**Review on Heavy metals in freshwater fish: source, distribution pattern, accumulation levels and human health risk assessment in major rivers in Nigeria**

**Abstract**

Nigeria's waste management and supervision are very inadequate and of low quality. Usually, human activities pollute rivers by releasing contaminant into them. This study reviewed the various sources, distribution patterns, levels of accumulation, and health risks associated with heavy metals in Nigerian freshwater as compared to marine water (lagoons), as well as the mean concentration of heavy metals in various parts of fish body and any potential negative health effects from consuming fish that are high in heavy metals. It is possible to declare that each session could affect the discharge of heavy metals above the allowable limit, including those related to food processing, industrial waste, pharmaceuticals, and dredging, as well as oil and gas, fertilizer production, batteries, tyres, and pesticides (i.e. Federal Environmental Protection Agency). The aquatic environment could be exposed to these heavy metals by runoff brought on by precipitation. As a result, concentrations of these contaminants have risen in fish tissues and organs over the peak values advised by a number of organizations, including the Food and Agriculture Organization, World Health Organization, and United States Environmental Protection Agency. It is impossible to overstate the harmful effects of heavy metal bioaccumulation in aquatic creatures, thus checkmate should be required. In order to compare the accumulation of heavy metals in fish from both marine and freshwater biomes, this review's conclusion revealed that freshwater fish bioaccumulate heavy metals more than marine fish do, the distribution pattern of heavy metals for both the marine and fresh water fishes was not consistent which suggests that rivers should be properly monitored and waste should be recycled.

**Keywords: freshwater fish, marine water fish, heavy metals, source, Accumulation level, health risk assessment**

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## Introduction

Due to their flavor, low cholesterol, soft flesh, and capacity to offer a significant amount of animal protein and important elements to the human diet, fish are widely accepted in menus around the world (Hamidalddin and Al-Zahrani, 2016). While fresh water makes up only one-fourth of the total amount of water on Earth and contains almost no salt, marine water contains

many salts and covers about three-fourths of the planet's surface. Heavy metals in the environment can be brought on by either natural processes or contamination brought on by human activity (Franca *et al.,* 2005). Because they occupy many levels of the food chain, fish have been considered to be excellent indicators of heavy metal contamination in aquatic and marine environments (Karadede-Akin and Unlu, 2007). As a result, fish is a key source of the food chain's transmission of heavy metals to humans (Kaplan, *et al.,* 2011).
Heavy metals are metallic chemical elements with a limited permissible concentration and a highly poisonous ability at low concentrations. They are naturally occurring trace elements in the aquatic environment and part of the earth's crust, and their levels have increased as a result of industrial and agricultural activities (Martin *et al.,* 2015 and Li *et al.,* 2017).

Fish are affected by heavy metal accumulation in the aquatic environment. Compared to marine fish, freshwater fish are more susceptible and exposed to heavy metals. This is due to the fact that freshwater fish typically gain water while losing salt, as opposed to marine fish, which typically lose water while gaining salt (Nikinmaa, 2014). Water solubility, feeding habits, ecology, and fish physiology, including species, age, size, reproductive status, fish health, bioavailability, and various environments, are just a few of the many elements that affect metal accumulation in different sections of fish body (Perugini *et al.,* 2014 and Anandkumar *et al.,* 2017).

In general, heavy metal (iron, zinc, lead, nickel, manganese, etc.) pollution of natural freshwater is a global issue (Abdullah *et al.,* 2007). Generally, fish species found in different location in Nigeria water ways have been widely studied by several authors (Odo *et al.,* 2009; Abowei and Hart, 2007; 2008; Abowei and Ogamba, 2013; Abowei *et al.,* 2007; 2008; Ezekiel *et al.,* 2002; Ogamba *et al.,* 2013a; 2013b;), Solomon *et al.,* (2012), Badejo and Oriyomi (2015), Oyewo (2015), Davis (2009), Sikoki *et al.,* (2008). The types of water bodies and the current water quality conditions determine which fish species are present. For instance, brackish water, estuaries, and sea/marine water are home to shellfish like bivalve and periwinkle, whereas surface water, including fresh water, is home to a variety of fish species, marine and brackish ecosystem. In an aquatic ecosystem, there are three main components. Water, sediment, and aquatic life are some of them (i.e. planktons, fisheries etc). Titilayo and Olufemi (2014) state that fishes can acquire larger concentrations of contaminants than soil and water and are frequently

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found at the top of the aquatic food chain. Fish normally take metals from the metal-contaminated water and bioaccumulate them in their body (tissue, gill, liver, kidneys, bone, blood, and fin).

Fish mostly absorb heavy metals through their epithelia surface, gill pores, water, and food they consume. The assessment of the health risks associated with heavy metal exposure in fish is detrimental and may result in alterations to their physiological and metabolic processes (Emere and Dibal, 2013). Heavy metal could cause lesion in the body and lead to hematological, histopathological and biochemical impairment which could eventually leads to any cardiovascular diseases and cancer. Due to the apparent bioaccumulation and magnification of heavy metals in fish, as pathways to pollution from one trophic level to the other (Akan *et al.*, 2012), biomonitoring of hazardous substance need to be checkmated in fishes. Fishes are used as bioindicators to monitor heavy metals levels in aquatic ecosystem (Uniyimadu *et al.*, 2008). In Nigeria, most industries dispose their effluents without treatment into the environment (Idris *et al.*, 2013). In this way, the various constituents of such wastes may end up in the aquatic food chain. Since fishes is a major source of protein to several people in Nigeria. This review examines information on various heavy metals found in fish from various aquatic system of Nigeria, including their sources, patterns of distribution, degrees of accumulation, and assessments of the risks to human health in Nigeria's major rivers.

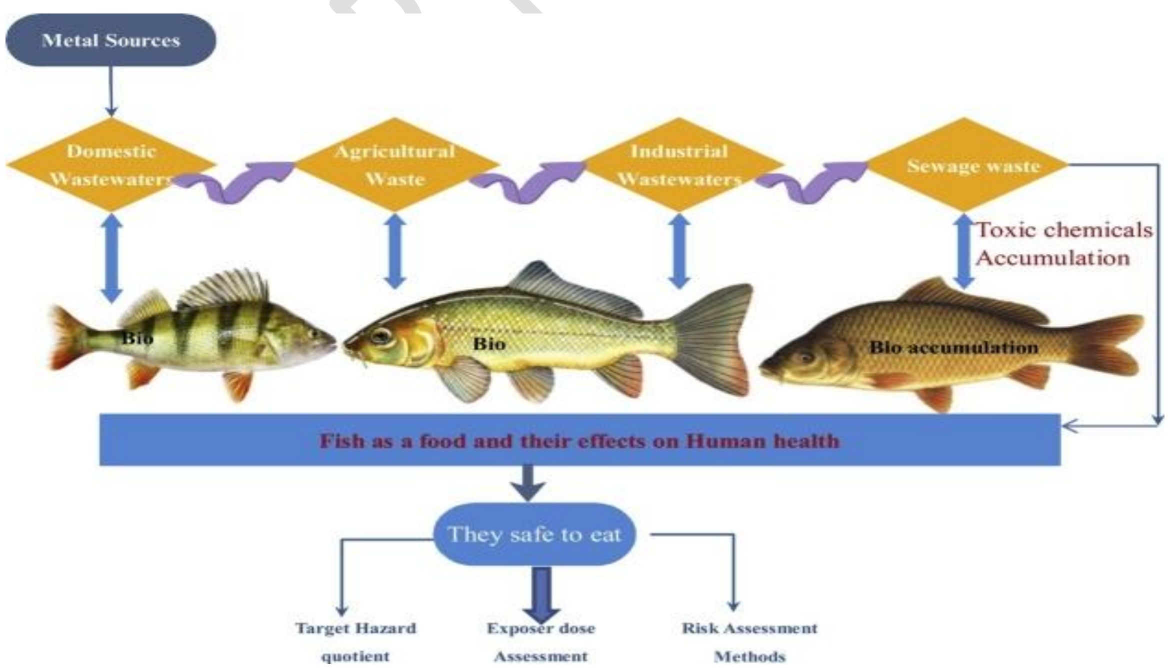


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**Figure 1: Diagrammatic representation of the supply of heavy metal, source, their bioaccumulation in fish, and an evaluation of the health risks (Maurya et al., 2019).**

## Methodology of the Review

Empirical studies published between 2002 and 2023 from Google and Google scholar were downloaded using various keywords such as freshwater fish, marine water fish, heavy metals, source, distribution pattern, Accumulation level, and health risk assessment in fish. All the sourced articles were previewed for importance, and those whose only focus was on heavy metals level in water, sediments and those with focus on other aquatic organisms aside from fish were sectioned out. The chosen articles were then sectioned as stated by the region to each state to give a regional view of metal concentration and their bioaccumulation level in fish.

