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**Original Research Article**

# Evaluation of Heavy Metals in Water, Sediments and African Catfish (*Clarias gariepinus*) Obtained from Earthen and Concrete Fish Ponds in Port Harcourt, Nigeria

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## Abstract

This study investigates the concentrations of heavy metals and physicochemical properties of water, sediment, and African catfish (*Clarias gariepinus*) from earthen and concrete ponds used for aquaculture in Port Harcourt, Rivers State, Nigeria. Physicochemical analysis showed that water from earthen ponds had a pH of 5.60-7.52, salinity of 0.06-1.03 ppt, conductivity of 170-1671 $\mu Scm^{-1}$, and turbidity of 38.71-163 NTU. In contrast, concrete ponds had a pH of 6.75-7.56, salinity of 0.18-0.71 ppt, and conductivity of 325-1442 $\mu Scm^{-1}$, indicating differences in water quality. Water samples from earthen ponds exhibited cadmium (Cd) levels ranging from 0.013 to 0.187 mg/kg, lead (Pb) from 0.649 to 0.651 mg/kg, zinc (Zn) from 0.052 to 0.80 mg/kg, copper (Cu) from 0.009 to 0.158 mg/kg, and iron (Fe) from 1.198 to 4.112 mg/kg. In contrast, Concrete ponds showed Cd levels from -0.014 to 0.008 mg/kg, Pb from -0.0154 to 1.518 mg/kg, and Zn from 0.072 to 3.038 mg/kg. In earthen pond sediment, Cd ranged from 0.059 to 0.326 mg/kg and Pb from 0.505 to 1.160 mg/kg, exceeding permissible limits, especially at sites B and C, indicating contamination. Fish from earthen ponds had high heavy metal levels, with Cd from 0.175 to 22.433 mg/kg and Pb from 1.121 to 22.613 mg/kg, showing significant bioaccumulation. Conversely, concrete ponds had lower contamination, with Cd in sediment from 0.250 to 0.412 mg/kg and Pb in fish from 0.693 to 5.376 mg/kg, closer to safe thresholds. The results indicate significant contamination differences between pond types, with earthen ponds exhibiting higher heavy metal levels due to soil composition and exposure. In contrast, concrete ponds, which minimize soil-water interaction, showed lower metal presence in fish, highlighting a safer aquaculture environment. These findings stress the importance of continuous monitoring of earthen ponds and improved management practices to ensure consumer safety and sustainable aquaculture.

**Keywords:** Heavy Metals, Physicochemical Properties, African Catfish, Aquaculture, Earthen Ponds, Concrete Ponds, Port Harcourt.



## INTRODUCTION

In recent decades, concerns about environmental pollution and its potential impact on human health have escalated, with a particular focus on the accumulation of heavy metals in aquatic ecosystems. Heavy metals are naturally occurring elements that, at elevated levels, can pose serious threats to both ecological balance and human well-being due to their persistence and toxic nature. Among various aquatic organisms, fish have been recognized as significant indicators of environmental contamination and bioaccumulation of heavy metals, as they are at the top of aquatic food chains and can accumulate these toxic substances over time [1]. Fish accumulate toxic chemicals such as heavy metals directly from water and diet, and contaminant residues may ultimately reach concentrations of hundreds or thousands of times above those measured in the water, sediment and food [2].

The global consumption of fish has seen a rapid increase in recent years, driven by growing awareness of its nutritional and therapeutic benefits. However, the presence of toxic heavy metals in fish can negate these advantages. The detrimental effects of heavy metals on human health have been well-documented for some time. Aquatic ecosystems are particularly vulnerable to heavy metal pollution, and the continual rise of these metals in the environment, largely due to human activities like accidental chemical waste spills, industrial and sewage discharge, agricultural runoff, domestic wastewater, and fuel leakage from fishing boats, has become a cause for concern [3].

Aquatic pollution is a global issue that demands immediate attention and prevention [4]. Heavy metals, due to their slow biodegradability and chemical breakdown compared to organic pollutants, persist in the environment. When combined with natural weathering processes, they create nutrient-rich deposits that can support aquatic organisms [5, 6].

The bioaccumulation of heavy metals in the tissues of marine organisms serves as an indirect indicator of metal abundance and availability in the marine environment [7]. Therefore, monitoring the contamination of fish tissues plays a crucial role as an early warning system for sediment contamination and related water quality issues [8], enabling timely action to safeguard both public health and the environment. Several factors, including seasonal variations and the physical and chemical properties of water, can significantly influence the accumulation of metals in different fish tissues [9]. Studies have also shown that fish can accumulate and retain heavy metals from their surroundings, depending on factors such as exposure concentration and duration, as well as environmental factors like salinity, temperature, hardness, and the metabolic rate of the fish [10].

The primary objective of this study was to investigate the concentrations of selected heavy metals, namely Ni, Pb, Cd, Cu, Fe, and Zn, in water, sediments, and African Catfish (*Clarias gariepinus*) sampled randomly from three earthen and three concrete ponds in Port Harcourt, Rivers State, Nigeria.

