38 mg/L during the rainy season and 0.06 mg/L during the dry season. It was found that both results fell between the FMH (3 mg/L) and WHO (5 mg/L) acceptable limits. However, during the rainy season, the zinc concentration of 0.38 mg/L was higher than the USEPA's maximum allowable level of 0.12 mg/L. The concentration of cadmium in the Geidam River was similarly found to be greater in the wet season—0.05 mg/L and 0.06 mg/L, respectively—than in the dry season. Both results, however, exceeded the WHO's maximum allowable limit of 0.001 mg/L. On the other hand, copper concentrations were higher during the dry season (0.92 mg/L) than during the rainy season (0.42 mg/L), however, both values were still within FMH, USEPA, and WHO-acceptable levelsLead concentrations showed a similar trend, with zinc and cadmium concentrations being greater in the rainy season (0.08 mg/L) compared to the dry season (0.06 mg/L). However, both readings exceeded the FMH (0.01 mg/L) and WHO (0.05 mg/L) allowable limits. The study revealed that the concentration of chromium was greater during the dry season (0.08 mg/L) compared to the rainy season (0.06 mg/L). The maximum allowable limits of FMH (0.05 mg/L) and WHO (0.05 mg/L) were exceeded by both values, but they were still within the limits set by USEPA (0.1 mg/L). mpared to the dry season (0.40 mg/L), zinc levels in A1 were greater during the rainy season (0.45 mg/L). These readings fall between the FMH (3 mg/L) and WHO (5 mg/L) allowable limits, but not the USEPA (0.12 mg/L) standard. Additionally, it was shown that the content of cadmium was higher in the rainy season (0.06 mg/L) than in the dry season (0.04 mg/L). It was discovered that A1's cadmium content exceeded the WHO's maximum allowable limit of 0.001 mg/L. The concentration of copper was 0.92 mg/L during the dry season and 0.44 mg/L during the rainy season, respectively. All of these readings fell between the WHO (1 mg/L), USEPA (1.3 mg/L), and FMH acceptable limits. (1mg/L). Lead was also found to have higher concentration during the dry season (0.20 mg/L) than the rainy season (0.06 mg/L). However, both values were above the permissible limits set aside by WHO (0.05 mg/L) and FMH (0.01 mg/L). Chromium was found in abnormally high amounts in both dry and rainy season at values of 0.65 mg/L and 0.73 mg/L respectively. These values were found to be above the permissible limit of WHO (0.05 mg/L), USEPA (0.1 mg/L), and FMH (0.05 mg/l).

In A2, zinc concentration was found to be higher in rainy season (0.90 mg/L) than the dry one (0.06 mg/L). This followed similar pattern with A1. These values are within the permissible limits of WHO (5 mg/L) and FMH (3 mg/L), but not that of USEPA (0.12 mg/L). The concentration of cadmium was found to be the same during the rainy and dry seasons at a value of 0.05 mg/L. Just like in A2, the cadmium concentration in A3 was found to be above the maximum permissible limits of 0.001 mg/L set by WHO. For copper, the rainy season had a concentration higher than that of the dry season at 0.50 mg/L against 0.22 mg/L, respectively. These values were all within the permissible limits of WHO (1 mg/L), USEPA (1.3mg/L), and FMH (1mg/L). Lead was found to have higher concentration during the rainy season (0.07 mg/L) than the dry season (0.06 mg/L). However, both values were above the permissible limits set aside by WHO (0.05 mg/L) and FMH (0.01 mg/L). Chromium was found in both dry and rainy season at values of 0.05 mg/L and 0.20 mg/L, respectively. The dry season concentration value stood just on the permissible limit mark of 0.05mg/L designated by FHM and WHO. However, the rainy season value is obviously above these limits, and also above the limit put forward by the USEPA (0.1 mg/L).

Zinc concentration in A4 was 0.71 mg/L during the wet season and 0.60 mg/L during the dry season. It was found that both results fell between the FMH (3 mg/L) and WHO (5 mg/L) acceptable limits. Both amounts, however, exceeded the USEPA's maximum allowable level of 0.12 mg/L. The concentration of cadmium was the same in both dry and rainy season at 0.06 mg/L. This concentration was found to be higher than the WHO-established acceptable limit of 0.001 mg/L. The concentration of copper was 0.50 mg/L during the wet season compared to 0.45 mg/L during the dry season. All of these results, however, fell within the WHO (1 mg/L), USEPA (1.3 mg/L), and FMH (1 mg/L) permitted limits. During the wet season (0.47 mg/L) and the dry season (0.42 mg/L), lead concentrations were exceedingly high. These results were found to be significantly higher than the FMH (0.01 mg/L) and WHO (0.05 mg/L) acceptable levels. Like lead, chromium was found in abnormally high amounts in both dry and rainy season at values of 0.65 mg/L and 0.70 mg/L, respectively. These values were found to be way above the permissible limit of WHO (0.05 mg/L), USEPA (0.1 mg/L), and FMH (0.05 mg/l).