## The Concentration of heavy metals in tissues/organs and their health implications on freshwater fishes in major rivers in Nigeria

Abarshi *et al.*, 2017 studied the amounts of heavy metals (Cu, Zn, Fe, Mn, Ni, Pb, and Cd) in the muscles, gills, and liver of *Pseudotolithus senegalensis* fish from the Bonny and Finima rivers were examined in this study. The findings showed that every heavy metal in the species under investigation had been found to some degree, with the exception of Cd, which was found only in the gills from the two sample sites. The levels of several metals that were examined in various organs changed significantly (Ᵽ $p<0.05$) between the locations of the samples. Also, the findings demonstrated that, in comparison to other tissues examined, gills had the greatest quantities of heavy metals such Mn, Ni, Pb, and Cd. According to the study, Cu accumulated in all of the fish tissues that were looked at; the greatest mean concentration of the liver tissue of the Finima creek sample contained 52.64-3.01 mg/g dry weight. In contrast, the muscles of fish taken in the Bonny River had the lowest concentration (3.50- 0.77 mg/g dry weight). The concentration of Cu that accumulated in the fish organs examined in both locations was in the range of liver > gills > muscles.

Due to their function in storage, metabolism, and detoxification, binding proteins like metallothioneins may increase the liver's propensity to store necessary metals at higher concentrations, which could explain these increased accumulations of critical metals like copper

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in the liver (Gorur *et al.*, 2012; Zhao *et al.*, 2012). Although Cu concentrations in fish tissues were much greater than the maximum allowed limits established by the Joint FAO/WHO committee (Food and Agriculture Organization/World Health Organization, 1989), the findings made this conclusion crystal evident. According to the study's findings, compared to the muscles, the liver and gills accumulated larger levels of these metals in both sampling sites. An unusually high concentration of heavy metals in fish tissues may be caused by the regular crude oil spills as well as other industrial discharge around the region particularly, the Finima River, which had the highest quantities of all the metals analyzed, and other industrial waste in the area in particular. The levels of various heavy metals found in fish organs that were tested were higher than the suggested maximum allowed limits established by the joint FAO/WHO criteria, suggesting that there may be a risk to humans.

Ojaniyi *et al.,* 2021 The study found that three different fish species were tested in the Ogbaru axis of the River Niger for mean concentrations of As, Al, Cd, Fe, Cr, Cu, Hg, Pb, Ni, and Zn. According to Ismaniza *et al.* (2012) observation of a concentration range of 15.39 - 320.6 mg/kg for aluminum, the highest concentration was found in *Clarias gariepinus*, followed by *Heterotis niloticus* with concentrations of 0.019 mg/kg and 0.005 mg/kg, respectively. This concentration range was attributed to industrial waste, erosion, the dissolution of minerals and salts, atmospheric dust pollution, and rain (Lenhardt *et al.,* 2012). Anguilla labiate had the lowest concentration of arsenic (As), which was lower than that reported by Zrnčić *et al*. (Zrnčić *et al.,* 2013). At 0.002 mg/kg, the values for *Cyprinus carpio* ranged from 0.021 to 0.048 g/g during the research while *C. gariepinus* had the highest value at 0.093 mg/kg. In a watershed area for a tin mining operation, Ashraf *et al.* (2012) measured a concentration of 0.87 mg/kg for *Hampala macrolepidota*. Chromium (Cr) levels in *C. gariepinus* and A. labiate were 0.001 mg/kg. The mean concentration of copper ranged from 2.16 mg/kg to 10.56 mg/kg, with *C. gariepinus* having the lowest value and Anguilla labiate having the highest value. Ikema and Egieborb (Ikema, and Egieborb, 2005) determined that the concentration of copper in a fish sample was only 0.03 mg/kg. The highest concentration of mercury was found in *C. gariepinus*, which had a 0.311 mg/kg concentration, below the 0.5 mg/kg threshold established by the European Communities Commission in 1998.

*Heterotis niloticus* had the highest mean lead content (0.394 mg/kg), followed by Anguilla labiate (0.299 mg/kg), and *Clarias gariepinus* (0.276 mg/kg), which was within the FAO/WHO limit of 0.4 mg/kg for fish species (FAO/WHO, 2011). Cadmium values varied from 0.020 mg/kg to 0.028 mg/kg. Anguilla labiate's muscles had the highest concentration, whereas

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*Heterotis niloticus'* muscles had the lowest. For all three fish species, the zinc value was between 0.245 mg/kg and 1.242 mg/kg. *Heterotis niloticus* had the greatest nickel concentration (0.514 mg/kg), whereas Anguilla labiate had the lowest value (0.322 mg/kg). Anguilla labiate had the highest concentration of iron (Fe), at 1.93 mg/kg. Whereas *Heterotis niloticus* had the lowest value, 1.23mg/kg.

The same samples of heavy metals (Al, As, Cr(VI), Cr(III), Cd, Cu, Pb, Fe, Hg, Ni, Zn), as reported throughout various exposure paths in adults and children, were also the subject of a study on the carcinogenic risk assessment. One can observe that both children and adults were within and above the USEPA standard range of 1.00E-06 - 1.00E-04 (USEPA, 2020), which implies that there will not be any linked cancer risks across different exposure pathways. Al, Cr (III), Cu, Fe, Hg, Zn (0.00E+00), As (2.30E-05), Cd (1.74E-05), Cr (VI) 1.12E-06, Ni (1.72E-04), and Pb (1.33E-06) are the exposure pathways (cancer risk) for adults, while Al, Cr (III), Cu, Fe, Hg, As (9.90E-06), Cd (2.14E-05), Cr (VI) (1.68E-06), Ni (7.83E-05), Pb, Zn (0.00E+00), and (5.96E-07). Children are more likely than adults to experience cancer health risks, even though the value is within the USEPA reference range, as the cumulative cancer risk for children is 1.12E-04 compared to 2.15E04 for adults (USEPA, 2011)

Heavy metals (Al, As, Cd, Cr (III), Cr (VI), Cu, Fe, Hg, Ni, Pb, and Zn) were also tested for their non-carcinogenic risk (THQ). The hazard quotient (THQ) was less than 1 for adults and less than 1 for children, except for dietary exposure to fish (*Anguilla labiate*) in Cu, which had a THQ of 2.09. The adult total exposure pathway to heavy metals (THQ) is more than 1 for Cu and less than 1 for other heavy metals, such as Al (1.26E-05), As (1.19E-01), Cd (2.82E-02), Cr (III) (1.61E-06), Cr (VI) (3.01E-04), Fe (2.59E03), Hg (3.82E-01), Ni (2.30E-02), Pb (1.01E-01), and Zn (2.57E-03). For children, the total THQ is Al (4.39E05), As (2.60E-01), Cd (1.11E-01), Cr (III) (8.93E-06), Cr (VI) (4.45E-03) Cu (2.96E+00), Fe (5.89E-03), Hg (1.30E+00), Ni (5.42E-02), Pb (2.37E-01) and Zn (6.36E-03), which demonstrates that Cu and Hg were larger than 1 and less than 1 for other heavy metals. As a result, we can observe that children's cumulative hazard quotient is 4.93 and whereas adults' cumulative hazard quotient is 2.02, indicating that children are significantly more at risk than adults. The total cancer risk determined by the findings shows that fish consumption in youngsters, both dermally and orally, will result in cancer-related symptoms (Omokpariola, and Omokpariola, 2020). According to the study's total hazard quotient calculations, exposure to fish through any pathway increases the risk of

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unfavorable health effects in both adults and children, thus extra caution is advised (Verbruggen, 2012). These findings indicate that anthropogenic activities that are dispersed over a vast area and released into the River Niger have had a significant impact on fish samples.

Orosun *et al.* (2016) in their study, the results of the heavy metal analysis on catfish and tilapia samples taken from Kiri and Gongola Dams were published. Pb levels in Kiri's catfish vary from 0.012 to 0.021 ppm with a mean of 0.0156 ppm, while levels in samples of tilapia range from 0.005 to 0.012 ppm with a mean of 0.0098 ppm.

The mean Pb concentration in Bare (Downstream) and Mada (Upstream) is 0.0135 and 0.0085 ppm for Catfish and 0.0115 and 0.0120 ppm for Tilapia, respectively. All of the fish samples had varying Pb concentrations, but the catfish from Kiri had the highest mean concentration. The WHO standard of 0.4–0.5 ppm for consumable fish is not exceeded in any of the mean Pb readings, Yet, Pb can bioaccumulate in the human body over time if these fish samples are consumed continuously. For catfish, the content of Cd in Kiri varies from 0.021 to 0.031 ppm, with a mean of 0.0258 ppm, while for Tilapia; it varies from 0.008 to 0.014 ppm, with a mean of 0.0116 ppm. For catfish and tilapia, the mean Cd concentrations in Bare and Mada are 0.0265 and 0.0275 ppm and 0.011 and 0.0085 ppm, respectively. Exposure to cadmium has been linked to increased hypertension and renal damage (Lawrence, 2014).

