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Original Research Article

Evaluation of Some Selected Heavy Metals Concentration in Five Fish Species, Water, and Sediment Samples Obtained in Argungu River and Two Surrounding Lakes

Siddiku Umar Gwadangaji[1]*, Maliki Sani[1], Naziru Salisu[2], Sarajo Bala Dandare[1]

[1]Department of Science Technology, Chemistry Unit, Waziri Umaru Federal Polytechnic, Birnin Kebbi, Kebbi State, Nigeria
[2]Department of Biological Sciences, Federal University Birnin Kebbi, Kebbi State, Nigeria

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***Corresponding author:** Siddiku Umar Gwadangaji
Department of Science Technology, Chemistry Unit, Waziri Umaru Federal Polytechnic, Birnin Kebbi, Kebbi State, Nigeria

Abstract

This study was conducted to investigate the concentration level of heavy metals in the water, sediment, and five fish species of the Argungu River and two surrounding lakes in Kebbi State, Nigeria. This was carried out using an atomic absorption spectrophotometer. The metal with the highest mean concentration in all fish species is Fe, followed by Cu, Pb, Cd, and Cr. The mean concentration of metals determined in the water samples ranged from 0.01 ± 0.00 mg/L to 52.52 ± 0.09 mg/L, and for sediment samples, it ranged from 0.25 ± 0.00 mg/kg to 97.70 ± 0.53 mg/kg. Hyperopisus bebe has the highest concentration of all the heavy metals analyzed. The metal concentrations in the fish samples were ranked in the following sequence: Malapterurus electricus > Alestes baremose > Clarias gariepinus > Hydrocunus brevis > Tilapia zilli. The overall concentrations of heavy metals detected in the fish, water, and sediment samples were in the following order: Fe > Pb > Cu > Cd > Cr. Fe and Pb accounted for over 90% of all the metals studied. A one-way analysis of variance (ANOVA) was employed to reveal significant differences in the measured variables. Concentrations are often lower in water, followed by sediment and fish. The results obtained indicated that the heavy metal concentrations in the fish, sediment, and water were found to be above the permissible limits set by the World Health Organization. Thus, the study revealed that there is significantly high heavy metal pollution in these fish species sampled from Argungu River and the surrounding lakes, and the consumption of the available fish species in the river may cause harmful effects to human beings.

Keywords: Heavy Metals, Sediments, *Malapterurus electricus*, Argungu river and Atomic Absorption Spectrophotometer.

INTRODUCTION

Sediment, water, and aquatic biota species are the three main sources of heavy metals in the aquatic environment. (Ogiesoba-Eguakun *et al.*, 2025). The discard of waste dump site, sludge, acid deposition, municipal sewage, Agricultural activities and other human activities have harmful effects on the water, soils and aquatic environments in many developing countries, including Nigeria. Airborne deposition in trash, surface water, erosion into ground or surface water from the ground, and human activities like industrial processes, farming (using fertilizer and agrochemicals), and mining are some of the ways that heavy metals can enter water. They can also dissolve as water passes through subterranean mineral deposits (Bello *et al.*, 2025); (Osesua *et al.*, 2019) (Nasir *et al.*, 2021);(Pelić *et al.*, 2024). Pollution is the introduction of contaminants into the atmosphere leading to a reduction in the quality of the environment. Municipal sewage, Industrial activities, domestic waste, dust, and smoke air, can get into land and sea. In a similar vein, contaminants such as heavy metals, fertilizers, fungicides, pesticides, and car emissions are released into water bodies, where they either directly or indirectly find their way into our food (Elekima *et al.*, 2020). The toxicity, durability, and abundance of heavy metal pollution in the aquatic ecosystem have drawn attention from all around the world (Otene & Iorchor, 2019).

It is through the water-atmosphere contact that the harmful metals are carried. Aquatic ecosystems are contaminated by heavy metals due to anthropogenic activity and geochemical processes. Heavy metals are elements that are extremely poisonous and have a high density. Mercury, zinc, cadmium, copper, arsenic, lead, iron, and chromium are a few examples of heavy metals. They are poisonous when they surpass threshold levels, have a higher density, and are often more than 5.00 g/cm³ (Bello *et al*., 2025); (OSEJI & EDEMA, 2019); (Ohaturuonye *et al*., 2024). Heavy metals are regarded as naturally occurring trace elements in the aquatic environment. For fish to have a regular metabolism, some metals must be absorbed in trace levels from food, water, or sediment. For instance, all aquatic species use copper, iron, and zinc in their metabolic processes (Shaker *et al*., 2018).

Heavy metal contamination of aquatic environments is a global ecological issue. In developing nations, the poisoning of water and sediments by heavy metals has grown to be a significant concern (Akpobi *et al*., 2025). Mercury (Hg), cadmium (Cd), arsenic (As), and lead (Pb) are examples of heavy metals that are non-biodegradable and have a tendency to build up in sediments, water bodies, and fish species (Akpobi *et al*., 2025); (Pelić *et al*., 2024). The systematic form of these metals can be discovered in the earth's strata, and they have the ecological permanence, bioaccumulation, and inability to break down or degrade (Osesua *et al*., 2019). There are different ways they could get into the environment and aquatic system: through the air, through drinking water, or through other produced goods and chemicals. They can be administered by ingestion, inhalation, and cutaneous absorption. They damage the quality of the human health and aquatic environment. These toxic metals enter the biosphere through human activities, which include agricultural activities, burning of fusel fuel, sewage, mining, transportation, and industrial production (Bello *et al*., 2025).

Water in coastal areas, estuaries, rivers, and lakes, can be utilized as an indicator of metal pollution, according to numerous researchers (Vajargah, 2021); (Mustapha *et al*., 2021); (Musa *et al*., 2025); (Afzaal *et al*., 2022). Some primary sources of metal pollution are burning fossil fuel, Municipal sewage, metals smelting from the municipality, and agricultural activities involving the use of fertilizers, and pesticides are other sources of pollution, as these products often contain metals such as Cupper, Iron and cadmium (Ibrahim *et al*., 2024); (Akpobi *et al*., 2025);(Pelić *et al*., 2024)). Heavy metal toxicity lowers vitality, interferes with brain function, and affects the kidney, liver, brain, lungs, and blood composition, among other organs. (Bello *et al*., 2025) (Izuchukwu Ujah *et al*., 2017).