## EXPERIMENTAL METHOD

### Description of Study Area

Port Harcourt, the capital of Rivers State in Nigeria, is situated alongside the Bonny River, which flows through the eastern distributaries of the Niger River. The city boasts one of Nigeria's largest deepwater seaports, serving as a crucial hub for the export of various commodities including crude oil, palm oil, palm kernels, timber from the surrounding regions, coal from Enugu, and tin and columbite from the Jos Plateau. Port Harcourt stands as a prominent industrial center in Nigeria, home to the Trans-Amadi Industrial Estate located approximately 4 miles (6 km) to the north. This expansive 2,500-acre (1,000-hectare) site serves as a manufacturing hub for a wide range of products, encompassing tires, aluminum goods, glass containers, and paper. Additionally, the city is a key producer of steel structural components, corrugated tin, paints, plastics, enamelware, wooden and metal furniture, cement, concrete products, and various other items. Notably, Nigeria's inaugural oil refinery, established in 1965, is situated at Alesa-Eleme, just 12 miles (19 km) to the southeast of Port Harcourt. The city is well-connected via pipelines that transport both oil and natural gas to Port Harcourt, where an additional refinery is located, as well as to the port of Bonny, situated 25 miles (40 km) to the south-southeast. Furthermore, refined oil is transported to Makurdi in Benue state. Port Harcourt is also known as a hub for boatbuilding and fishing industries.

### Collection and Estimation of Heavy metals in Sediment Samples

Sediment samples were obtained from two designated sites using a grab sampler. After collection, these samples were transported to the laboratory and subjected to air-drying at room temperature. Following the drying process, the sediment samples were pulverized and sieved through a 160 µm mesh. Subsequently, they were carefully packed into polyethylene bags and stored at temperatures below -20°C before undergoing analysis.

For the analysis, sediment samples were accurately weighed and then introduced into digestion bombs, along with a 10 mL mixture of $HNO_3$ and HCl (in a 1:3 v/v ratio). The digestion of these samples was conducted within a microwave digestion system. The analytical procedures adhered to previously established methods, as outlined in the work of [11].

### Collection and Determination of Heavy Metals in Fish Samples

A combined total of six catfish samples, each weighing 1.2 kilograms, were gathered, with three collected from earthen fish ponds and three from concrete fish ponds (Fig 2 and 3). Fish samples were dried in an oven at 70 – 105 °C overnight. The samples were removed from the oven, allowed to cool, and were grinded into powered form and 1gram was weighed out and placed in 100 mL beakers. For the determination of heavy metals in catfish samples, a digestion process was employed involving a mixture of $HNO_3$, $HClO_4$, and $H_2O_2$. Initially, 2.0 grams of the homogenized sample were carefully weighed into a digestion tube, followed by the addition of 10 $cm^3$ of concentrated $HNO_3$. The tube was covered with a watch glass and left to stand overnight. The following day, the sample was subjected to heating at 125°C until the solution became clear. Subsequently, 10 $cm^3$ of $HNO_3$, 4 $cm^3$ of $HClO_4$, 4 $cm^3$ of $H_2O_2$, and 2 $cm^3$ of HCl were added, and the temperature was maintained at 135°C for 1 hour until the solution lost its color. Special care was taken to ensure an excess of $HNO_3$ and a small amount of $H_2O_2$ were present until most of the organic materials were completely destroyed. The resulting solution was slowly evaporated to near dryness, avoiding excessive heating, and then cooled and dissolved in 5 $cm^3$ of 1 mol/L $HNO_3$.

Following digestion, the samples were filtered through Whatman number 1 filter paper and were subsequently diluted to a final volume of 25 $cm^3$ using 0.25 mol $dm^{-3}$ $HNO_3$ before being stored for analysis using Atomic Absorption Spectrometry (AAS). The determination of heavy metals in the fish samples was carried out in accordance with the methods outlined by [12].


**Figure 1: Map of Port Harcourt City and it environ showing sample locations**

**Figure 2: Concrete Fish Pond**

**Figure 3: Earthen Fish Pond**

**Physicochemical Analysis of Water Samples**

In the laboratory, pH, salinity, electric conductivity, turbidity, total dissolved solid, total suspended solids, total acidity, total hardness, total acidity in the water samples obtained from three (3) different ponds each for earthen fish ponds and concrete fish ponds respectively were identified using standard methods [13].

**Statistical Analysis of Experimental Data**

Experimental data in this research work where analyzed using descriptive statistics such as the mean, standard deviation, Pearson correlation coefficient matrix as found in the Excel software.

## RESULTS AND DISCUSSION

**Physicochemical Characteristic of Water Samples from Concrete and Earthen Ponds**

Water quality is a critical factor in aquaculture, as it directly affects the health and growth of aquatic organisms. In the context of breeding African catfish, understanding the physicochemical properties of water in concrete and earth ponds is crucial for successful management and optimization of the breeding environment. This discussion will analyze the physicochemical results of water samples collected from both types of ponds, focusing on parameters such as pH, salinity, conductivity, turbidity, total dissolved solids, total suspended solids, total acidity, and total hardness. All physicochemical parameters analyzed were measured three times and the range, mean with standard deviations are presented in Table 1.

pH is the measurement of the potential activity of hydrogen ions in a liquid sample. The pH of water plays a vital role in the overall health of aquatic organisms. The pH measurement helps to determine if the water is a proper environment for fish, plants and algae [14]. Fish are known to have an average pH of 7.4 therefore pond water average within this range is optimum. In the earthen ponds, the pH ranges from 5.62 to 7.51, indicating some variability in acidity levels. In contrast, the concrete ponds exhibit a narrower pH range, varying from 6.76 to 7.55. The relatively stable pH levels in concrete ponds might be attributed to the buffering capacity of the concrete material. However, both ranges generally fall within an acceptable range for African catfish, which typically thrive in a pH range of 6.5 to 8.5. The desirable range for pond pH is 6.5 - 9.5 and acceptable range is 5.5 - 10.0 [14]. The findings are slightly lower than those obtained by [13], in Akure (Nigeria) which reported a pH (7.10 ± 0.06 - 8.39 ± 0.01) for concrete ponds and earthen ponds.