For catfish, the Cr concentration in Kiri spans from 0.08 to 0.21 ppm with an average value of 0.136 ppm, while for tilapia samples, it ranges from 0.05 to 0.12 ppm with an average value of 0.094 ppm. The average amount of Cr in samples from Bare and Mada are, respectively, 0.11 ppm and 0.135 ppm for catfish, and 0.09 ppm and 0.075 ppm for tilapia fish. The content of iron (Fe) in Kiri varies from 0.510 to 0.820 ppm, with an average value of 0.600 ppm for catfish and from 0.420 to 0.610 ppm, with a mean value of 0.526 ppm for tilapia. All of the Kiri, Bare, and Mada tilapia fish samples were below the detectable limit for arsenic (As) levels. Catfish samples from Mada exhibit a similar pattern. The amount of As that is present in trace amounts is 0.001, and regardless of the region, it has been found that catfish have higher concentrations of these particular heavy metals than tilapia.

For both the general public and the fishermen in all the places, the estimated THQ of each metal owing to fish consumption is less than 1, indicating that there are no obvious health hazards associated with ingesting any particular metals through fish diet. Fe significantly increased risk for both the general populace and fishers in every area. On average, it represented 58% of the

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entire THQ. The second-highest risk, Cr, averaged a contribution of 20.4% to the overall THQ. Cd, Pb, and As are next, with averages of 17.7%, 2.8%, and 1.1%, respectively. For each metal, the predicted target quotients (THQ) fell in the order Fe>Cr>Cd>Pb>As. Catfish THQ values were greater than equivalent Tilapia THQ values in all the areas. This is inferred from the fact that, regardless of location, catfish have higher concentrations of these particular heavy metals than tilapia, which was previously thought to be a result of their different dietary habits and physiologies.

Although there is a relative chance of unfavorable effects, a THQ>1 does not necessarily imply that people would have negative or severe health problems. This suggests that in all the categories, there is no proof of an unacceptable non-cancer risk for the general population. Fishermen and the general public are not thought to be at major risk for health problems as a result of consuming the chosen fish, according to an assessment of the health hazards linked with their eating, heavy metals absorbed by these fishes, accordingly, there is no evidence of an unacceptable non-cancer danger. It is widely recognized that metabolic activity is one of the most crucial elements that significantly contribute to heavy metal buildup in aquatic species (Yujun, Zhifeng, and Shanghong, 2011). The risks to human health from eating fish from this region went much beyond insignificant levels; hence it is important to limit the sources of heavy metal contamination in the hydrosphere.

Akan *et al.* (2012) showed that the tissues of *Tilapia zilli, Clarias anguillaris, Synodentis budgetti*, and *Oreochronmis niloticus* now have high quantities of heavy metals. Fe levels in *T. zilli* varied from 1.08 to 9.23 g/g???, along with 0.33 to 3.45 g/g ??? Zn, 0.11 to 0.44 g/g Mn, 0.05 to 0.32 g/g Cr, 0.12 to 0.39 g/g Cu, 0.11 to 0.96 g/g Cd, 0.16 to 0.31 g/g Pb, 0.11 to 0.69 g/g Ni, and 0. The bioaccumulation of metals in these *T. zilli* tissues is arranged in descending order as follows: Fe > Zn > Cd > Co > Ni > Mn > Cu > Cr > Pb. The order of these metals' bioaccumulation may be because various metals tend to accumulate in different ways in the tissues of various fish species. Fe was the highest in this investigation, followed by Zn, while Pb displays the lowest value.

According to this study, there are heavy metals in the amounts seen in *C. anguillaris'* organs. Fe was present in concentrations between 0.98 and 8.88 g/g, along with Zn, 0.06 to 0.44 µg/g, 0.14 to 0.38 µg/g Mn, 0.22 to 0.93 µg/g Cr, 0.08 to 0.29 µg/g Cu, 0.11 to 0.76 µg/g Cd, 0.13 to 0.45 µg/g Pb, 0.23 to 0.73 µg/g Ni, and 0.26 to 0.89 µg/g Co. The bioaccumulation of metals in these

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tissues occurs in the following order: Fe > Cr >Co> Cd > Ni > Pb > Zn > Mn > Cu. According to this study's analysis of the heavy metal concentrations in the tissues of *S. budgetti*, Fe levels ranged from 0.11 to 0.31 µg/g, Cu from 0.13 to 1.03 µg/g, Cd from 0.04 to 0.38 µg/g, Pb from 0.04 to 0.38 µg/g, Ni from 0.12 to 0.78 µg/g, and Co from 0.08 to 0.34 µg/g. The outcome displays the levels of heavy metals in several *O. niloticus* tissues. Fe concentrations were 0.68 to 8.92 µg/g, 0.08 to 0.21 µg/g Zn, 0.11 to 0.38 µg/g Mn, 0.33 to 0.85 µg/g Cr, 0.14 to 0.38 µg/g Cu, 0.18 to 0.85 µg/g Cd, 0.12 to 0.61 µg/g Pb, 0.23 to 0.95 µg/g Ni, and 0.06 to 0.48 µg/g. *S. budgetti* gill tended to acquire the highest levels of all the metals, whilst *O. nilolitus* showed the lowest levels. All fish have gills that tend to absorb higher quantities of heavy metal than other tissues. *S. budgetti* liver contains significantly more Mn and Cd; *T. zilli* stomach contains the highest concentration of Fe and Zn, while *C. angullaris* has greater amounts of Cr, Pb, Cd, and Co. The buildup and elimination of heavy metals both depend on the liver (Yousafzai, 2004). Fish exposed to high concentrations of heavy metals produce metallothioneine proteins (MT), which proteins bind to metals (Phillips and Rainbow, 1989). The gills of *T. zilli* had the highest concentration of copper in the fish samples (0.39 µg/g), while O. niloticus' flesh had the lowest concentration (0.06 µg/g). The highest concentration, 0.39µg/g, was, nevertheless, below the FAO's recommended limit of 30 µg/g. As a result, all of the Cu concentrations in the fish samples examined fell below the FAO's suggested standard (FAO, 1983). T. zilli's gills had the greatest Zn concentration (3.45 µg/g), and the lowest value of 0.06 µg/g was measured in the *C. angullaris* flesh. Zn has a 30 µg/g maximum guideline set by the FAO (FAO, 1983).

The gill of *O. niloticus* had the highest concentration of Ni (0.95 µg/g), whereas the flesh of *C. angullaris* had the lowest detectable quantity (0.11 µg/g). Ni's estimated maximum recommendation is between 70 and 80 µg/g (USFDA, 1993). As a result, all of the samples' Ni contents were far lower than the established limit. The flesh of C. angullaris had the lowest concentration of Cd (0.11 µg/g), whereas the flesh of S. budgetti had the greatest concentration (1.03µg/g). Humans get Cd from their diet, which contains it. Cr deficiency causes growth impairment and issues with the metabolism of carbohydrates, lipids, and proteins (Calabrese et al., 1985). Cr is a crucial trace metal, and its physiologically useable form is crucial for the metabolism of glucose. The flesh of *S. budgetti* had the lowest detectable concentration, 0.05µg/g, while the gill of *C. angullaris* had the greatest detectable value, 0.93µg/g. The four fish samples' gills and liver had the greatest concentrations of all the metals in the research, while

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the flesh had the lowest concentrations. Thus, the fish in this study region did not provide a risk to humans when consumed.

According to Owhonda *et al.* (2020), the trend of Cd in fish tissues, was as follows: muscles > livers > gills. When compared to upstream fish, downstream fish had a greater concentration of Cd in their gills. From December to March, the mean Cd-1 mg/kg in fish gills varied between 0.048± 0.015 (upstream) and 0.549± 0.152 (downstream), 0.037± 0.030 (upstream) and 0.769± 0.100 (downstream), 0.026± 0.015 (upstream) and 0.902± 0.118 (downstream), and 0.040± 0.018 (upstream) and 0.727± 0. 157 downstream

Fish muscles upstream were higher than those measured downstream in terms of Cd, as opposed to fish gills and livers, which had lower levels. The mean Cd-1mg/kg were found in fish caught from upstream of the study watercourse 5.009 ± 0.363, 5.322 ± 2.048, 4.666 ± 0.860, 4.757 ± 0.962 from December to March. Mean Cd-1mg kg were 2.958 ±0.674, 2.721± 0.885, 3.495± 0.226, and 4.505 0.460 in fish samples collected downstream from December to March. Upstream and downstream fish liver samples showed that Cd levels in December were highest (2.775± 0.303 mg kg-1 and 2.386± 0.528 mg kg-1, respectively), whereas January and March showed the lowest levels (1.627± 0.513 mg kg-1 and 1.638± 0.313 mg kg-1, respectively). In December and March, an analysis of variance showed that there were statistically significant differences ($p < 0.05$) between the upstream and downstream samples.