In addition to accumulating pollutants, sediments may serve as the ecosystem's long-term metal storage facilities (Zanna *et al*., 2021). Sediments are fundamental for assessing the quality of aquatic systems. This is due to the fact that since the start of civilization, major cultural developments have always been focused on natural freshwater lakes. Rich mineral resources are originated in sediments, which also function as a repository for information about human influence on the marine ecosystem, particularly the effects of intense biological and chemical activity near the sediment-water interface. Sediment is essential for the aquatic ecosystem because it can trap heavy metals (DAVIES & and EKPERUSI, 2021); (Mustapha *et al*., 2021) (Afzaal *et al*., 2022). In aquatic environment, sediment has been employed by many researchers to detect metal contamination (DAVIES & and EKPERUSI, 2021); (Afzaal *et al*., 2022). The disposal of agricultural inputs, untreated wastewater from various enterprises and municipal trash into water bodies in Rima River of Argungu town has resulted in a concerning situation. Keeping these negative impacts in mind over the last decade, several types of research have been carried out in lakes, estuaries, rivers and marine water, emphasizing the aquatic environment (Alam *et al*., 2025). The purpose of this study is to assess the levels of the heavy metals Cd, Fe, Cu, Pd, and Cr in fish, water, and sediment in the Argungu River and two nearby lakes in Kebbi State, Nigeria.

MATERIALS AND METHODS

Description of Study area

The Argungu Rima River, Argungu Local Government Area, Kebbi State, Nigeria, is where this study was carried out (Figure 1). Argungu, which covers an area of roughly 428 km^2 and rises to a height of 241 m above sea level, is situated in the far north-western region of Nigeria. The coordinates of study area in Argungu: Upstream site (12^0 45'17.32"N 4^0 31'35.93"E), Downstream Site (12^0 44'48.31"N 4^0 31'11.94"E), Lungu Lake Site (12^0 45'6.05"N 4^0 31'14.06"E), and Laka Lake Site (12^0 45'1.87"N 4^0 31'9.51"E). The town is encircled in Sokoto State by the Yabo Local Government Area to the east, the Birnin Kebbi Local Government Area to the south, and the Arewa and Augie Local Government Areas to the west and north. Argungu experiences 800 mm of rain on average each year, with an average temperature of 26°C. The weather is tropical, with extended dry seasons and brief wet seasons that alternate. The predominant vegetation is grass, shrubs, and sparse trees. Before it merges with the River Rima in Sokoto, the River Argungu originates in Funtua,Katsina State, and travels through Gusau, Zamfara State, and Sokoto, Sokoto State. It flows from Sokoto to Birnin Kebbi, where it joins the Niger River, via Argungu. In addition to serving as the primary supply of drinking water in Argungu town, the river is used for leisure pursuits, including fishing and an annual international fishing festival. The quality of Argungu river water is under risk due to intensive farming and the disposal of waste in and around the river.