**Table 1: Physicochemical Characteristic of water samples from Concrete and Earth Ponds used for breeding African Catfish (*Clarias gariepinus*) in Port Harcourt, River State Nigeria**

| | Sample Code | pH | Salinity (ppt) | Conductivity (µScm-1) | Turbidity (NTU) | Total Dissolved Solid (mg/L) | TSS (mg/L) | Total Acidity (mg/L) | Total Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| **Earthen ponds** | | | | | | | | | |
| Range | AEW | 7.5-7.52 | 0.89-0.91 | 1669-1671 | 120-121 | 835-835.5 | 2.645-2.646 | 116-118 | 147-150 |
| Mean | | 7.51 | 0.9 | 1670 | 120.333 | 835 | 2.64533 | 117 | 148.3 |
| STD. Dev. | | 0.01 | 0.01 | 1 | 0.57735 | 0.5 | 0.00057 | 1 | 1.527 |
| Range | BEW | 6.90-6.94 | 0.06-0.008 | 170-172 | 38.71-38.74 | 85-86 | 1.24-1.25 | 42-44 | 38-39 |
| Mean | | 6.92 | 0.07 | 171 | 38.7233 | 85.5 | 1.24333 | 43 | 39 |
| STD. Dev. | | 0.02 | 0.01 | 1 | 0.01527 | 0.5 | 0.00577 | 1 | 1 |
| Range | **CEW** | 5.60-5.64 | 1.01-1.03 | 1308-1310 | 160-163 | 654-659.5 | 5.30-5.33 | 205-208 | 222-225 |
| Mean | | 5.62 | 1.02 | 1309 | 161.666 | 656.166 | 5.31666 | 206.33 | 223.6 |
| STD. Dev. | | 0.02 | 0.01 | 1 | 1.52752 | 2.92973 | 0.01527 | 1.5275 | 1.527 |
| **Concrete ponds** | | | | | | | | | |
| Range | **ACW** | 7.54-7.56 | 0.70-0.71 | 1439-1442 | 70-72 | 719.5-721 | 1.764-1.766 | 136-138 | 185-187 |
| Mean | | 7.55 | 0.7 | 1440.333 | 71 | 720.1667 | 1.765 | 137 | 186 |
| STD. Dev. | | 0.01 | 0.01 | 1.527525 | 1 | 0.763763 | 0.001 | 1 | 1 |
| Range | **BCW** | 7.04-7.08 | 0.70-0.72 | 1378-1380 | 48.48-48.52 | 684-689 | 2.426-2.428 | 86-88 | 118-120 |
| Mean | | 7.057 | 0.71 | 1379 | 48.5 | 687.8333 | 2.427 | 87 | 119 |
| STD. Dev. | | 0.0201 | 0.01 | 1 | 0.02 | 3.329164 | 0.001 | 1 | 1 |
| Range | **CCW** | 6.75-6.78 | 0.18-0.19 | 325-326 | 42.54-42.57 | 162-163 | 1.44-1.47 | 76-78 | 54-56 |
| Mean | | 6.7633 | 0.1867 | 325 | 42.557 | 162.5 | 1.4566 | 77 | 55 |
| STD. Dev. | | 0.0153 | 0.0058 | 1 | 0.0153 | 0.5 | 0.0153 | 1 | 1 |

Salinity, the concentration of dissolved salts in water, significantly impacts osmoregulation in fish. In earthen ponds, salinity varies widely, from 0.07 to 1.02, suggesting potential fluctuations in salt content. In contrast, concrete ponds exhibit a more limited range, ranging from 0.18 to 0.71. These values remain relatively low, indicating that both types of ponds maintain low salinity levels suitable for African catfish, which are freshwater species.

Conductivity measures the water's ability to conduct an electrical current and is closely associated with salinity. It is also an indicator of dissolved ions or solutes such as metals present in the water. The FAO acceptable limit for conductivity in aquaculture is between 20 and 1500 µs/cm [15]. In earthen ponds, the conductivity ranges from 171 to 1670 µS/cm, demonstrating considerable variability. Conversely, concrete ponds show a narrower range, fluctuating from 325 to 1440 µS/cm. The conductivity ranges however in the ponds were ideal for fish culture except for sample code AEW (earthen pond). Both ranges suggest the presence of dissolved ions in the water, as expected in freshwater systems. The fluctuations in conductivity may be attributed to variations in the composition of the surrounding soil in earthen ponds. Earthen ponds generally have lower salinity and conductivity values compared to concrete ponds. This suggests that concrete ponds may have a more stable and controlled environment. African catfish are freshwater species, and elevated salinity levels can be detrimental to their health.

Turbidity, which refers to the cloudiness or haziness of water caused by suspended particles, plays a significant role in water quality. In earthen ponds, turbidity varies widely, ranging from 38.723 to 161.666 NTU (Nephelometric Turbidity Units). In contrast, concrete ponds exhibit a more limited range, with values fluctuating from 42.557 to 71 NTU. The higher turbidity levels in earthen ponds may result from suspended clay particles in the soil or organic matter, which can significantly impact water quality and visibility. Concrete ponds maintain clearer water, potentially benefiting fish health and management.