Pb concentrations in fish tissues increased in the following order: muscles, liver, gills. When compared to fish sampled from Woji Creek's upstream, Fish from the creek's upstream often had higher Pb concentrations. Fish gills in upstream fishes had Pb of 6.324 ± 0.388 mg kg−1, 5.140 ± 1.249 mg kg−1, 5.459 ± 0.471 mg kg−1 and 5.730 ± 0.859 mg kg−1 while downstream fishes had Pb 7.732 ± 0.640 mg kg−1, 9.401 ± 0.711 mg kg−1, 7.575 ± 0.624 mg kg−1 and 7.644 ± 0.637 mg kg−1 in December to March accordingly.

Upstream, the mean Pb concentrations in fish muscles were 0.001 mg kg-1 ±0.001 mg kg-1, 0.001±0.001 mg kg-1, and 0.001± 0.001 mg kg-1, respectively, while values downstream were 40.023±7.984 mg kg-1, 50.860±0.730 mg kg-1, and 51.004±6.047 mg kg-1 and 44.071 ± 5.251 mg kg−1 respectively. An ANOVA analysis of the Pb concentrations in the fish livers showed a statistically significant difference ($p<0.05$) between upstream and downstream samples for each month that was investigated. Mean Pb ranged from 0.003±0.003 mg kg-1 upstream to 24.190± 1.182 mg kg-1 downstream from December to March. It was 0.001±0.001 mg kg-1 upstream to

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22.845±0.463 mg kg-1 downstream in January, 0.001±0.001 mg kg-1 upstream to 25.014±4.218 mg kg-1 downstream in February, and 0.001 mg kg-1 upstream to 24.053 mg kg-1 downstream in March.

When compared to tilapia gills, muscles, and livers sampled upstream and downstream from the research, mean Cd levels in Grey mullet (*Mugil cephalus*) gills, muscles, and liver from the same creek were higher; Mean Pb in tilapia muscles and liver from the study's downstream, however, was higher than that found in Grey mullet (Ihunwo *et al.,* 2020). Although the levels of Cd and Pb in the Redbelly tilapia's muscles and livers were lower than those found in Greychin tilapia sampled from downstream of Woji Creek, the pollution level still poses a serious threat to the health of people who interact with other environmental elements. Fishes can bioaccumulate toxins including metals, metalloids, and other toxic compounds in a contaminated environment through feeding behaviors and physiological processes; through the food chain, these substances may be eaten by people and cause sickness or fatal illnesses (Souza I da et al., 2018). Leaded gasoline, lead-based paint, pottery, lead-battery production, recycling, and disposal, industry operations, and other things are sources of heavy metals.

Mean THQ Cd attributable to intake of fish muscles upstream was 1.30E-01±1.30E-02 and 1.50E-01±1.40E-02 for male and female minors, respectively; however, for male and female adults, it was 1.10E-01±1.00E-02, and 1.10E-01±1.00E-02. Downstream estimated THQ Cd for male and female children were 8.80E-02±1.80E-02 and 1.00E01±2.00E-02, respectively, whereas for male and female adults it was 7.00E-02±1.40E-02 and 7.20E-02±1.50E-02. For male and female children, the target lead hazard quotients owing to eating fish muscles upstream were 7.20E-06 and 8.10E-06, respectively, whereas, for male and female adults, the target hazard quotients were 5.70E-06 and 5.90E-06. For male and female children, the mean THQ Pb attributable to intake of fish muscles downstream was 3.30E-01±3.30E-02, and 3.80E-01± 3.80E-02, whereas for male and female adults, the mean THQ Pb was 2.60E-01± 2.70E-02, and 2.70E-01±2.70E-02.

According to Rios and Méndez-Armenta (2019), metallurgy, fossil fuel exploration, and waste burning are only a few anthropogenic activities that emit cadmium into the environment. The health of people is potentially always at risk from dietary cadmium. Consuming seafood exposes people to various levels of cadmium; the volume ingested and the concentration of cadmium in the seafood are the main determinants of this exposure (Djedjibegovic, 2020). Increased and

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regular eating of fish's internal organs, including the liver and kidney can result in a larger buildup of cadmium in people (ATSDR, 2012).

According to the study, even though children's Hazard Index values were higher than adults', all Hazard Index values were less than 1, indicating non-hazardous conditions for non-carcinogenic risk. The risk of cancer from eating fish muscles was higher in fish sampled upstream of the creek than in fish sampled downstream. For male and female youngsters, the estimated upstream carcinogenic risk index was 1.14E-06 and 1.29E-06, respectively; for male and female adults, it was assessed to be 9.07E-07 and 9.35E-07. According to estimates, the carcinogenic risk index downstream was 7.23E-07 and 7.45E-07 for male and female adults and 9.09E-07 and 1.03E-06 for male and female youngsters, respectively.

The study's findings demonstrated that lead content was higher than cadmium in the fish tissues studied, including the gills, livers, and muscles. While the mean Cd in fish muscles and livers was over the maximum permitted limit (MPL) for FAO, FAO/WHO, and WHO, the mean Cd in fish gills was below the FAO maximum permissible limit (MPL). For FAO, FAO/WHO, and WHO, Pb deposited in the gills of fish upstream and downstream was higher than MPL. The eating of fish upstream and downstream did not indicate a non-carcinogenic risk to human health for either metal. Although upstream fish samples showed minimal adult cancer risk, the cancer risk index (CRI) indicated moderate child cancer risk (male and female). CRI indicated a low risk for adults and juvenile fish in the fish samples taken downstream and modest danger for female children but a high risk for male youngsters.

According to Madu *et al.,* 2017 the study reported that the three fish species have concentrations of heavy metals in the order of gill > liver > muscle. Among the three tissues, *Synodontis resupinatus* showed the greatest level of all heavy metals. Only the levels of Fe and Mn in the fish's gills indicated variations that were statistically significant ($p < 0.05$). The three fish species under study each had a different heavy metal concentration, with Fe having the greatest concentration and Pb having the lowest. The fish's gills consistently accumulated metal in the following order: Fe > Ni > V > Mn > Pb. The ranking order of metal accumulation in the livers of *S. resupinatus* and *Heterotis niloticus* was the same Fe > Ni > V > Mn > Pb; Contrarily, *Clarias gariepinus's* liver exhibited a distinct composition: Fe > Ni > Mn > V > Pb. For *C. gariepinus* and *S. resupinatus*, the muscle of the three fish species studied revealed different

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ranking orders in their patterns of heavy metal accumulation, but for *H. niloticus*, it revealed Fe > Ni > V > Mn > Pb.

The risk of consuming fish on human health was assessed using the mean levels of heavy metals in the muscle of the three fish species. To assess the health risk, the average concentration of each metal in the fish's muscle tissues was transformed from dry weight to wet weight. The except for its Ni content (1.31), *H. niloticus* had the lowest metal concentrations of any species (1.31 mg kg−1), which ($p > 0.05$) did not significantly differ from that of *S. resupinatus*. According to the fish species, the estimated daily intake (EDI) was as follows: *S. resupinatus* > *C. gariepinus* > *H. niloticus*. All three fish had higher EDIs for Fe than for Ni (1.228 in *S. resupinatus*, 0.920 in *C. gariepinus*, and 0.889 in *H. niloticus*). All three fish had the highest target hazard quotients for Pb (0.03 in *S. resupinatus*, 0.02 in *H. niloticus*, and 0.02 in *C. gariepinus*, respectively), but Fe and Mn were lowest in *H. niloticus*, *S. resupinatus*, and *C. gariepinus*.

The concentrations of iron, the most accumulated metal from the study, varied little in the fish, with *S. resupinatus'* gill having the greatest concentration, measuring 132.97 mg kg-1, These results are in line with those of Javed and Usmani, who discovered that *Mastacembelus armatus'* gills in Harduaganj Reservoir, Uttar Pradesh, India, with a maximum Fe content of 799.66 mg kg1 (Javed and Usmani, 2013). Fish tissue dysfunction could result from Pb concentrations in the study's fish tissues above the WHO (2011) limit of 0.01 mg kg-1. Moreover, Ni contents in the tissues of the three fish species were higher than those in *Channa punctatus*, ranging from 6.14 mg kg-1 in the muscle of C. *gariepinus* to 23.88 mg kg-1 in the gill of *S. resupinatus*, *Heteropneustes fossilis* and *Trichogaster fasciata* from urban rivers in Bangladesh (Islam et al., 2015).