The dry season (3.32 mg/L) had a higher zinc content for the A5 site than the wet season (3.00 mg/L). The results were between the WHO's (5 mg/L) and USEPA's (0.12 mg/L) allowable limits. Both the dry and rainy seasons had levels of cadmium, 0.07 mg/L, and 0.06 mg/L, respectively. The concentration of cadmium in A5, as in all other sampling sites, was determined to be higher than the WHO's maximum allowable limit of 0.001 mg/L. The concentration of copper was 1.50 mg/L during the dry season and 1.30 mg/L during the wet season, respectively. These readings were over the WHO (1 mg/L), USEPA (1.3 mg/L), and FMH (1 mg/L) allowable limits. Lead concentrations were found to be significantly higher in the dry season (0.77 mg/L) than during the rainy season (0.72 mg/L). These results were found to be considerably greater than the FMH (0.01 mg/L) and WHO (0.05 mg/L) acceptable levels. Comparable to A3, anomalously elevated levels of chromium were observed in A5 throughout both the dry and wet seasons, with values of 0.75 mg/L and 0.76 mg/L, respectively. It was found that these values were significantly greater than the FMH (0.05 mg/l), USEPA (0.1 mg/L), and WHO (0.05 mg/L) acceptable limits.

Table 1: Bioaccumulation of Heavy Metals in *Clarias gariepinus* and *Tilapia zilli* Species of Geidam River

Heavy Metals	Body Parts	Clarias	Tilapia	p-value
Zn	Flesh	36.68±3.55	34.50±2.73	0.675^{ns}
	Liver	113.99±20.24	63.69±30.06	0.300^{ns}
	Gills	78.66±3.30	49.91±4.06	0.032*
Cd				
	Flesh	0.00±0.00	0.00±0.00	-
	Liver	1.68±1.68	0.00±0.00	0.423^{ns}
	Gills	0.00±0.00	0.12±0.00	0.423^{ns}
Cu				
	Flesh	0.09±0.00	0.08±0.00	0.941ns
	Liver	145.50±5.50	1.74±0.00	0.001*
	Gills	0.00±0.00	0.45±0.00	0.138ns
Pb				
	Flesh	0.00±0.00	0.00±0.00	-
	Liver	0.00±0.00	0.95±0.00	0.423^{ns}
	Gills	21.45±21.45	0.00±0.00	0.423^{ns}
Cr	Flesh	0.00±0.00	0.00±0.00	-

	Liver	0.00±0.00	0.00±0.00	-
	Gills	0.00±0.00	0.041±0.03	0.42^{ns}
As	Flesh	0.00±0.00	0.00±0.00	-
	Liver	0.00±0.00	0.00±0.00	-
	Gills	0.00±0.00	0.003±0.002	0.42^{ns}

Values are Mean ± SD, ns= not significantly different, * significantly different ($p<0.05$) using independent sample t-test

Table 2: Seasonal Comparative Analysis of Mean Heavy Metals Concentration in Water of Geidam River with the Permissible Limits

Sampling Sites	Season	Zn (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Cr (mg/L)	As (mg/L)
A1	Dry	0.06±0.01	0.05±0.02	0.92±0.53	0.06±0.01	0.08±0.02	0.00
	Rainy	0.38±0.0.1	0.06±0.03	0.42±0.01	0.08±0.03	0.06±0.02	0.00
A2	Dry	0.40±0.02	0.04±0.01	0.92±0.20	0.20±0.02	0.65±0.03	0.00
	Rainy	0.45±0.10	0.06±0.02	0.44±0.00	0.06±0.01	0.73±0.02	0.00
A3	Dry	0.06±0.02	0.05±0.02	0.22±0.02	0.06±0.01	0.05±0.02	0.00
	Rainy	0.90±0.02	0.05±0.01	0.50±0.20	0.07±0.01	0.20±0.01	0.00
A4	Dry	0.60±0.11	0.06±0.02	0.45±0.02	0.47±0.10	0.65±0.03	0.00
	Rainy	0.71±0.03	0.06±0.01	0.50±0.03	0.42±0.02	0.70±0.01	0.00
A5	Dry	3.32±0.60	0.07±0.03	1.50±0.01	0.72±0.03	0.75±0.03	0.00
	Rainy	3.00±0.04	0.06±0.01	1.30±0.01	0.77±0.01	0.76±0.02	0.00
FMH (2007)		3.0	-	1.0	0.01	0.05	-
USEPA (2003)		0.12	-	1.3	0.00	0.1	-
WHO (1993, 2003, 2005)		5.0	0.001	1.0	0.05	0.05	-

Key:

FMH: Federal Ministry of Health

USEPA: United States Environmental Protection Agency

WHO: World Health Organization

Table 3: Comparative Analysis of Heavy Metals Concentration in Sediments of Geidam River with the Permissible Limits