Total Dissolved Solids (TDS) is a critical water quality parameter that measures the concentration of all inorganic and organic substances present in water in a dissolved form. TDS could either be high or low depending on the concentrations of these ions in the water. NESREA [17], stipulates 450 mg/L as the standard limit in freshwaters for optimum growth and development of aquatic organisms. In earthen ponds, the TDS range varies widely, ranging from 85.5 to 835 mg/L. This broad range suggests fluctuations in the concentration of dissolved substances in the water. High TDS levels can affect water quality and, if excessive, may lead to issues like reduced oxygen availability and increased osmotic stress on fish. In concrete ponds, the

TDS range is comparatively narrower, fluctuating from 162.5 to 720.1667 mg/L. The concrete material itself may contribute to TDS, but in a more controlled and consistent manner. Concrete can release calcium and magnesium ions into the water, which contribute to TDS. . The TDS values of some sampling points from both earthen and concreter ponds falls above the standard level for the sustenance of aquatic organisms.

Total Suspended Solids (TSS) measure the concentration of suspended particles in water, encompassing organic and inorganic matter. In earthen ponds, TSS displays a broader range, fluctuating from 1.2433 to 5.3166 mg/L. In contrast, concrete ponds have a narrower range, with values ranging from 1.4566 to 2.427 mg/L. The lower TSS levels in concrete ponds suggest improved water clarity, which can be advantageous for fish health and overall management.

Total Acidity and Total Hardness are vital parameters that impact water quality. In earthen ponds, total acidity varies from 43 to 206.33 mg/L, while total hardness ranges from 39 to 223.6 mg/L. Concrete ponds, on the other hand, exhibit narrower ranges for both parameters, with total acidity fluctuating between 77 to 137 mg/L and total hardness ranging from 55 to 186 mg/L. The wider range of total acidity in earthen ponds, suggests potential fluctuations in the levels of acidic compounds. These acids can originate from the surrounding soil, organic matter, or other external factors. High acidity levels can adversely affect fish health, leading to stress and reduced growth. While relatively more stable acidity range in concrete ponds may be attributed to the buffering capacity of the concrete material used in the pond construction. Concrete can neutralize acidic substances, helping to maintain a less variable pH and acidity level. However, it's essential to monitor and manage acidity to ensure it remains within a suitable range for fish health.

### Heavy Metals in Water Samples from Concrete and Earth Ponds

The concentration of Heavy Metals Levels in Water Samples from Earth and Concrete Ponds used for breeding African Catfish (*Clarias gariepinus*) in Port Harcourt, River State Nigeria are presented in Table 2. The concentrations of Cd in the earthen pond range from 0.013 mg/kg to 0.187 mg/kg. These levels significantly fall below the WHO [18], and FEPA [19], standard of 0.003 mg/kg. Pb concentration levels span from 0.125 mg/kg to 0.651 mg/kg in the earthen pond. These measurements greatly surpass the WHO [18], and FEPA [19], standard of 0.010 mg/kg. The presence of elevated Pb concentrations is alarming, given its known ecological impacts and potential adverse health effects for humans.

**Table 2: Heavy Metals Levels in Water Samples from Earth and Concrete Ponds used for breeding African Catfish (*Clarias gariepinus*)**

| **Earth Ponds** | | | | | | |
|---|---|---|---|---|---|---|
| | Sample code | Cd | Pb | Zn | Cu | Fe |
| Range | A | 0.013-0.016 | -0212 to -0215 | 0.78-0.80 | -0.068 to -0.70 | 1.198-1.99 |
| Mean | | 0.014667 | -0.21367 | 0.079 | -0.069 | 1.198 |
| SD | | 0.001528 | 0.001528 | 0.001 | 0.001 | 0.001 |
| Range | B | 0.185-0.187 | 0.649-0.651 | 0.447-0.449 | 0.157-0.158 | 3.907-3.912 |
| Mean | | 0.083333 | 0.358667 | 0.203 | 0.016667 | 0.671333 |
| SD | | 0.001 | 0.001 | 0.001 | 0.001 | 0.002517 |
| Range | C | 0.030-0.033 | 0.125-0.127 | 0.052-0.054 | 0.009-0.011 | 4.109-4.112 |
| Mean | | 0.031667 | 0.126 | 0.053 | 0.01 | 4.110333 |
| SD | | 0.001528 | 0.001 | 0.001 | 0.001 | 0.001528 |
| **Concrete Ponds** | | | | | | |
| Range | A | -0.012 to -0.014 | -0.0154 to -0.014 | 0.104-0.106 | -0.012 to -0.014 | 0.942 – 0.948 |
| Mean | | -0.013 | -0.155 | 0.105 | -0.075 | 0.944667 |
| SD | | 0.001 | 0.001 | 0.001 | 0.001 | 0.003055 |
| Range | B | -0.005-0.008 | -0.148 to-0.151 | 0.101-0.103 | -0.047 to -0.050 | 0.948-0.956 |
| Mean | | -0.00133 | -0.14967 | 0.102 | -0.04867 | 0.952667 |
| SD | | 0.008145 | 0.001528 | 0.001 | 0.001528 | 0.004163 |
| Range | C | 0.0089-0.91 | 0.548-0.550 | 0.072-0.073 | 0.0036-0.038 | 1.409-1.411 |
| Mean | | 0.09 | 0.549 | 0.073 | 0.037 | 1.41 |
| SD | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| WHO/FEPA Standard (mg/kg) | | 0.003 | 0.010 | 3.000 | 1.000 | 0.003 |