A limit of 0.01 mg $kg^{-1}$, may result in fish tissue dysfunction. Mn is an essential metal (EJM, 2011), and its mean concentrations in the tissues of *C. gariepinus* from the study were higher than those reported in the tissues of *C. gariepinus* from the Ikpoba and Ogba Rivers, Nigeria (Obasohan *et al.*, 2008). The tissues of the three fish species had different vanadium concentrations. The V concentration was highest in the gill of *S. resupinatus* (13.97 mg $kg^{-1}$) and lowest in the muscle of *H. niloticus* (3.86 mg $kg^{-1}$). Freshwater fish intake has grown in popularity among Nigerians, particularly those who reside near rivers. The ingestion of

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freshwater fish that contains harmful substances raises serious safety concerns for people (Al-Misned and Mortuza, 2015).

According to USEPA, the estimated daily intakes of Fe, Mn, Ni, and Pb were less than the respective recommended reference values of 7.0x$10^{-1}$ (unit?), 1.4 x$10^{-1}$(unit?), 2.0x $10^{-1}$(unit?), and 3.6x$10^{-1}$(unit?), respectively (2011, 2012). The results of this study consequently support the conclusions of Al-Misned and Mortuza (2015), which assessed the potential health risks associated with eating edible fish in Saudi Arabia. The fish from the river is deemed safe for consumption because there isn't much of a risk to human health from eating unless the river's pollution level rises above its current level. Thus, it is advised that solid wastes be recycled rather than disposed of carelessly. Liquid waste, such as industrial effluents, should be cleaned up before disposal, and environmentally harmful chemicals should be used as little as possible in agricultural methods.

Olayinka-Olagunju *et al.,* 2021 findings of this study indicate the amounts of heavy metals in fish organs (liver, heart, and gills) and muscle (flesh). Four of the eight species that were caught for this investigation were analyzed. Because they were caught across the course of the study's months, these species were chosen. The study shows that there was no evidence of Cr in the hearts of *Clarias gariepinus, Hepsetus odoe*, or *Parachanna obscura*. The quantity found in *Oreochromis niloticus*, however, was 0.002 ppm. The findings indicate that the concentration was below the 0.05–0.15 ppm acceptable level. These low amounts may result from the rapid water flow and mobility of heavy metals at the time the fish sample was collected.

The concentration of cadmium in the fish heart ranged from not detected (ND) to 0.001 ppm. Only the heart of *C. gariepinus* (0.001 ppm) contained the metal, and even then, the concentration was below the legal limit of 0.05 ppm. This suggests that the fish heart was not cadmium-contaminated. Cd, however, may still be extremely harmful at low concentrations, leading to kidney damage and occasionally arthritis (Maurya and Malik 2016; Jarup, 2003). The heart of *T. zillii* had the highest mean copper concentration (0.257 ppm), while *C. gariepinus* had the lowest mean copper concentration (0.086 ppm), both of which are within the range of 3.0 ppm. However, when the four mean concentrations were compared, significant differences ($p<<< 0.05$) were found between *O. niloticus* and *H. odoe*; neither *C. gariepinus* nor *P. obscura* showed any significant statistical differences ($p > 0.05$).

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All the fish species analyzed, except for *H. odoe*, had arsenic (As) found in their hearts. Arsenic may cause skin cancer in people if consumed in fish or water over an extended time (Jarup, 2003). Also, the concentrations of Fe, Mn, and Zn in the fish heart were lower than allowed. These metals are critical trace elements for fish survival, and iron is a crucial component of hemoglobin, which carries oxygen throughout the body. The distribution of the hepatic organ may be impacted by a high Zn concentration in any fish organ. The heart's order of heavy metal content is Fe > Zn > Mn > Cu > As > Pb > Cr > Cd. The results of Maurya and Malik (2018) and Jezierska and Witeska (2006) are comparable to those of this sequence. The tendency suggests that these necessary trace metals are present in the environment and that it is impossible to completely rule out their functions.

The permitted limits were met by the mean concentrations of Fe in the livers of *C. gariepinus, T. zillii, H. odoe,* and *P. obscura*, which ranged from 0.001 to 0.365 ppm, 0.001 to 0.622 ppm, and 0.001 to 0.543 ppm, respectively. Iron is a crucial element that fish require for the synthesis of blood (Ali and Khan, 2019). Cadmium was only found in *H. odoe* and ranged from ND to 0.001 ppm. Copper concentrations ranged from 0.155 to 0.299 ppm on average, additionally, these amounts were under the 5 ppm statutory limit.

In addition, the concentrations of Pb, As, Mn, and Zn varied from ND to 0.029 ppm, 0.001 to 0.002 ppm, 0.198 to 512 ppm, and 0.269 to 519 ppm, respectively. However, it should be noted that all of these metals were within acceptable bounds. Because they are below the established regulatory limits, show that the fish livers were not polluted with the heavy metals. The distribution pattern in the fish liver is Fe > Zn > Mn > Cu > As > Cr > Pb > Cd, which is consistent with findings in fish hearts and Maurya and Malik investigations (2018). Cr levels in the gills were found to be between 0.001 and 0.029 ppm. This average value is below the regulatory threshold, but when the mean concentrations of *C. gariepinus* and *T. zillii* were compared, a significant difference ($p < 0.05$) was found. The same concentration of 0.002 ppm of cadmium was found in *T. zillii* and *P. obscura* but not in *C. gariepinus* or *H. odoe*. These concentrations were below the allowable threshold.

Copper was found in all of the samples analyzed, with *T. zillii* recording the highest mean value of 0.722 ppm and *C. gariepinus* recording the lowest concentration of 0.376 ppm. The average copper content found was below the allowable level. Pb concentrations ranged from 0.004 to 0.030 ppm on average. Significant differences ($p<0.05$) were found when the mean

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concentrations of the heavy metal found in the fish species were compared. The average Pb levels in the gills were, however, less than the WHO-recommended safe limit of 0.29 ppm. Zn varied from 0.542 to 1.308 ppm, As from ND to 0.002 ppm, and Fe ranged from 0.849 to 1.355 pm, while manganese ranged from 0.481 to 0.853 ppm. All of the heavy metals studied were found to be within the established regulatory limits, according to the study's findings.

This study also includes the average levels of heavy metals in fish muscles. The findings showed that the average amounts of Cu ranged widely between 0.230 and 0.373 ppm. The average concentrations were discovered to be below the allowed levels. Four fish species showed substantial differences ($p = 0.001$) from one another. The average zinc concentration was between 0.505 and 0.11 ppm, which is below the permitted legal limit. Significant differences in zinc buildup between fish species were observed ($p = 0.005$). Pb values varied from 0.02 to 0.487 on average. *C. gariepinus* had the lowest concentration, whereas *P. obscura* had the greatest. Manganese levels in the muscle were lower than the regulatory threshold and varied from 0.316 to 0.378 ppm. According to the data discussed above, the levels of heavy metals in the fish organs were below acceptable ranges; however, this restriction could hurt the river's lower aquatic life. According to the findings, there may not be a major concern because all heavy metals from all species are beyond FAO/detection WHO limit.

Oboh and Okpara, 2019, The findings indicate that the mean concentrations of Ni, Zn, Pb, Fe, and Cr in the liver and muscle of *C. gariepinus* were 0.25, 0.57, 0.02, 2.18, 0.48, and 0.15, 0.15, 0.07, 1.60, and 0.62, respectively, whereas *P. obscura* recorded mean concentrations of 0.34, 0.72, 0.28, 5.67, 0.66 for the liver and 0.27, 0.38, 0.18, 3.13, and 0. While the liver and muscle of *P. obscura* in the Owan River had the same order of Fe > Cr > Zn > Ni > Pb, there were notable variances (Fe > Zn > Cr > Ni > Pb and Fe > Cr > Ni > Zn > Pb, respectively). Both of the fish under study consistently had higher concentrations of iron.

The estimated daily intake for *C. gariepinus* was in the following order: Fe > Cr > Ni = Zn > Pb, whereas the total dietary intake was as follows: Cr > Pb > Ni > Fe = Zn, with risk values of 0.015, 0.004, 0.001, 0.000, and 0.000(unit?), respectively. The risk index stood at 0.021(unit?). Whereas the Target Hazard Quotient for *P. obscura* was in the decreasing sequence of Cr > Pb > Ni > Fe > Zn with risk values of 0.014, 0.010, 0.002, 0.001, and 0.000(unit?), respectively, the EDI was in the order of Fe > Cr > Zn > Ni > Pb. This fish's heavy metal hazard index (HI) was 0.027. Chromium made up the largest percentage of the HI in both fish species.

The physiological functions of each organ vary, which can be explained by the differences in degrees of accumulation in the various fish organs. The differences in accumulation in these organs may be significantly influenced by additional characteristics such as regulatory capacity, behavior, and eating habits (Kehinde *et al.*, 2016). Moreover, the metals' chemical makeup, ionic strength, and pH usually act as controlling factors in the accumulation process (Eneji *et al.*, 2011). It was discovered that *C. gariepinus* and *P. obscura* had accumulated heavy metals in their muscle and liver. The Ni levels in *P. obscura* vary from 0.12 to 0.61 mg/kg, which is similar to the values observed by Obasohan (2007) This was less than the 1.28 mg/kg recorded for *C. gariepinus* and *P. obscura* (Adewumi *et al*., 2014).