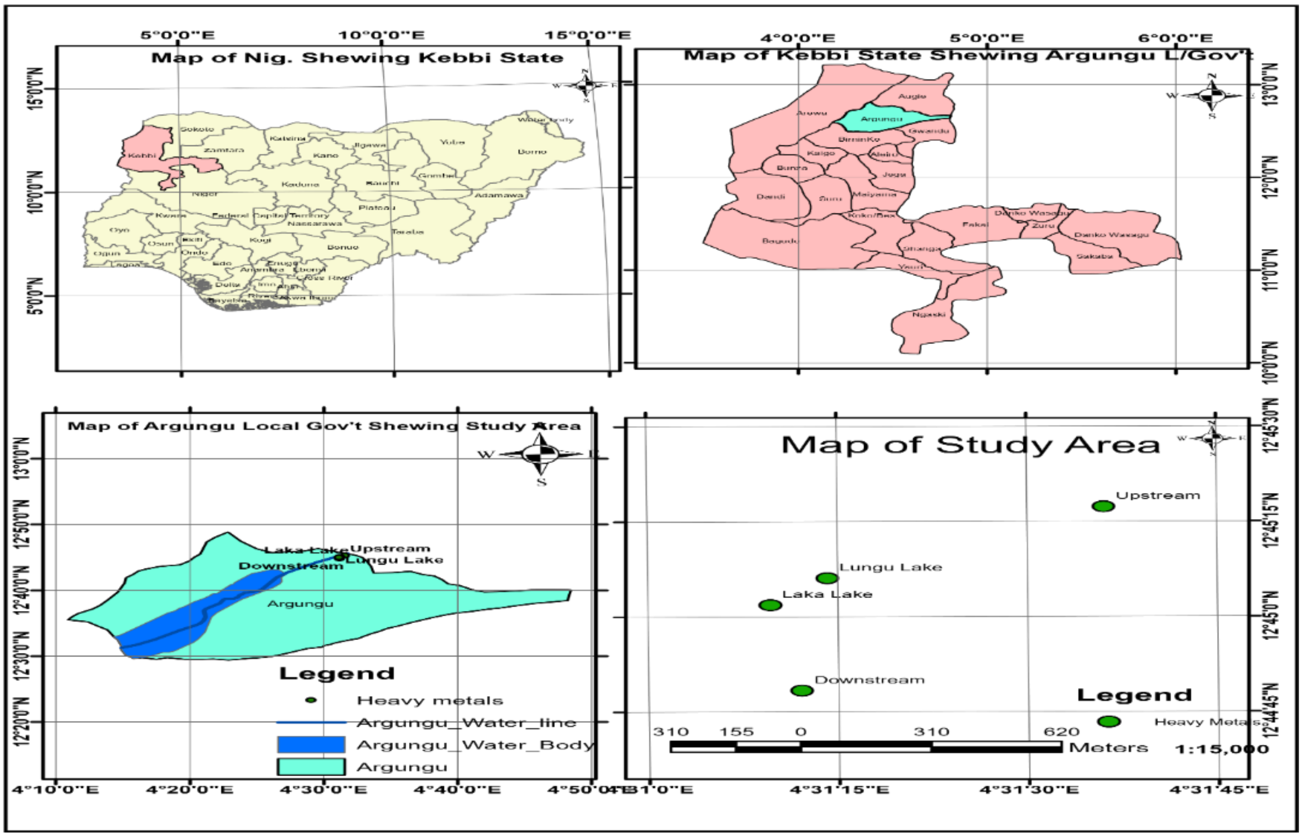

Figure 1: Map showing the study areas

Collection of fish, water and sediment samples

The methodology developed by Umar *et al.,* (2024) was used. At the landing site, 135 fish of uniform size (5 fish samples from each site) were gathered from Argungu after the fishermen used fishing nets to capture them. *Malapterurus electricus, Alestes baremose, Hydrocunus brevis, Clarias gariepinus,* and *Oreochromis niloticus* are the fish samples that were taken into consideration. After the fishermen used fishing nets to catch the fish, five samples of each species were purchased at the landing location once a month for three months. To separate the muscles of each species, the fish samples were collected, cleaned with distilled water, and then dissected on-site. Each separate muscle part was put into a separate pre-cleaned polyethene bag and transported to the Usmanu Danfodiyo University Sokoto Old Chemistry laboratory for drying in readiness for digestion process.

The sampling was conducted according to the method reported by (Engdaw *et al*., 2022). Over the course of three months, nine water samples were taken once a month. At each sampling location (upstream, downstream, Lungu Lake, and Laka Lake), duplicate water samples were taken along the river's breadth, 10–20 cm below the surface. One composite sample per point was created by homogenizing duplicate water samples in a single container. Composite water samples were collected in pre-cleaned plastic bottles (using 10% H_2SO_4, rinsed with HNO_3 and distilled water) and preserved by adding 5 cm³ of concentrated nitric acid (HNO_3) to it. The samples were filtered through a 0.47 m glass microfiber filter (GFF) using a 300 cm³ vacuum hand filter. Prior to being transported to the Usmanu Danfodiyo University Sokoto Old Chemistry laboratory for additional analysis, the filtered water samples were stored in a cool box.

With a stainless-steel trowel, nine fine sediment samples weighing roughly 300 g each were taken from four sampling locations for sediment heavy metal analysis. At a depth of one meter, three duplicates were collected from the same sampling location (upstream, downstream, Lungu Lake, and Laka Lake). Plastics, large stones, plants, and other large contaminants were separated. After being collected, all of the sediment samples were promptly wrapped in plastic bags and kept in a refrigerated box until they arrived to the Usmanu Danfodiyo University Sokoto Old Chemistry lab for additional analysis.

Preparation of aqua regia solution

The method by (Ejike & Liman, 2017) was adopted. Aqua Regia solution, HCl-HNO_3 (3:1) was prepared by adding 25 cm^3 of Concentrated HCl to 75cm^3 of Concentrated HNO_3.

Preparation/digestion of fish sample

The fish samples were prepared using the method adopted by (Umar *et al*., 2024). The fish sample's muscles that were required for examination were separated and oven-dried for 48 hours at 80°C. Using a clean mortar and pestle, these samples were ground into a powder. 20 cm^3 of the aqua regia solution was added to each beaker containing one gram of the homogenized fish portion (muscles), which was then digested using a hot plate set at 80°C to produce a clear, colorless solution. After cooling, the digests were passed through Whatmann No. 1 filter paper. After the filter was moved into a 100 cm^3 volumetric flask, distilled water was added to make it up to the mark. In preparation for analysis using an Atomic Adsorption Spectrophotometer (AAS), the prepared sample solution was moved into the previously cleaned and labeled sample bottles. For AAS analysis, all of the digested samples were transported to Usmanu Danfodiyo University's Centre for Advance Science Research and Analytical Science in Sokoto.

Digestion of water samples

Before adding 5 cm^3 of strong hydrochloric acid, 100 cm^3 of the water sample was measured using a measuring cylinder. After that, the solution was moved into a conical flask and heated to 25 cm^3 for two hours at 105°C on the hot plate. Following its transfer to a 100 cm^3 volumetric flask, it was filtered and placed in a previously cleaned sample bottle before being transported to the Center for Advance Science Research and Analytical Science at Usmanu Danfodiyo University in Sokoto for AAS analysis.

Digestion of sediment samples

The sediment samples were crushed into smaller pieces and allowed to air dry for three days before being sieved and going through the digestion process. After weighing and pouring 2 g of the sediment sample into a beaker, 5 cm^3 of hydrogen trioxonitrate (v) acid (HNO_3), 2 cm^3 of perchloric acid ($HClO_4$), and 5 cm^3 of hydrogen fluoride (HF) were added. The mixture was then heated for one hour at 160°C on a heater. Following adequate digestion, the material was cooled before being filtered. After the filter was moved into a 100 cm^3 volumetric flask, distilled water was added to make it up to the mark. For AAS analysis, the prepared sample solutions were placed in the previously cleaned, labeled sample bottles and transported to Usmanu Danfodiyo University's Centre for Advance Science Research and Analytical Science in Sokoto.

Preparation of blank solution

All of the reagents were combined in a 50 ml volumetric flask to create the blank solution, which was then diluted with deionized water to the appropriate level.

Heavy metals determination

The digested samples were taken to the Centre for Advance Science Research and Analytical Science, Usmanu Danfodiyo University, Sokoto for AAS analysis, for AAS determination of heavy metals are: Cd, Fe, Cu, Pd, and Cr.

Statistical analysis

Descriptive Statistics: Mean, and standard deviation of heavy metal concentrations were calculated for fish muscles, water, and sediment samples.

Analysis of Variance (ANOVA): ANOVA and $P < 0.05$ was used to identify significant differences in heavy metal concentrations between fish species, water, sediment and sampling locations. All with Minitab software application.