Copper concentrations range from 0.009 mg/kg to 0.158 mg/kg in the earthen pond. These levels significantly fall below the WHO [18], and FEPA [19], standard of 1.000 mg/kg. Elevated Cu concentrations can disrupt aquatic ecosystems, affecting aquatic life. Moreover, Cu toxicity can extend to humans, especially if water is used for consumption or irrigation. Iron concentration levels vary between 1.198 mg/kg to 4.112 mg/kg in the earthen pond. These measurements exceed the WHO [18], and FEPA [19], standard of 0.300 mg/kg. Although iron is naturally abundant, its elevated presence can lead to water quality issues, sedimentation, and altered aquatic habitats. Elevated iron levels are commonly associated with industrial discharges and natural weathering. The earthen pond's Zn concentrations range from 0.052 mg/kg to 0.449 mg/kg. These values do not surpass the WHO [18], and FEPA [19], standard of 3.000 mg/kg.

The concentration levels of metals in concrete pond water samples exhibit a wide range of values, incorporating positive, negative, and non-detectable values. This variability can be attributed to factors such as analytical techniques, sample characteristics, and possible contamination sources. In concrete ponds, Cd concentrations ranged from negative values (-0.012 mg/kg to -0.014 mg/kg) to a positive range of 0.0089 mg/kg to 0.091 mg/kg in pond C. Cd concentrations in concrete pond C exceed the WHO [18], and FEPA [19], standard of 0.003 mg/kg, indicating potential contamination. Nickel concentrations were non-detectable (ND) in concrete ponds except for concrete pond C, where levels ranged from 0.265 mg/kg to 0.267 mg/kg. Although within the detected range, these Ni concentrations might have varying impacts depending on local conditions and exposure routes. Copper concentrations in concrete ponds ranged from -0.012 mg/kg to -0.014 mg/kg, and in pond C, Cu concentrations ranged from 0.0036 mg/kg to 0.038 mg/kg. All detected Cu concentrations remain within the WHO [18], and FEPA [19], standard of 1.000 mg/kg.

**Evaluation of Heavy Metals Level in Sediment Samples from Earth Ponds**

The concentration of heavy metals in sediments of the earthen fish pond was evaluated and the data presented in Table 3.

**Table 3: Heavy Metal Levels in Sediment Samples from Earthen Ponds used for breeding African Catfish (*Clarias gariepinus*).**

| Earthen pond | Sample code | Cd | Pb | Ni | Zn | Cu | Fe |
|---|---|---|---|---|---|---|---|
| Range | A | 0.059 - 0.061 | 0.505-0.507 | 0.716-0.718 | 0.243-0.245 | 0.123-0.125 | 94.305-94.310 |
| Mean | | 0.06 | 0.506 | 0.717 | 0.244 | 0.124 | 94.30767 |
| SD | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002517 |
| Range | B | 0.143-0.146 | 0.797-0.799 | 0.852-0.854 | 1.044-2.046 | 0.358-0.459 | 148.607-250.008 |
| Mean | | 0.116667 | 0.700667 | 0.807667 | 1.444667 | 0.347 | 197.641 |
| SD | | 0.001528 | 0.001 | 0.001 | 0.001 | 0.001 | 0.710189 |
| Range | C | 0.324-0.326 | 1.158-1.160 | 0.596-0.599 | 0.523-0.525 | 0.058 - 0.061 | 35.38-37.378 |
| Mean | | 0.325 | 1.159 | 0.597667 | 0.524 | 0.06 | 36.04467 |
| SD | | 0.001 | 0.001 | 0.001528 | 0.001 | 0.001 | 1.154702 |
| WHO/FEPA Standard (mg/kg) | | 0.006 | 0.040 | - | 0.0123 | 0.025 | 0.030 |

The analysis of sediment samples from earthen fish ponds A, B, and C reveals noteworthy variations in heavy metal concentrations, each with distinct implications for environmental health and potential risks to human consumption. Pond A, while showing Cd concentrations (0.059 - 0.061 mg/kg) slightly above the WHO [18], standard of 0.006 mg/kg, signifies a moderate level of concern. This suggests a need for ongoing monitoring and potential remediation efforts to prevent further contamination. Moreover, the lead (Pb) concentrations in Pond A (0.505 - 0.507 mg/kg) are notably higher than the WHO [18], standard of 0.040 mg/kg, emphasizing potential risks to aquatic life and human health. While Pond A's contamination levels are concerning, they are comparatively less severe than Ponds B and C.

In Pond B, the situation is more alarming, with cadmium (Cd) concentrations ranging from 0.143 to 0.146 mg/kg, significantly exceeding the WHO [18], standard. Zinc (Zn) concentrations in Pond B are even more concerning, ranging from 1.044 to 2.046 mg/kg, far surpassing the standard of 0.0123 mg/kg. These findings point to severe contamination, posing substantial risks to aquatic life and potentially hazardous levels of heavy metals in fish that could be consumed by humans. Additionally, the extraordinarily high iron (Fe) concentrations in Pond B, ranging from 148.607 to 250.008 mg/kg, raise concerns about the disruption of the aquatic ecosystems balance. Finally, Pond C exhibits elevated heavy metal concentrations, with lead (Pb) levels ranging from 1.158 to 1.160 mg/kg, exceeding the WHO [18], standard. While zinc (Zn) concentrations are within the standards (ranging from 0.523 to 0.525 mg/kg), the consistently high lead levels indicate potential environmental concerns and a potential risk to human health if fish from this pond are consumed. These findings suggest potential sediment contamination due to natural and anthropogenic factors, requiring detailed assessments to understand the origins and implications.