These heavy metals may ~~be~~ polluted ~~with~~ *C. gariepinus* and *P. obscura*, according to the bioaccumulation parameters that were found in this study. According to Jezierska and Witeska (2006), bioaccumulation of metals in different fish organs may result in structural lesions and functional disruptions, which could affect the fish's physiological processes and pose substantial risks to humans who consume these species. Consuming *C. gariepinus* and *P. obscura* resulted in risk indices of 0.021 and 0.027, respectively. As the HI is less than one (1), it may be deduced that eating these fish will not likely have any negative effects on customers' health, allaying concerns about heavy metal-induced health problems.

Tyokumbur, and Umma, 2017 In the order of bone, intestine, muscle, liver, gills, gut, and fins in the two fish species, *Late niloticus*, the mean Ni concentration was highest in the fins (2.73ppm) and lowest in the bones (0.1ppm). In *Channa obscura*, the gut had the greatest mean Ni concentration (1.24 ppm), whereas the intestine had the lowest (0.11 ppm), in the following order: intestine<muscle<gills<bone fins gut. The two fish species' organs and tissues all had mean Ni concentrations that were higher than the World Health Organization's (WHO) tolerable recommended limit threshold of 0.07 ppm (WHO, 2008).

The fins of *L. niloticus* had the highest mean V (6.50 ppm), whereas the muscle of *C. obscura* had the lowest mean V (0.13 ppm). The fins of *C. obscura* had the greatest value (2.35ppm), whereas the leaves had the lowest was 0.05ppm (intestine) in the order: intestine<liver<muscle<bone<gut<fins. The bones, muscles, liver, gut, intestine, and fins of *L. niloticus* had the lowest mean V concentration (0.14 ppm), whereas the fins had the greatest mean V concentration (6.50 ppm). The two fish species' organs and tissues had mean V levels throughout were higher than the WHO permitted limit recommendation norm of 0.02 ppm.

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The intestine of the two fish species, *L. niloticus*, had the greatest mean Se content (11.80 ppm), while the gills of *C. obscura* had the lowest (0.12 ppm) concentration. The fins of *C. obscura* had the highest mean value (0.89 ppm), while the gills had the lowest (0.12 ppm), in that order. gills<muscle<intestine<gut<liver<fins. In *L. niloticus*, the intestine had the greatest mean Se concentration (11.80ppm), followed by the liver (0.58ppm), the fin (0.58ppm), the muscle (0.58ppm), and the bones (0.58ppm). The mean Se content in all of the organs and tissues of the two fish species under study was higher than the WHO-recommended tolerable limit guideline standard of 0.04 ppm (World Health Organization, 2008).

The fish is unfit for human eating as evidenced by the high mean concentration of Ni, V, and Se, which exceeded the World Health Organization's (WHO) permitted limit guideline levels. When Cu is the heavy metal in question, the muscles (flesh) of both fish are safe to eat. It is significant to highlight that all the heavy metals, including Ni, V, Se, and Cu, have well-known physiological roles in cells; they could endanger the health of people at the top of the food chain if their consumption is kept above the recommended level (Cui *et al.*, 2015). As a result, the study demonstrates that >75% of the mean heavy metal content in the organs and tissues of *C. obscura* and *L. niloticus* was beyond the safe intake threshold set by the World Health Organization.

Obasohan *et al.*, 2008 discovered that the accumulation of each metal differed not just between the rivers but also between stations of the same river. The order of Cu levels in the Catfish tissues of the Ikpoba River was offal> gills> liver>muscle (Station 1) and offal> muscle> gills> liver (Station 2), whereas the order of Cu levels in the tissues of the Ogba River was offal> liver>muscle>gills (Station 1) and offal> muscle> gills> liver (Station 1) (Station 2). The majority of tissues had varying Cu concentrations ($p<0.05$). The computed bioaccumulation factor (BF), which was much greater in offal and indicated that Cu uptake was presumably through food in the stomach, supported this. The distribution of Cu in tissues appeared to have followed that in water. Similar results on fish bioaccumulation in the Ogba River were reported (Wangboje and Oronsaye, 2001). Across the rivers, there were no discernible differences in the levels of copper in tissues ($p>0.05$).

Fish from the Ikpoba River had tissue Zn levels that were muscle>offal>gills>liver (Station 1) and offal>muscle>gills~~>gills~~ (Station 2), whereas fish from the Ogba River had tissue Zn levels that were liver>offal>muscle>gills (Station 1) and offal>muscle>gills>gills (Station 2). Zn levels

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were higher in offal than in gills, similar to the case with Cu, indicating uptake most likely through the stomach. The estimated bioaccumulation factor of tissue Zn values, which were similarly highest in offal, supported this (except liver at Station 2 of Ogba River). Except for the liver and gills, the tissues' Zn levels in the rivers were similar (p>0.05) (Ogba River). Fish from the Ikpoba River have higher levels of Mn in their gills than in their muscles, offal, and liver. On the other hand, in the Ogba River, the order was offal>liver>muscle>gills (Station 1) and gills>offal>muscle> liver (Station 2). Across sites along the same river and between the rivers, Mn profiles did not reveal any distinctive patterns. In the Ikpoba River, there were no stations with significantly different amounts of Mn tissue (p>0.05), but in the Ogba River, the gills and liver had distinct levels (p<0.05). Fish from the Ikpoba River had tissue levels of Cd in the following order: offal=liver>muscle>gills (Station 1), gills>liver=muscle>offal (Station 2), whereas fish from the Ogba River had tissue levels in the following order: offal>liver>muscle>gills (Station 1), offal>liver=muscle>gills (Station 2). Except at Station 2 in the Ikpoba River, Cd profiles generally followed a trend that showed maximum levels in offal and lowest levels in gills. The fish's tendency to feed on the bottom may account for the high levels of offal. According to Idodo-analysis Umeh's, (2002), fish that is bottom-feed acquired more heavy metals in their offal.

Although in the Ogba River, the order was liver > offal > muscle > gills (Station 1) and gills>offal > muscle > liver (Station 2), the Cr mean levels in fish tissues of the Ikpoba River were in the order of gills > liver > muscle > offal (Station 2). Cr levels in tissues did not follow any particular patterns; however offal levels were higher at the river stations than in tissues, except for Station 1 of the Ogba River. The significant discrepancies (p<0.05) between the Cr tissue levels in the rivers and the tissue levels at the station correlate with the water's Cr content. This might be caused by variations in the water chemistry at the rivers' stations. Large concentrations in the gills suggested Cr uptake by fish gills. Station 1 of the Ogba River had the highest BF values of Cr in all tissues, which may account for the station's considerably elevated (p<0.05) tissue levels.

The buildup of Pb in the fish tissues of the two rivers did not exhibit any clear trends, but it appeared that the gills and muscles had the highest concentrations of Pb, except for the liver at Station 1 of the Ikpoba River and the offal at Station 1 of the Ogba River. Except for the gills in rivers, the differences in tissue levels at the stations were not significant (p>0.05) in Ogba River.

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Variations in metal bioaccumulation in fish tissues depend on a variety of factors, including the fish's diet and foraging style, trophic status, the source of a specific metal, the organism's proximity to the source of contamination, and the presence of other ions in the environment (Giesy and Wiener, 1977), the availability of food (Chen and Folt, 2000), the bio-magnification and/or diminishing of a specific metal (Barlas, 1999), and the presence of metallothioneins and other metal-detoxifying proteins in the fish's body (Deb and Fukushima, 1999); temperature, metal transport across the membrane, and the animal's metabolic rate (Oguzie, 2003); species, age, size, and exposure time (Idodo Umeh, 2002); and the location and function of the organ in the fish (Nussey *et al.*, 2000).

The levels of all the metals in the tissues of the fish from the two rivers were higher than the maximum permitted limits for food fish established by the WHO in 1984 and the FEPA in 2003. The conclusion implied that the fish from the Ikpoba and Ogba Rivers were tainted to a point where eating them might be dangerous. With the sizeable population that depends on these rivers for their fish supply, this has major ramifications.