RESULTS AND DISCUSSION

Table 1.0: Mean Concentration of Heavy Metals in Fish Samples with FAO/WHO/FEPA Standard Limit in mg/kg

Heavy Metals	Months	Locations	*Malapterurus electricus*	*Alestes baremose*	*Hydrocunus brevis*	*Clarias gariepinus*	*Tilapia zilli*	FAO/WHO/FEPA Standard (mg/kg)
Cd	December	River Site	0.72±0.13	0.33±0.00	1.08±0.00	2.00±0.00	1.25±0.00	**0.01**
	January	Lungu Lake	0.75±0.00	0.33±0.00	1.25±0.00	2.00±0.00	1.25±0.00	
	February	Laka Lake	0.03±0.00	0.25±0.00	0.67±0.00	2.00±0.00	1.25±0.00	
Fe	December	River Site	28.79±0.06	30.25±0.15	23.98±0.11	26.5±0.36	22.68±0.27	**0.3**
	January	Lungu Lake	11.96±0.07	24.92±0.12	18.39±0.15	21.20±0.29	23.28±0.31	
	February	Laka Lake	31.95±0.12	16.42±0.08	12.80±0.06	13.92±0.18	14.11±0.19	
Cu	December	River Site	2.81±0.00	3.70±0.00	2.50±0.00	3.75±0.00	2.92±0.00	**2.25**
	January	Lungu Lake	2.17±0.00	2.92±0.00	2.00±0.00	2.92±0.00	2.56±0.05	
	February	Laka Lake	1.83±0.00	1.92±0.00	1.42±0.00	1.92±0.00	1.50±0.00	
Pb	December	River Site	5.94±0.00	2.78±0.00	2.86±0.05	3.44±0.00	2.86±0.00	**0.01**
	January	Lungu Lake	4.39±0.00	1.67±0.00	2.31±0.00	2.75±0.00	2.36±0.00	
	February	Laka Lake	3.33±0.00	1.44±0.01	1.50±0.00	1.81±0.00	0.92±0.00	
Cr	December	River Site	0.92±0.00	1.08±0.00	0.58±0.00	1.00±0.00	1.00±0.00	**0.5**
	January	Lungu Lake	0.75±0.00	0.92±0.00	0.67±0.00	0.86±0.00	0.92±0.00	
	February	Laka Lake	1.75±0.00	0.55±0.09	0.47±0.00	0.58±0.00	0.53±0.05	

Note: FAO/WHO/FEPA= Food and Agriculture Organization/ World health organization/ Federal Environmental Protection Agency (Membere & Abdulwasiu, 2020)

Discussion

Heavy metals Concentration in species of fish

The concentration of heavy metals in the muscles of fish species obtained from three (3) distinct locations within the Argungu River water system is displayed in Table 1.0. Cadmium is a recognized carcinogen that harms the kidneys and lungs, particularly associated with intestine and lung cancers. Low fetal weight, behavioral and learning abnormalities, and skeletal deformity in pregnant animals are all linked to cadmium. Additionally, studies indicate that cadmium is the cause of low birth weight and low sperm count (Bello *et al*., 2025). Cadmium was significantly above the permissible limit meaning there is a danger of cadmium contamination in the species of fish. This suggests that vital humans' organs may end up being damaged if Cd is allowed to bio accumulate.

Clarias gariepinus had the highest concentrations of Cd (2.00±0.0 mg/kg) across all sites during the study period, but they were significantly higher than the findings of Jim-Halliday *et al.,*(2024), who examined the levels of heavy metals in *Clarias gariepinus* collected from earthen ponds in Port Harcourt, Rivers State, Nigeria, and *Malapterurus electricus* at Laka Lake in February, which had the lowest concentration (0.03±0.00 mg/kg). Ibemenuga *et al.,* (2019), who investigated the bioaccumulation of several heavy metals in certain organs of three commercially relevant fish from the Niger River, Onitsha Shelf, Anambra State, Nigeria, found that the results were substantially greater than those of their study. Their findings were further supported by the Cd concentration in the fish species *Malapterurus electricus*, which had a mean value of 0.032 ± 0.02 mg/kg. All fish species had Cd levels over the study period, and the results of the analysis of variance (ANOVA) revealed a significant difference ($p<0.05$) across locations and months ($P = 0.000$). With mean concentrations of 31.95±0.12 mg/kg and 11.96±0.07 mg/kg, respectively, the muscles of *Malapterurus electricus* fish obtained from Laka Lake in February had the highest concentration of iron, while those from Lungu Lake in January had the lowest. Furthermore, the average Fe content in *Malapterurus electricus*, as reported by OSEJI & EDEMA (2019), was 1.348±0.233, which was much lower than the current investigations. Fe is an essential element that is present in almost all living things and is regarded as the boundary between macro and microelements. Heme-prosthetic groups, which are frequently found in iron-containing proteins and enzymes, aid in a variety of biological oxidations and transport processes. It was discovered that the Fe content of every fish sample exceeded the WHO maximum allowable limit of 0.3 mg/kg. Despite being a crucial dietary component needed by hemoglobin, a high concentration of iron damages the liver, heart, pancreas, and spleen (Bello *et al*., 2025).With mean values of 2.00 - 93.13 mg/kg and 16.88 - 41.88 mg/kg for *Tilapia zilli and Clarias gariepinus*, respectively, the Fe concentration was within the range of those reported for the muscles of these fish species by Adebesi *et al.,*(2022), who examined three fish species (*Tilapia zilli, Synodontis nigrita, and Clarias gariepinus*) from Tagwai dam. Ejike and Liman (2017), however, found that the muscular parts of *Oreochromis niloticus and Clarias gariepinus* were equivalent to the new findings. The results of the analysis of variance (ANOVA) revealed that the Fe level in all fish species during the study period did not differ significantly ($p>0.05$) between locations and months ($P = 0.825$). Copper is required for the formation of hemoglobin and is a crucial component of many enzymes. Fish absorb copper toxicity directly from the water through their gills. The continuous use of insecticides, pesticides, fungicides, algaecides, nematocides, molluscicides, and waste discharges containing copper as an active ingredient are the main causes of copper pollution. At levels above the globally permissible limits, the copper content of these chemical compounds is extremely harmful to aquatic creatures' internal processes. The fish's gills easily absorb copper, which is then easily deposited in the liver. Even at low atmospheric temperatures, this buildup is most likely the result of nutrition or environmental exposure. Common side effects include renal changes and a lot of mucus on the outside of the body, under the gill coverings, and between the gills. With mean values of 3.75±0.00 mg/kg and 3.70±0.00 mg/kg in December, *Clarias gariepinus and Alestes baremose* from the river site had the highest Cu concentration, while Laka Lake had the lowest in February, with a mean value of 1.42±0.00 mg/kg from the research site. The results of the study on the Proximate, Mineral, and Heavy Metal Compositions of Some Freshwater Fishes from Erinle Dam, Ede, Osun State, Nigeria, by Adeyeye & Ayoola (2013) were substantially lower than this one, but it was still consistent with the result reported by Umar *et al.,* (2024). The results of the analysis of variance (ANOVA) revealed that the Cu level in all fish species during the study period did not differ significantly ($p>0.05$) between sites and months ($P = 0.535$). Lead (Pb) is the most important heavy metal because of its toxicity and abundance in the crust of the earth. Even trace amounts of lead can be harmful. Pb exposure has been demonstrated to impair children's physical development and reduce their IQ, making children more susceptible than adults. Lead exposure has been linked to hormonal disruption, antisocial behavior, attention deficit, an endocrine condition, and hyperactivity problem. Lead is also known to be a neurotoxic and carcinogenic material (Bello *et al*., 2025). Lead (Pb) levels in all of the examined fish samples were much higher than the WHO's maximum allowable limit, suggesting that Pb contamination might occur if left unchecked. The agricultural runoff from lead-based fertilizers and pesticides is the cause of the elevated Pb levels in the fish samples. The species that had the highest Pb concentration (5.94±0.00 mg/kg) was Malapterurus electricus, which was collected from a river site in December. The species that had the lowest Pb concentration, Tilapia zilli, which was collected from