**Estimation of Heavy Metals Concentration in African Catfish (*Clarias gariepinus*) from Earthen and Concrete Fish Ponds**

The levels of heavy metals in African catfish (*Clarias gariepinus*) obtained from earthen fish ponds and concrete fish ponds were evaluated and the results are presented in Tables 4 and 5.

**Table 4: Heavy Metals Level in African Catfish (*Clarias gariepinus*) obtained from Earthen Ponds in Port Harcourt, River State Nigeria**

| | Sample code | Cd | Pb | Ni | Zn | Cu | Fe |
|---|---|---|---|---|---|---|---|
| Range | A | 0.174-0.176 | 0.112-0.122 | 0.634-0.636 | 0.556-0.557 | 0.050-0.052 | 1.402-1.407 |
| Mean | | 0.175 | 1.121 | 0.635 | 0.558667 | 0.051 | 1.404333 |
| SD | | 0.001 | 0.001 | 0.001 | 0.001528 | 0.001 | 0.002517 |
| Range | B | 0.48-0.50 | 0.298-0.30 | 0.259-0.261 | 0.112-0.1124 | 0.08 -0.82 | 11.462 – 11.466 |
| Mean | | 0.193 | 0.299 | 0.26 | 0.113 | 0.081 | 11.46433 |
| SD | | 0.24855 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002082 |
| Range | C | 0.299-0.301 | 0.837-0.840 | 0.954-0.956 | 0.528-0.530 | 0.008 -0.012 | 3.304 -3.308 |
| Mean | | 0.3 | 0.838333 | 0.595 | 0.529 | 0.01 | 3.305667 |
| SD | | 0.001 | 0.001528 | 0.001 | 0.001 | 0.002 | 0.002082 |

**Table 5: Heavy Metals Level in African Catfish (*Clarias gariepinus*) obtained from Concrete Ponds in Port Harcourt, River State Nigeria**

| | Sample code | Cd | Pb | Ni | Zn | Cu | Fe |
|---|---|---|---|---|---|---|---|
| Range | A | 0.250-0.253 | 1.074-1.076 | 0.663-0.666 | 0.606-0.609 | 0.048-0051 | 2.012-2.016 |
| Mean | | 1.257 | 5.376 | 3.323 | 3.038 | 0.25 | 10.068 |
| SD | | 2.264 | 9.676 | 5.983 | 5.467 | 0.45 | 18.122 |
| Range | B | 0.318-0.320 | 1.518-1.50 | 0.29-0.833 | 0.663-0.665 | 0.025-0.028 | 1.786-1.806 |
| Mean | | 0.319667 | 1.517667 | 0.830667 | 0.664 | 0.026667 | 1.797333 |
| SD | | 0.001528 | 0.002517 | 0.002082 | 0.001 | 0.001528 | 0.010263 |
| Range | C | 0.187-0.861 | 0.692-0.694 | 0.190-0.192 | 0.548-0.550 | 0.041-0.043 | 2.30-2.317 |
| Mean | | 0.412 | 0.693 | 0.191 | 0.549 | 0.042 | 2.310667 |
| SD | | 0.388846 | 0.001 | 0.001 | 0.001 | 0.001 | 0.009292 |
| WHO/FEPA Standard (mg/kg) | | 0.5 | 2.0 | | 30.0 | 3.0 | 0.5 |

The cadmium (Cd) concentrations in all catfish samples, whether from earthen or concrete fish ponds, are below the WHO [18], and FEPA [19], standard of 0.5 mg/kg. This is a positive finding, indicating that the fish are not exposed to excessive cadmium levels, which could have detrimental effects on human health. The concentrations of lead (Pb) in the analyzed catfish samples are below the WHO [18], and FEPA [19], standard of 2.0 mg/kg, however, a few instances in the concrete fish pond samples at sampling points A and B showed slightly elevated lead concentrations. These exceedances are likely due to environmental factors such as runoff or localized contamination sources. The zinc (Zn) levels in African catfish from both earthen and concrete fish ponds are significantly lower than the WHO [18], and FEPA [19], standard of 30.0 mg/kg. This confirms that the zinc levels in the fish are well within safe limits and do not present any risk to human consumption. The measured copper (Cu) concentrations in the catfish from both types of fish ponds are comfortably below the WHO [18], and FEPA [19], standard of 3.0 mg/kg. This suggests that the copper levels in the fish are within the recommended limits and do not raise concern regarding potential health risks. Nickel (Ni) concentrations in the catfish from both earthen and concrete fish ponds are well below the WHO [18], and FEPA [19], standard of 2.0 mg/kg. This suggests that the fish are not accumulating unsafe levels of nickel and that the aquatic environments are relatively free from significant nickel contamination. The iron (Fe) concentrations in the catfish from both types of fish ponds are higher than the WHO/FEPA 2003 standard of 0.5 mg/kg. However, it is important to note that iron is a common element and essential nutrient. Increased level of iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues [20]. While these levels may be elevated, they are unlikely to pose a direct health concern. Elevated iron concentrations are likely due to the natural presence of iron in the aquatic environment and are not a significant cause for concern.