Sampling Sites	Heavy Metals (mg/kg)	Mean± STD	ASV	TRV	USEPA	WHO	WRS
A1	Zn	13.26±6.75	95	110	0.12	3.0	350
	Cd	0.22±0.07	0.30	0.60	-	0.003	-
	Cu	5.85±3.00	45	16	1.3		100
	Pb	14.55±4.33	20	31	0.00		-
	Cr	60.00±5.30	90	26	0.1	0.01	100
	As	1.07±0.40	-	-	-		-
A2	Zn	17.60±4.50	95	110	0.12	3.0	350
	Cd	0.23±0.01	0.30	0.60	-	0.003	-
	Cu	2.80±0.70	45	16	1.3		100
	Pb	12.55±4.40	20	31	0.00		-
	Cr	80.70±7.55	90	26	0.1	0.01	100
	As	0.03±0.00	-	-	-		-
A3	Zn	16.22±6.50	95	110	0.12	3.0	350
	Cd	0.20±0.01	0.30	0.60	-	0.003	-
	Cu	4.56±2.55	45	16	1.3		100
	Pb	14.25±5.12	20	31	0.00		-
	Cr	89.23±9.55	90	26	0.1	0.01	100
	As	0.00	-	-	-		-
A4	Zn	14.30±5.70	95	110	0.12	3.0	350
	Cd	0.25±0.10	0.30	0.60	-	0.003	-
	Cu	9.44±5.11	45	16	1.3		100
	Pb	10.85±5.23	20	31	0.00		-
	Cr	59.77±11.40	90	26	0.1	0.01	100
	As	0.00	-	-	-		-
A5	Zn	19.22±6.67	95	110	0.12	3.0	350
	Cd	0.28±0.04	0.30	0.60	-	0.003	-
	Cu	12.05±5.55	45	16	1.3		100
	Pb	15.50±2.21	20	31	0.00		-

	Cr	65.44±9.55	90	26	0.1	0.01	100
	As	1.15±0.06	-	-	-		-

Key:
ASV: Average Shale Values
TRV: Toxicity Reference Values
WHO: World Health Organization
WRS: World River System
USEPA: United State Environmental Protection Agency

Discussion

One of the primary environmental problems is the contamination of aquatic habitats by heavy metals. The reason for this is because heavy metals cannot be broken down; rather, they accumulate, incorporate, or combine into water, sediments, and aquatic life, which results in heavy metal pollution (Malik et al., 2010). In this study, the heavy metal concentrations in two fish species, the water, and the sediments of the Geidam River were examined. The findings of the study revealed the presence of Zn, Ni, Cu, Mn, Pb, and Cd in fish, water, and sediment samples. This finding is consistent with Shareef's (2011) findings, which demonstrated that the order of heavy metal bioaccumulation is Zn > Ni > Cu > Mn > Pb > Cd. Zinc showed higher levels than the other elements in the bioaccumulation of heavy metals among the fish samples that were analyzed. The distribution of heavy metals in the Geidam River was found to be as follows: Zn > Cu > Pb > Cd > Cr > As. The majority of the heavy metals (Zn, Ni, Cu, Mn, Pb, and Cd) that were the subject of this investigation had concentrations that were below the World Health Organization's (WHO) maximum allowable level. Among these are: The liver of the fish species was found to have a high zinc and cadmium concentration that exceeded the WHO guideline. The lead levels in the fish gills from the River Geidam were likewise over the WHO maximum permitted limit (1990, 1994). These heavy metals that contaminate the water body may be caused by agricultural runoffs from the area's all-year farming system, which may be a contributing factor to the seasonal variance (rainy season more than dry season) in heavy metals (Heath and Claassen 1999).

So also, the fish, water and sediment sample responded by indicating the presence of those metals that may be present in pesticides and herbicieds (Heath and Claassen 1999). The result of this study therefore, unveils the adverse health effects of the people in the study area where They could be exposed to these metals by eating fish portions that have been shown to have high amounts of heavy metals (Koller et al., 2004). The results of water and sediment samples from the Geidam River revealed an overall higher concentration of each of the heavy metals examined. This concentration is most likely due to the large volumes of urban garbage it receives from the two rivers, as well as the fish's ravenous feeding habits.

Conclusion

Finally, the two fish observed in the Giedam River had Zn, Ni, Cu, Mn, Pb, and Cd in their gills, liver, and tissue. Similarly, the river's water and sediment. The seasonal concentrations of these heavy metals varied, and they were above the WHO/FMOH/USEPA permitted levels.

Recommendations

1. In view of the importance of fish to diet of Man, it is necessary that regular biological monitoring of the water bodies and fish meant for consumption should be done. Regular monitoring of metallic content of edible materials in

the environment such as fish is very important in order to ensure the safety of consumers.

2. Similarly, studies may be performed to check contamination with other toxic heavy metals such as mercury and cobalt in fish, water and sediment from these water bodies to ascertain their bioaccumulative indices.
3. Establishing of suitable standards for fish quality including both fresh and frozen types according to international guidelines is required.

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