Laka Lake in February, had a mean of 0.92±0.00 mg/kg. The muscular portion of Malapterurus electricus had the lowest Pb concentration (0.02 mg/kg), which was much lower than the results of the current investigations when compared to the results obtained by Adeyeye & Ayoola (2013). The results of the analysis of variance (ANOVA) revealed that the Pb levels in all fish species during the study period did not differ significantly (p>0.05) between sites and months (P = 0.221). The human body needs Cr as a key element for the metabolism of carbohydrates. Hexavalent Cr (Cr^{6+}), on the other hand, is regarded as hazardous due to its significant oxidative potential and capacity to pass through cell membranes (Nigam *et al*., 2014). Heavy metal toxins have the potential to cause mutagenesis and cancer. Additionally, some enzyme systems involved in the synthesis of cellular energy may be inhibited by their toxicological mode of action. The muscles of *Malapterurus electricus* fish collected from Laka Lake in February had the maximum concentration of Cr (1.75±0.00 mg/kg), whereas the *Hydrocunus brevis* fish sample had the lowest concentration (0.47±0.00 mg/kg) in the same month.

The current results were substantially lower than those of the study conducted by Obasohan *et al.,* (2017) on the heavy metal contents in *Chrysichthys nigrodigitatus and Malapterurus electricus* from the Ogba River in Benin City, Nigeria. The results of the analysis of variance (ANOVA) revealed that the Cr level in all fish species during the study period did not change significantly (p>0.05) between sites and months (P = 0.344). Similarly, the range observed by Umar *et al.,* (2024) applies to the muscle portion of *Hydrocunus brevis* of Cr concentrations. All of the fish samples taken from the research area had concentrations of Cr higher than the WHO-recommended upper limit of 0.5.

Fe and Pb made up more than 90% of all the metals examined, and the concentrations of heavy metals in the various muscle regions of the five fish species were found to be in the following order: Fe > Pb > Cu > Cd > Cr. Salam *et al.,* (2019), Akan *et al.,* (2012), and Nwude *et al.,* (2020) all found a similar finding. The concentration levels of these metals were similar to those that Nwude *et al.,* (2020) observed for these fish species' muscles. They reported 0.735-1.585 mg/kg of zinc, ND-0.392 mg/kg of lead, 19.572-125.217 mg/kg of iron, and ND-0.947 mg/kg of Cd for Lagos' Ikorodu lagoon, which is lower than the current study by OPALUWA *et al.,* (2012).

Out of all the heavy metals examined, *Malapterurus electricus* has the greatest concentration. The following order was used to grade the metal concentrations in the fish species: *Malapterurus electricus Alestes baremose* > *Clarias gariepinus* > *Hydrocunus brevis* > *Tilapia zilli*. According to data from earlier research, the amount of metal in fish fillets varied greatly according on the species, location, and level of pollution in the water body.

Fish muscle is the most palatable portion of the fish that is eaten, but it is not an active tissue in the accumulation of heavy metals, according to Taiwo *et al.,* (2019). It has also been acknowledged that certain fish in contaminated waterways may build up significant metal concentrations in their muscles, which may surpass the uppermost permissible limits. There are many scientific references available on the levels of heavy metals in fish, but not many on the many kinds of fish found in the Argungu River and a few nearby lakes. Five distinct fish species from these areas were the subject of this study.

According to table 1.0, this study found that the mean concentrations of heavy metals in the muscles of the five distinct fish species varied. Fish species vary in the bioaccumulation of heavy metals. Fish buildup of heavy metals is also associated with feeding behaviors and the habitats in which the species lodge (Taiwo *et al*., 2019).