**Comparative Analysis of Heavy Metals Concentration in African Catfish (*Clarias gariepinus*) between Earthen Pond and Concrete Pond**

Heavy metal concentrations in African catfish from two distinct fish pond types were examined, and the comparative analysis is depicted in Table 6 and Figure 4. A comparative analysis of heavy metal concentrations in African catfish from earthen and concrete ponds shows significantly higher contamination levels in earthen ponds. Cadmium (Cd), lead (Pb), nickel (Ni), zinc (Zn), copper (Cu), and iron (Fe) were consistently elevated in earthen pond samples, with Cd and Pb reaching up to 22.43 mg/kg and 22.61 mg/kg, respectively, in the CEF sample. These elevated levels suggest that soil interaction in earthen ponds increases metal exposure to fish, likely due to leaching and sediment interactions.

In contrast, concrete ponds exhibited lower metal levels across all tested metals, with Cd and Pb peaking at 1.26 mg/kg and 5.38 mg/kg, respectively, in ACF. This suggests concrete ponds provide a safer aquaculture environment by limiting soil-water interactions and reducing bioaccumulation risks. The results emphasize concrete ponds as a preferable option for minimizing heavy metal contamination in aquaculture.

**Table 6: Data for Computation of Comparative Analysis of Heavy Metals Concentration in African Catfish (*Clarias gariepinus*) between Earth Pond and Concrete Pond**

| Sample code | Cd | Pb | Ni | Zn | Cu | Fe |
|---|---|---|---|---|---|---|
| **Earthen ponds** | | | | | | |
| AEF | 0.175 | 1.121 | 0.635 | 0.558667 | 0.051 | 1.404333 |
| BEF | 18.35 | 18.43267 | 18.41967 | 18.37133 | 18.306 | 22.15533 |
| CEF | 22.43333 | 22.61333 | 22.53167 | 22.50967 | 22.33 | 23.435 |
| **Concrete ponds** | | | | | | |
| ACF | 1.257 | 5.376 | 3.323 | 3.038 | 0.25 | 10.068 |
| BCF | 0.319667 | 1.517667 | 0.830667 | 0.664 | 0.026667 | 1.797333 |
| CCF | 0.412 | 0.693 | 0.191 | 0.549 | 0.042 | 2.310667 |

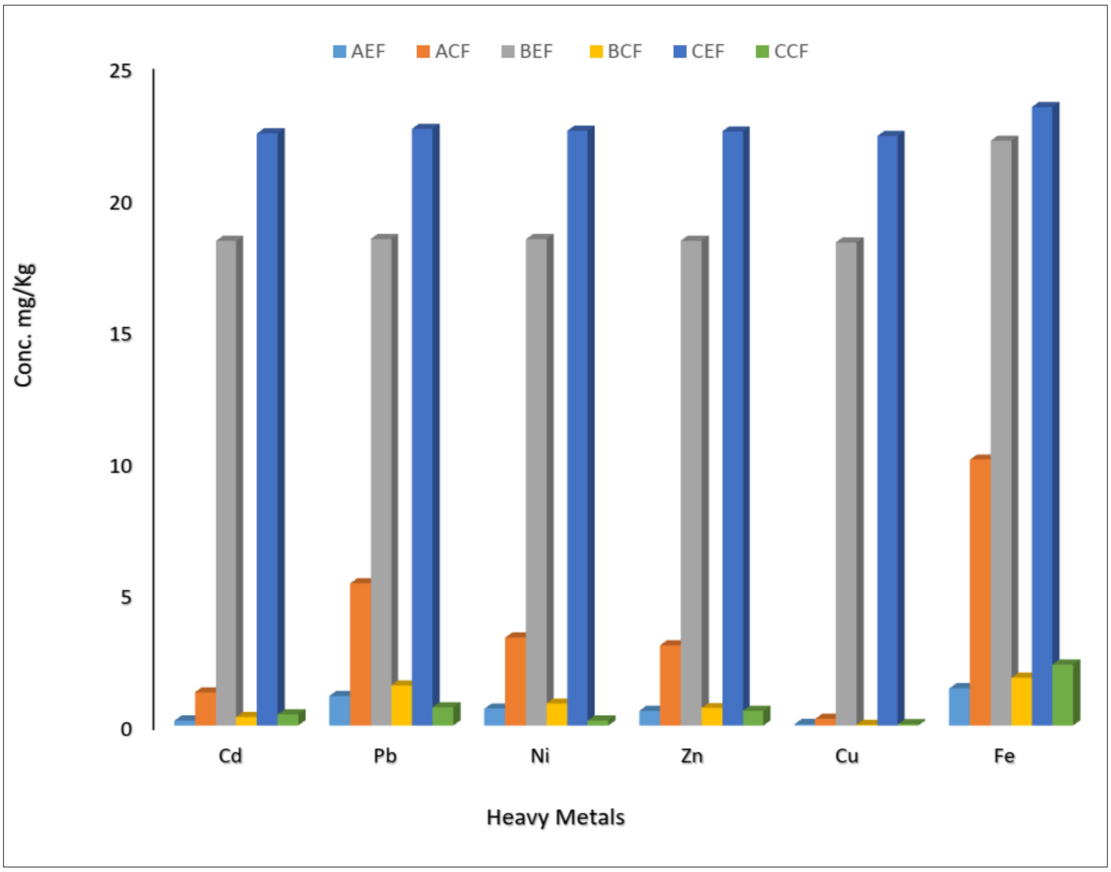


**Figure 4: Comparative Analysis of Heavy Metals Concentration in African Catfish (*Clarias gariepinus*) between Earth Pond and Concrete Pond**

## CONCLUSION

This study reveals significant differences in heavy metal concentrations and physicochemical properties between earthen and concrete ponds used for breeding African catfish (*Clarias gariepinus*) in Port Harcourt, Nigeria. The analysis indicated that while both pond types contained detectable levels of cadmium (Cd) and lead (Pb), concrete ponds had notably higher mean concentrations of Cd (1.257 mg/kg) compared to earthen ponds (0.175 mg/kg), surpassing WHO and FEPA standards. These elevated levels raise concerns for fish health and human consumption. Additionally, physicochemical assessments highlighted variations in water quality, with earthen ponds exhibiting greater turbidity. The findings underscore the need for improved management practices in aquaculture to mitigate heavy metal contamination and protect public health, emphasizing the importance of regular monitoring to ensure the safety of fish products and the integrity of aquatic ecosystems.