**Figure 2: An illustration of the heavy metals contamination of the aquatic ecology. (Environmental Pollution with Heavy Metals: A Public Health Concern DOI: http://dx.doi.org/10.5772/intechopen.96805)**

**Table 1: Frequency of fish species that are frequently found from common rivers at different states across the six geopolitical zones of Nigeria**

| Region | River | State | Fish Specie |
|---|---|---|---|
| **South South** | Bonny River | Rivers | *P. senegalensis,* |
| | Finima creek | Rivers | *P. senegalensis* |
| | Ogbaru axis | Rivers | *C. gariepinus, H. niloticus* |
| | Intertidal creek | Delta | *S. melanotheron, M. cephalus* |
| | Woji creek | Delta | *Greychin tilapia* |
| | Lower sombreiro river | Delta | *Mugil cephalus* |
| | Ogba Rivers | Edo | *C. gariepinus, S. resupinatus, H. niloticus,* |
| | Ikpoba river | Edo | *C. gariepinus* |
| | Owan River | Edo | *P. obscura, C. gariepinus, E.fimbrata* |
| | Ogba river | Edo | *P. obscura* |
| | River Nun | Bayelsa | *C. citharus,* |
| | River okumeshi | Delta | *C. gariepinus* |
| | Warri River | Delta | *Arius gigas, E. fimbrata* |
| | Calabar river | Cross-river | *C. gariepinus* |
| **South West** | Ogbese River | Ondo | *C. gariepinus, H. odoe,* and *P. obscura. O. niloticus* |
| | Lagos lagoon | Lagos | *C. nigrodigitatus, C. gariepinus, S. melanotheron, T. zilli, P. senegalensesis* |
| | Ogun estuary | Ogun | *H. forskahlii, E. fimbrata* |
| | Alaro stream | Oyo | *S. melanotheron* |

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**Table 2: Frequency of fish species that are frequently found from common rivers at different states across the six geopolitical zones of Nigeria (Continued)**

| Region | River | State | Fish Specie |
|---|---|---|---|
| North | Kiri and gongola dam | Adamawa | *S. melanotheron,C. gariepinus* |
| | Bare and mada stream | Nasarawa | *S. melanotheron,C. gariepinus* |
| | Benue River | Adamawa | *T. zilli, C. anguillaris, S. budgetti* and *O. niloticus* |
| | Niger river | Kogi | *S. resupinatus, H. niloticus, C. nigrodigitatus, C. gariepinus* |
| | River oil, kainji lake | Niger | *C. nigrodigitatus,E.fimbrata* |
| | River Benue | Makurdi | *T. zilli, C. gariepinus, E.fimbrata* |
| | Wukari River | Taraba | *C. gariepinus, L. niloticus C. obscura,* |
| | Yobe River | Yobe | *C. gariepinus,* |
| | Adamu lake | Jigawa | *O. niloticus* |
| | River Galma kubanni | Kaduna | *C. gariepinus,* |
| South East | Oguta Lake | Imo | *O. niloticus, A. rostrata, C. gariepinus, C. arous* |
| | Imo river | Imo | *C. gariepinus* |
| | Qua Iboe River | Abia | *C. gariepinus* |
| | Abia River | Abia | *M. cephalus, T. guineesis* |
| | River Niger | Anambra | *T. zilli, M. electricus, C. gariepinus* |

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**Comparison of the freshwater fish and marine water (lagoon) fish in Nigeria**

According to the Bawa-Allah *et al.,* 2018 report, the heavy metal accumulation in *Sarotherondon melanotheron* collected from Lagos lagoon revealed that *S. melanotheron* bio-concentrated Pb, Zn, by factors of 2.35 and 11.00 by following the surrounding media. This result was obtained from Lagos lagoon for marine fish. *S. melanotheron* was found to have less heavy metal (Pb, Zn, Ni, Co, Cr, and Cd) than the FAO's maximum suggested limit (1983) The final consumer is not in danger of *S. melanotheron* contamination. The content of Zn is highest in the fish body.

According to a study by Yahaya *et al.,* 2021, Pb and Cd levels in catfish from the Bariga session of the Lagos lagoon were higher than WHO-allowed limits, whereas Zn, Cu, and Mn levels were normal. Pb and Cd were found in the fish's head, trunks, and tail. The concentration of Zn was highest in the fish body (2.300.020mg/kg), and the concentration of Cu was lowest (0.370.500mg/kg). Zn has a high concentration in this study compared to other heavy metals. That might be because of the natural abundance of zinc in the Nigerian environment, which has a significant concentration in the aquatic environment. Particularly concerning are the Cd and Pb levels that were found to be above the allowable limit.

According to Abdul *et al.,* 2019 study on the heavy metal pollution in the Lekki session of the Lagos lagoon, all fish samples had Zn and Fe in their livers, gills, and muscles. *Schilbe mystus* and *Mormyrus rume* had traces of Ni in their livers and gills, while *Gymnarchus niloticus* was the only species with Cr in its gills. However, not all of the samples contained Co, Cd, or Pb. The livers of *Cynoglossus senegalensis* (0.633 mg/kg) and *M. rume* (1.119 mg/kg) have the highest levels of iron and zinc. Fe levels changed in the following order: For samples from *G. niloticus*, *C. senegalensis*, and *M. rume*, in the following order: Liver>Gill>Muscle for *S. mystus* and *Chrysichthys nigrodigitatus*, gills>muscle>liver and gills>liver>muscle was present. Zn, on the other hand, was found in the following sequence in *M. rume*: Liver>Muscle>Gill, while it was found in the following sequence in *S. mystus*, *G. niloticus*, and *C. nigrodigitatus*. The order of the zinc concentrations in *C. senegalensis* was Gill>Muscle>Liver. Because of the possible impacts of pollution on both fish and humans, the quantity of metal deposition in fish is of great interest (Burger and Gochfield, 2005). *M. rume* bioaccumulated Zn in connection to water at a higher concentration than other fish species, according to the bioaccumulation factors (BAF) of

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heavy metals in fish concerning water and sediment from the study. After it came *S. mystus*, *C. senegalensis*, *G. niloticus*, and *C. nigrodigitatus*. *S. mystus* has high bioaccumulation of nickel, and the bioaccumulation of Fe, Zn, and Cr in all fish species in connection to sediment was detected from the study, however, it was relatively modest when compared to fish to water. Yet, the levels of these metals in the fish species are within acceptable ranges.

It can be seen that freshwater fish tend to accumulate more heavy metals in their organs than marine fish when comparing the accumulation of heavy metals in fish from both the marine and freshwater biomes. Since freshwater fish prefer to lose salt and gain water, the two biomes differ significantly from one another. Marine fish, on the other hand, frequently lose water while gaining salt. Freshwater fish are therefore more exposed and fragile to metal-heavy contamination, (Nikinmaa, 2014). As a result of their toxicity and capacity to bioaccumulate in aquatic biomes, heavy metals are particularly significant (Miller et al., 2002).

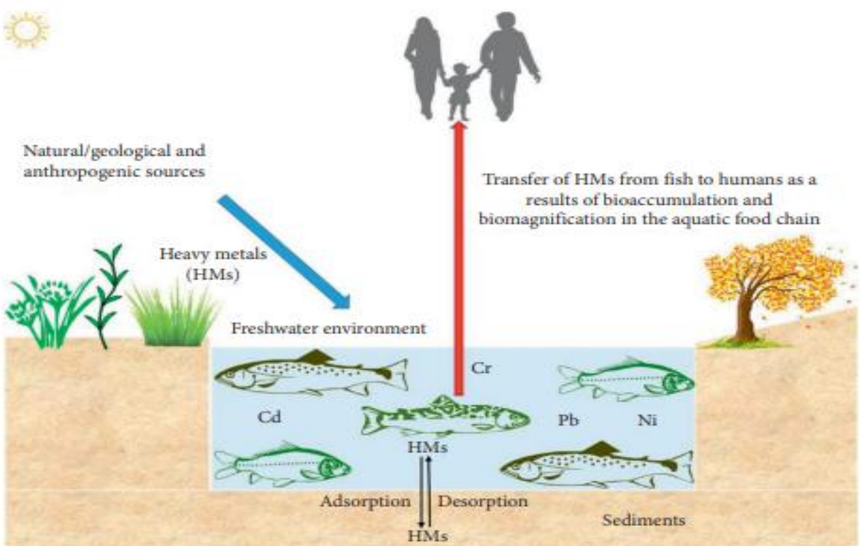


**Figure 3: Tropical human food chain transmission of heavy metals from freshwater fish to humans (Ali et al., 2019).**

**General overview of the source and accumulation level of heavy metals in freshwater and marine water fish**

In Nigeria, surface water sources have been the source of numerous reports of heavy metals in fish. The concentration, source, pattern of distribution, and health risk assessment of the heavy metals that are frequently found in Nigeria are covered in this section of the review along with their permissible/tolerable limits as advised/specified by the Food and Agricultural Organization, World Health Organization, and the United States Environmental Protection Agency. According to the analysis above, the numbers of heavy metals that have been detected in various fish parts in Nigeria often exceed the limits advised by Food and Agricultural Organization/ World Health Organization, and seldom exceed the limit recommended by United State Environmental Protection Agency. Various fish species have been reported for bioaccumulation, including *Chrisichthyes nigrodigitatus, C. gariepinus, Tilapia zilli, Mormyrus rume, Anguilla labiate, Heterotis niloticus, Hepsetus odoe, Lates niloticus, Synodentis schall, Oreochromics niloticus, Parachana obscura, Synodentis budgetti, Sarotherodon melanotheron, Channa obscura and Synodontis resupinatus* geopolitical zones of Nigeria (i.e. South-South, South-East, South-West, North-Central, NorthEast, and North-West).