Gender, size (body length and weight), tissue types examined, age and growth rates, and physiological conditions may also be factors contributing to the differences in heavy metal concentrations across the various fish species Nwude *et al.,* (2020). Heavy metal levels in various fish species are also influenced by differences in the water body caused by the kind and degree of pollution, water temperature, pH level, metal chemical form, concentrations, oxygen content, and transparency. Even within the same species of fish, the season and geographic location of capture may result in varying metal concentrations (Nwude *et al*., 2020).

Results

Table 2.0: Mean Concentration of Heavy Metals in Water Samples with WHO Standard Limit in mg/L

Locations	Metals	Cd	Fe	Cu	Pb	Cr
Downstream	December	0.01±0.00	31.64±0.45	0.19±0.00	0.17±0.00	0.04±0.00
	January	0.01±0.00	22.15±0.32	0.13±0.00	0.12±0.00	0.03±0.00
	February	0.01±0.00	15.82±0.23	0.09±0.00	0.08±0.00	0.02±0.00
Upstream	December	0.07±0.00	15.17±0.19	0.17±0.00	0.06±0.00	0.03±0.00
	January	0.07±0.00	10.62±0.13	0.12±0.00	0.04±0.00	0.02±0.00
	February	0.07±0.00	7.59±0.09	0.08±0.00	0.03±0.00	0.01±0.00
Laka Lake	December	0.05±0.00	52.52±0.09	0.13±0.00	0.05±0.00	0.04±0.00
	January	0.05±0.00	17.86±0.06	0.09±0.00	0.03±0.00	0.03±0.00
	February	0.05±0.00	12.76±0.04	0.06±0.00	0.02±0.00	0.02±0.00
Lungu Lake	December	0.12±0.00	19.17±0.08	0.15±0.00	0.08±0.00	0.04±0.00
	January	0.12±0.00	13.42±0.00	0.10±0.00	0.06±0.00	0.03±0.00
	February	0.12±0.00	9.59±0.04	0.07±0.00	0.04±0.00	0.02±0.00
WHO Standard (mg/L		**0.003**	**0.3**	**2.0**	**0.01**	**0.05**

Note: WHO= World health organization (Chiromawa, 2019).

Discussion

Heavy Metals Concentration in Water (mg/L)

The Cd concentration in the water samples from the four locations varied from 0.01±0.00 to 0.12±0.08 mg/L, according to the results in Table 2.0. Ohaturuonye *et al.,* (2024), who investigated the assessment of certain heavy metals in fish and water samples from Oguta Lake, Imo State, Nigeria, found that water samples from Lungu Lake had higher concentrations of Cd (0.12 ± 0.00 mg/L) than water samples from upstream (0.07 ± 0.00 mg/L). This suggests that water samples from Lungu Lake had greater levels of Cd pollution. The results of the analysis of variance (ANOVA) revealed that the levels of Cd found in water samples during the study period did not differ significantly ($p>0.05$) by location or month ($P=1.000$). Omozokpia *et al.,* (2015) observed similar findings from two fishing towns along the Kaduna River in Niger State, Nigeria (0.01 ± 0.00 to 0.03 mg/L). Yahaya *et al.,* (2021) found values of 0.774±0.001 mg/L in the Argungu River in Kebbi State, Nigeria, which is higher than the results obtained here. However, one of the study's reported results was higher than the WHO-recommended limit of 0.003 mg/L Cd for characterizing water, indicating Cd pollution.

Fe concentrations in water samples from upstream ranged from 7.59±0.09 ±0.09 to 15.17±0.19 ±0.19 mg/L, downstream water samples ranged from 15.82±0.23 to 31.64±0.45 mg/L, Laka Lake water samples ranged from 12.76±0.04 to 52.52±0.09 mg/L, and Lungu Lake water samples ranged from 9.59±0.04 to 19.17±0.08 mg/L. This suggests that, in contrast to the other sites, the concentration was higher at Laka Lake. Given that rocks have been described as excellent sources of mineral elements, the comparatively high quantities of iron may be the result of ongoing human activity and rock particles entering the lakes (Bawa *et al*., 2018). Given that each area showed a higher concentration in December and a lower concentration in February, there is a noticeable change in the distribution of Fe. The results obtained are greater than the concentrations reported by Engdaw *et al.,* (2022) in water samples from the Odo-Ayo River in Ado-Ekiti, Ekiti State, Nigeria (5.87 mg/L). However, the reported result indicated Fe pollution and was higher than the WHO-recommended limit of 0.3 mg/L Fe in drinking water. The results of the analysis of variance (ANOVA) revealed that the Fe level found in water samples during the study period did not change significantly ($p>0.05$) between sites and months ($P = 0.082$).

The water samples from Table 2.0 had a dispersion of Cu contents between 0.06 ± 0.00 and 0.19 ± 0.00 mg/L. With a minimum concentration of 0.06 ± 0.00 mg/L from the Laka Lake site in February and a high value of 0.19 ± 0.00 mg/L from the downstream, there was a noticeable range in the data. The results of

There was no significant difference at $P > 0.05$ (Table 2.0), indicating minimal Pb contamination. The lead concentrations in the water samples were 0.08 ± 0.00 to 0.17 ± 0.00 mg/L at the downstream site, 0.03 ± 0.00 to 0.06 ± 0.00 mg/L at the upstream site, 0.02 ± 0.00 to 0.05 ± 0.00 mg/L at the Laka Lake site, and 0.04 ± 0.00 to 0.08 ± 0.00 mg/L at the Lungu Lake site. When compared to the report specified by Ohaturuonye *et al.,* (2024), the greatest concentration, 0.17 ± 0.00 mg/L, was recorded at the downstream site in December. The results of the analysis of variance (ANOVA) revealed that the Pb level found in water samples during the study period did not change significantly ($p > 0.05$) between sites and months ($P = 0.323$). Membere & Abdulwasiu (2020) found values of 0.08 mg/L along the Escravos River in Delta State, Nigeria, and Edward (2013) found values of 0.17 mg/L from the Odo-Ayo River in Ado-Ekiti, Ekiti State, Nigeria. This demonstrates that environmental or anthropogenic causes can occasionally affect Pb concentration levels. According to WHO guidelines, the maximum amount of lead that can be present in drinking water is 0.05 mg/L.