## REFERENCES


1. Iketubosin, N. M., Erepamowei, Y., Ajoko, I. T., Ebong, C. U., & Oyaseiye P. E. (2024). Assessment of Heavy Metal Contamination in Water, Crab (*Scylla senrata*) and Sediments in Oil and Non-Oil Producing Communities in Akulga Local Government Area, Rivers State, Nigeria. *Sch Int J Chem Mater Sci*, *7*(9), 124-131.
2. Putshaka, J. D., Akyengo, O., Yakubu, A., & Adejube, A. A. H. (2015). Bioaccumulation of heavy metals in fish (*Tilapia zilli*) and bullfrog (Pyxicephalus edulis) from River Challawa Kano State Nigeria. *AASCIT*, *2*, 30-34.
3. Ali, M. M., & Soltan, M. E. (1996). The impact of three industrial effluents on submerged aquatic plants in the River Nile, Egypt. In Management and Ecology of Freshwater Plants: Proceedings of the 9th International Symposium on Aquatic Weeds, European Weed Research Society (77-83). Springer Netherlands.
4. Osman, A. G., & Kloas, W. (2010). Water quality and heavy metal monitoring in water, sediments, and tissues of the African Catfish Clarias gariepinus (Burchell, 1822) from the River Nile, Egypt. *Journal of Environmental Protection*, *1*(04), 389.
5. Jafari, N. G., & Gunale, V. R. (2006). Hydrobiological study of algae of an urban freshwater river. *Journal of Applied Sciences and Environmental Management*, *10*(2).
6. Ibeto, C. N., & Okoye, C. O. B. (2010). High levels of Heavy metals in Blood of Urban population in Nigeria. *Research Journal of Environmental Sciences*, *4*(4), 371-382.
7. Kumar, G. (2020). Lead Toxicity: Bioaccumulation and histopathological study of the gill of the Teleost fish, Anabas testudineus (Bloch, 1792) exposed to sublethal concentration of Lead nitrate. *Annals of the Romanian Society for Cell Biology*, 1533-1549.
8. Mansour, S. A., & Sidky, M. M. (2002). Ecotoxicological studies. 3. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. *Food chemistry*, *78*(1), 15-22.
9. Hayat, S., Javed, M., & Razzaq, S. (2007). Growth performance of metal stressed major carps viz. Catla catla, Labeo rohita and Cirrhina mrigala reared under semi-intensive culture system. *Pakistan Veterinary Journal*, *27*(1), 8.
10. Karthikeyan, S., Palaniappan, P. L. R. M., & Sabhanayakam, S. (2007). Influence of pH and water hardness upon nickel accumulation in edible fish Cirrhinus mrigala. *Journal of Environmental Biology*, *28*(2), 489.
11. Binning, K., & Baird, D. (2001). Survey of heavy metals in the sediments of the Swartkops River Estuary, Port Elizabeth South Africa. *Water Sa*, *27*(4), 461-466.
12. Osakwe, J. O., Adowei, P., & Horsfall Jr, M. (2014). Heavy metals body burden and evaluation of human health risks in African catfish (*Clarias gariepinus*) from Imo River, Nigeria. *Acta Chimica & Pharmaceutica Indica*, *4*(2), 78-89.
13. American Public Health Association (APHA). 1998. Standard Methods for the Examination of water and waste water.19th ed. New York, USA.
14. Olukunle, O. F., & Oyewumi, O. O. (2017). Physicochemical Properties of Two Fish Ponds in Akure, Implications for Artificial Fish Culture. *International Journal of Environment, Agriculture and Biotechnology*, *2*(2), 238756.
15. Stone, N. M., & Thomforde, H. K., (2004). Understanding Your Fish Pond Water Analysis Report. Cooperative Extension Program, University of Arkansas at Pine Bluff Aquaculture / Fisheries. 4.
16. Ntsama, I. S. B., Tambe, B. A., Biyegue, C. F. N., Pouokam, G., Mentho, H. C., Takadong, J. J. T., & Kansci, G. (2021). The 1st International Conference on Local Resource Exploitation.
17. National Environmental Standards Regulations Enforcement Agency (NESREA). (2011). Guidelines and standards for Environmental Pollution Control in Nigeria.
18. WHO (World Health Organization) (2003). Guidelines for Drinking Water Quality. Vol 1. Recommendation WHO. Geneva 130.
19. Federal Government Protection Agency (FEPA). (2003). Guidelines and Standards For Environmental Pollution Control in Nigeria. 238.
20. Onyena A. P., & Udensi, J. U. (2019). Evaluation of Heavy Metals Concentrations in *Oreochromis niloticus* and *Clarias gariepinus* from River and aquaculture systems within Owerri Metropolis, Imo State Nigeria. *Journal of Food Science and Engineering*, *9*, 131-138.