The research was conducted across Nigeria, According to Abarshi *et al.* (2017), in their study, heavy metal concentration exceeded the limits set by the Food and Agriculture Organization/World Health Organization, the European Union, and the United States Environmental Protection Agency for cadmium, lead, nickel, copper, manganese, iron, and zinc. It also frequently exceeded the limits for cadmium and lead and infrequently exceeded the limits for zinc. In addition to the Aghoghovwia *et al.* (2016) study from the Warri River, certain heavy metals like cadmium, lead, and iron frequently surpass the different thresholds, but chromium, copper, zinc, and manganese seldom ever do. Because their concentration in fish parts followed the trend of other metals, vigilance should be taken while handling fish that contain these metals to prevent any negative health repercussions. The pattern of heavy metal accumulation concerning different fish species and their components revealed inconsistency. This pattern in fish has been described by numerous writers. According to different parts, Abarshi *et al.* (2017) revealed that the fish's heavy metal trend was Cu>Zn>Fe (liver>gills>muscle), followed by Mn>Ni>Pb>Cd (gill>liver>muscle) in *P. senegalensis*. The trend of Fe>Zn>Mn>Cu>As>Pb>Cr>Cd (heart) and Fe>Zn>Mn>Cu>As>Pb>Cr>Cd (liver) was reported by Olayinka-Olagunju *et al.* (2021) in (*C. gariepinus* and O. niloticus). In addition, Madu *et al.* (2017) noted a strong tendency in fish tissues with the elements Fe>Ni>V>Mn>Pb (*S. resupinatus* and *H. niloticus*), Fe>Ni>Mn>V>Pb (*C. gariepinus*). Fish regulates manganese and chromium primarily through a variety of metabolic processes (Ekeanyanwu *et al.*, 2011)

The sources of heavy metal pollution are mostly human activities and, to a lesser extent, natural processes, and natural effects' scope. In general, when industrial wastes containing hazardous heavy metals enter the aquatic ecosystem, it may affect the aquatic biotic community, including

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fish. Because of the potential for toxicity, the presence of heavy metals in aquatic ecosystems is a serious problem (Ntiforo *et al.,* 2012). The ability of creatures to digest metals as well as the concentration of such metal in the water body, sediment, and adjacent soil eating habits of such species are major determinants of the bioaccumulation of heavy metals in aquatic animals (Eneji *et al.*, 2011).

The differences between the several heavy metals found in fish are extremely complex. Fundamentally, it might result from changes in the level of water bodies that are contaminated. Other authors have reported that heavy metal accumulation is influenced by internal and external factors, including individual variability, body size, development stage, sex, breeding condition, brooding, molting and growth, and behavior (Olgunolu *et al.,* 2015; Gokoglu *et al.*, 2008; Cogun *et al.,* 2006). External factors include dissolved metals, physicochemistry, dissolved oxygen, interactions between metals, sediment, food, seasonal effects, behavior, physicochemical properties of contaminants, their distribution pattern in the aquatic ecosystem, the feeding mode, lipid content in the tissue, and metabolism of the aquatic organism (Ezemonye *et al.,* 2009; Ada *et al.,* 2012; Eneji *et al.,* 2011; Olgunoğlu *et al.,* 2015; Perera *et al.,* 2015; Aghoghovwia *et al.,* 2016)

The level of bioaccumulation varies among fish under the same environmental conditions depending on the region. The amount of contamination in that particular river may be to blame for this. In general, the bioaccumulation and bioavailability patterns of the heavy metals in the various tissues and organs displayed irregularities. This variation was attributed by Eneji *et al.* (2011) to bioavailability, intrinsic fish processes, the trophic structure of the ecosystem, as well as variation in thresholds (i.e. concentration of the heavy metal at which it starts to affect the physiology of the fishes in such a way that once a specific level of the metal has been sequestered in the body). The gill is the primary pathway by which dissolved metals enter fish among all the tissues and organs. This can be a result of their sensitivity according to changes in the water and the gill filaments and lamellae's capacity to come into touch with pollutants (Olgunolu *et al.,* 2015). One of the primary locations where heavy metals accumulate in fish is in their gills (Eneji *et al.,* 2011; Ekeanyanwu *et al.,* 2011). This might be a result of the fact that the gills, or gill lamellae, are an essential component in respiration.

**Human Health Risks Associated with Heavy metals**

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Heavy metal-related illnesses are typically very serious. In a Japanese zinc mine, ittai-ittai, a rheumatic disease, claimed many lives in a single catastrophic event of cadmium poisoning, according to Akporido and Ipeaiyeda (2014). Many types of diseases may be brought on by chronic exposure to heavy metals through dietary consumption. The kidney, liver, and bone have all been reported to suffer substantial harm from chronic exposure to cadmium. The development of autoimmunity, in which a person's immune system attacks their cells, resulting in joint diseases, kidney, circulatory system, and neurodegenerative diseases, as well as cancer, abdominal pain, skin lesions, and kidney damage and hypertension (caused by cadmium), are additional diseases that could be brought on by exposure to heavy metals. Lead and arsenic are also known to cause brain damage at high concentrations (Akan *et al.*, 2010).

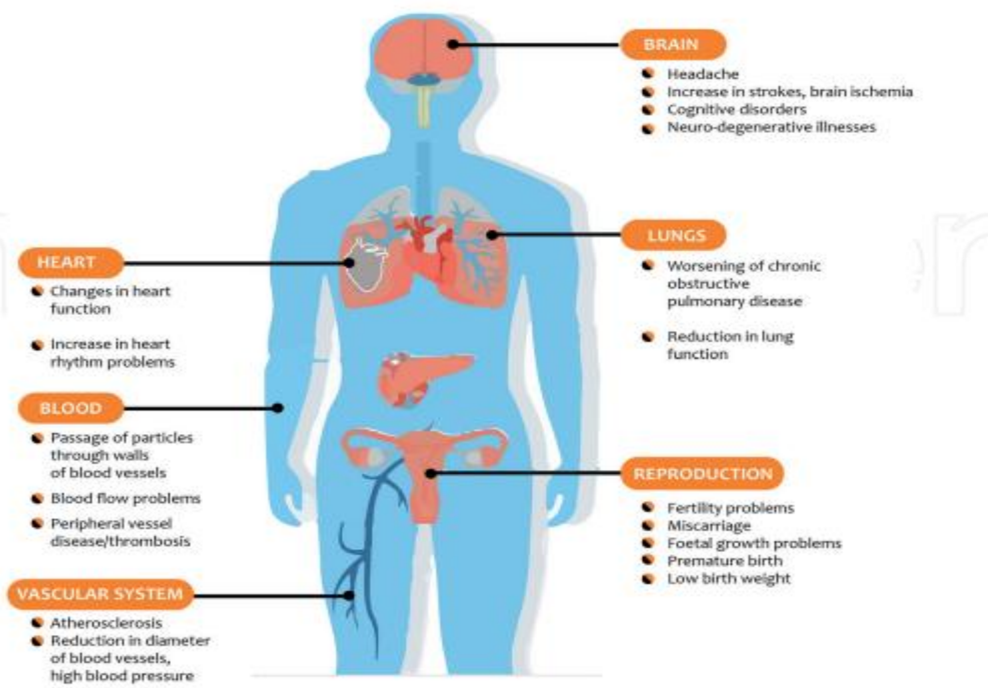


**Figure 4: Effects of heavy metals on several health-related essential organs in humans. Environmental Pollution with Heavy Metals: A Public Health Concern DOI: http://dx.doi.org/10.5772/intechopen.96805**

**Conclusion**

Liquid Waste, such as industrial effluents, should be cleaned up before disposal, and environmentally harmful chemicals should be used as little as possible in agricultural methods.

The maximum allowable level of heavy metals in freshwater fishes according to the WHO and FAO regulations was above (80%), yet the distribution pattern of heavy metal concentration and accumulation from this review did not indicate a consistent pattern when compared to seawater fish, which is within the limit, according to this review. It can be seen that freshwater fish tend to accumulate more heavy metals in their organs than marine fish when comparing the accumulation of heavy metals in fish from both the marine and freshwater biomes. Since freshwater fish prefer to lose salt and gain water, the two biomes differ significantly from one another. Marine fish, on the other hand, frequently lose water while gaining salt. Freshwater fish are consequently more exposed to and susceptible to heavy metal pollution. Because of their toxicity and capacity to bioaccumulate in aquatic biomes, heavy metals are particularly significant.

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