the analysis of variance (ANOVA) revealed that the Cu level found in water samples during the study period varied significantly ($p<0.05$) by location and month ($P = 0.001$). The river's high concentration of heavy metals was most likely caused by surface runoff from agricultural areas that contain agronomic chemicals like fertilizers, herbicides, fungicides, and so on, as well as rock weathering (Bawa *et al*., 2018). In February, the concentration from Lungu Lake was lower at 0.07±0.00 mg/L, while the concentration from Laka Lake was higher at 0.13±0.00 mg/L. The lakes' breakup may be the cause of this disparity. In contrast to the findings found in this study, Edward (2013) found a mean value of 0.84 mg/L from the Odo-Ayo River in Ado-Ekiti, Ekiti State, Nigeria. Similarly, Öztürk *et al.,* (2009) found that the concentration of Avsar Dam Lake in Turkey was 0.01 ± 0.001 mg/L, which was lower than the current study's findings. All of the study's findings were below the WHO-recommended permitted limit of 1 mg/L, suggesting that this metal was not contaminated in the sample under investigation.

All of the samples in Table 2.0 have Cr levels that vary from 0.01 ± 0.00 to 0.04 ± 0.03 mg/L. The upstream site in February had the lowest concentration of 0.01 ± 0.00 mg/L in the water sample, whereas downstream and the Laka and Lungu Lakes had the greatest value of 0.04 ± 0.00 mg/L in December, respectively. These findings are consistent with the current investigation and were compared to the value ranges of 0.014 ± 0.001 to 0.035 ± 0.003 mg/L published by Gerenfes & Teju (2018) for water, Oreochromis niloticus, and Labeobarbus intermedius samples from Abaya and Chamo Lakes. Adebayo (2017) reported a comparable value of 0.02±0.01 mg/L from Ureje Water Reservoir, which compares favorably with the current study. However, the concentrations found in the samples did not above the WHO-recommended limit allowable value of 0.002 mg/L, suggesting that there was no pollution for Cr. The results of the analysis of variance (ANOVA) revealed that the Cr level found in water samples during the study period varied significantly ($p<0.05$) by location and month ($P = 0.001$). Low-level contamination from agrochemical-based agricultural production may be to blame for this.

Results

Table 3.0: Mean Concentration of Heavy Metals in Sediment Samples with WHO/FEPA Standard Limit in mg/kg

Locations	**Downstream**			**Upstream Matan**			**Laka Lake**			**Lungu Lake**			**WHO/FEPA Standard (mg/kg)**
Metals	December	January	February	December	January	February	December	January	February	December	January	February	
Cd	0.33±0.14	0.33±0.14	0.33±0.00	0.50±0.00	1.50±0.00	1.50±0.00	0.67±0.00	1.50±0.00	1.50±0.00	1.50±0.00	1.50±0.00	1.50±0.00	**0.68**
Fe	25.00±0.27	33.33±0.36	16.66±0.18	73.27±0.40	97.70±0.53	48.85±0.27	35.03±0.20	46.70±0.27	23.35±0.13	52.17±0.52	69.56±0.69	34.78±0.34	**500**
Cu	5.67±0.14	5.67±0.14	3.75±0.00	6.25±0.00	6.25±0.00	4.25±0.00	7.25±0.00	7.25±0.00	4.75±0.00	6.25±0.00	6.25±0.00	4.25±0.00	**0.025**
Pb	2.33±0.14	2.33±0.14	1.50±0.00	3.08±0.14	3.08±0.14	2.00±0.00	2.25±0.00	2.25±0.00	1.50±0.00	2.00±0.00	2.00±0.00	0.25±0.00	**0.5**
Cr	1.75±0.00	1.75±0.00	1.00±0.00	1.75±0.00	1.75±0.00	1.00±0.00	1.25±0.00	1.25±0.00	0.75±0.00	1.25±0.00	1.25±0.00	0.75±0.00	**0.1**

Note: WHO/FEPA= World health organization/ Federal Environmental Protection Agency (Membere & Abdulwasiu, 2020)

Discussion

Heavy Metals Concentration in Sediment

All sampling sites during the study period had Cd concentrations between 0.33 ± 0.00 and 1.50 ± 0.00 mg/kg, as indicated in Table 3.0. The results of the analysis of variance (ANOVA) revealed that the levels of Cd found in sediment samples during the study period varied significantly ($p<0.05$) by location and month ($P=0.013$). This suggests that the cadmium metal is not very harmful. This result was different from the sediment sample results for heavy metal accumulation in fish, sediments, and water from the Yauri River in Kebbi State, Nigeria, which were reported by Osesua *et al.,* (2019) and ranged from 0.010 ± 0.008 to 0.198 ± 0.018 mg/kg. Additionally, in different parts of Pakistan, the range of contaminated soil varied from normal soil to 0.02 to 184 mg/kg (Waseem *et al*., 2014). There was no cadmium contamination in the sediment samples from the research region, since the results of this investigation fell below the WHO's recommended maximum allowable limit of 0.68 mg/kg for Cd.

Fe contents in sediments from the upstream site were greater in January (97.70±0.53 mg/kg) and December (73.27±0.40 mg/kg) (Table 3.0). In January, samples from the Lungu Lake site had a Fe content of 69.56±0.69 mg/kg, while samples from the Laka Lake location had a lower concentration of 46.70±0.27 mg/kg. Particularly in the upstream region, anthropogenic sources of contamination may be the cause of the greater concentration from the upstream site. These findings were contrasted with those of Membere & Abdulwasiu's (2020) sediments collected in the Escravos River in Delta State, Nigeria (384.5±0.71 to 509±1.41 mg/kg), which are greater than those of the current study. Ogiesoba-Eguakun *et al.,* (2025) reported values that were substantially higher than the current data, with a mean value of 349.715 ± 20.156 mg/kg. There was no Fe pollution in the research region for the sediment samples, as all of the Fe concentrations from this investigation were less than the 500 mg/kg WHO-recommended level for sediments. The results of the analysis of variance (ANOVA) revealed that the Fe level found in sediment samples during the study period varied significantly ($p<0.05$) by location and month ($P = 0.033$).

According to Table 3.0, the Laka Lake site had the highest concentration of Cu in January at 7.25±0.00 mg/kg, while the upstream location had the lowest concentration in February at 3.75±0.00 mg/kg. In December and January, the upstream site had a concentration of 0.34±0.00 mg/kg. These findings paled in comparison to those of Ogiesoba-Eguakun *et al.,* (2025). This may be the result of the area's getting large amounts of runoff from agricultural farmlands and effluents from waste disposal. Cu-based pollutants may have been released into the water as a result of cars and motorcycles washing downstream from upstream flows. These values were greater than the 0.167±0.0026 to 0.278±0.0023 mg/kg results obtained by Ibrahim *et al.,* (2021) when compared to the study's results from the Laka Lake site in December and upstream in February. The results of the current study, which are lower at 0.76 ± 0.2 mg/kg, compare positively with a study conducted by Membere & Abdulwasiu (2020) from Avsar Dam Lake in Turkey. The results of the analysis of variance (ANOVA) revealed that the Cu level found in sediment samples during the study period did not change significantly ($p>0.05$) by location or month ($P = 0.914$). There was a pollution issue for Cu from the study site of sediment samples since the concentration of Cu in sediment samples from all the study sites was higher than the WHO-recommended allowable limit of 0.025 mg/kg.

With a mean value of 2.461 ± 0.482 mg/kg, the upstream sediment sample had a higher Pb concentration (0.16 ± 0.00 mg/kg) than the downstream sediment samples (3.08 ± 0.14 mg/kg), but it was still higher than the result recommended by Ogiesoba-Eguakun *et al.,* (2025). Table 3.0 shows that the Lungu Lake site had a lower mean for Pb concentration of 0.25 ± 0.00 mg/kg. Due to the release of heavy metals from the sediment to the covering water as a result of both high temperatures and a fermentation process brought on by the breakdown of organic matter, Osesua *et al.,* (2019) reported that metal concentrations in the water increased, decreased, or varied during hot seasons. Likewise, monthly differences were also found in the metal content. These monthly differences could result from variations in the quantity of sewage effluents, waste disposal dumped into the river, and agricultural drainage water. However, these levels were greater than Pb values of 0.034±0.004 to 0.084±0.007 mg/kg for the sediment samples reported by Osesua *et al.,* (2019) from the Yauri River in Kebbi State, Nigeria. As is currently clear, human activity may be the cause of the elevated Pb level in the upstream area, which may then be further diluted as it flows downstream. The results of the analysis of variance (ANOVA) revealed that the Pb level found in sediment samples during the study period did not change significantly ($p>0.05$) by location or month ($P = 0.510$). However, the obtained result exceeds the WHO-recommended allowed limit of 0.04 to 0.5 mg/kg Pb in sediments, indicating a Pb pollution concern in the studied area.

All samples had Cr concentrations between 0.75 ± 0.00 and 1.75 ± 0.00 mg/kg, as indicated in Table 3.0. The downstream location yielded a mean concentration of Cr 1.75 ± 0.00 mg/kg, which was greater than the concentration found in all of the sediment sample research sites. Nonetheless, during the research periods, there is a notable variation across all sampling sites. According to Ogiesoba-Eguakun *et al.,* (2025) and Membere & Abdulwasiu (2020), the results were lower than those of 9.46 ± 3.51 mg/kg and 3.13 ± 0.04 to 4.53 ± 0.03 mg/kg for sediment samples collected from the Owena Multi-Purpose Dam in Ondo State, Nigeria, and from a few rivers in the southern Nigerian peri-urban region using pollution indices. The study's Cr concentrations are higher than the WHO-recommended threshold of 0.1 mg/kg, indicating a Cr pollution issue. The results of the analysis of variance (ANOVA) revealed that the Cr level found in sediment samples during the study period did not significantly differ ($p>0.05$) between sites and months ($P = 0.472$).

CONCLUSION

The concentration of the heavy metal in the sediments, water, and muscle sections of five (5) fish species from the Argungu River and two nearby lakes in Kebbi State, Nigeria, has been reported in this study. All fish species had significant amounts of Cd, Fe, Cu, Pb, and Cr, according to the heavy metal data, which could be dangerous for food consumers. The current research, however, demonstrated that concentrations are often lower in water but tend to rise in sediment and fish species. As a result, the order was Sediment > Water > Fish. Among all fish species, Fe has the highest mean content of the heavy metal, followed by Cu, Pb, Cd, and Cr. This demonstrated that Fe and Pb made up more than 90% of all the metals examined, with the order increasing from Fe > Cu > Pb > Cd > Cr. Out of all the heavy metals examined, *Malapterurus electricus* has the greatest concentration. The following order was used to rank the metal concentrations in the fish species: *Malapterurus electricus* > *Alestes baremose* > *Clarias gariepinus* > *Hydrocunus brevis* > *Tilapia zilli.* Therefore, the study found that the fish species sampled from the Argungu River and the nearby lakes had a notably high level of heavy metal contamination, and that humans may suffer negative consequences if they consume the fish species found in the river.

Therefore, in order to lower the amount of pollution through education and sensitization, it is necessary to continuously assess the level of metal pollution in these regions from the aforementioned sources.

RECOMMENDATIONS

Aquatic ecosystems, biodiversity, and human health are all seriously threatened by heavy metal contamination. We can endeavor to mitigate these issues and safeguard our valued water supplies by implementing the following suggestions.

- ✓ It is advised that the concentration of heavy metals in water be routinely checked.
- ✓ These kinds of data ought to be used to evaluate the population's health risk.
- ✓ It is important to properly treat industrial and agricultural waste before releasing it into a body of water.
- ✓ Public knowledge of the detrimental effects of heavy metal poisoning in our environment should be properly raised.
- ✓ More scientific studies on the toxicity of heavy metals and their impact on human health and the environment should be supported.

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