Progress in Chemical and Biochemical Research

Journal homepage: www.pcbiochemres.com

Original Research Article

Assessment of Heavy Metal Content in Fish Obtained from Selected Rivers and Ponds of Nasarawa West Region, Nasarawa State

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ARTICLE INFO

Article history

Submitted: 2023-07-31
Revised: 2023-09-08
Accepted: 2023-09-19
Available online: 2023-09-26
Manuscript ID: PCBR-2307-1270
DOI:10.48309/pcbr.2023.409486.1270

KEYWORDS

Fish
Pond
River
Heavy Metals
AAS

ABSTRACT

In this study, fish samples were collected from Karu, Keffi, Kokona, and Nasarawa local governments for heavy metal analysis via Atomic Absorption Spectrometry. The primary objective was to assess heavy metal concentrations (Cr, Cd, Pb, Cu, Mn, and Ni) in fish from rivers and ponds across these regions. Results exhibited substantial variations in heavy metal content. Manganese (Mn) concentrations spanned from 73.63 mg/kg to 124.60 mg/kg in Karu, 48.79 mg/kg to 99.5 mg/kg in Nasarawa, 78.52 mg/kg to 85.49 mg/kg in Keffi, and 32.07 mg/kg to 60.86 mg/kg in Kokona L.G.A. Chromium (Cr) levels ranged from 2.31 mg/kg to 6.99 mg/kg in Karu, 2.92 mg/kg to 6.86 mg/kg in Nasarawa, 5.00 mg/kg to 5.17 mg/kg in Kokona, and 2.02 mg/kg to 3.39 mg/kg in Keffi. Copper (Cu) exhibited a range of 18.82 mg/kg to 61.15 mg/kg in Karu, 14.86 mg/kg to 33.74 mg/kg in Kokona, 3.85 mg/kg to 24.52 mg/kg in Nasarawa, and 8.48 mg/kg to 16.92 mg/kg in Keffi. Cadmium (Cd) was solely detected in Kokona pond samples (0.06 mg/kg). Lead (Pb) concentrations spanned from 0.93 mg/kg to 1.93 mg/kg in Kokona, 0.01 mg/kg to 0.48 mg/kg in Karu, 0.003 mg/kg to 0.24 mg/kg in Nasarawa, and 0.08 mg/kg in Keffi. Nickel (Ni) content ranged from 2.48 mg/kg to 3.36 mg/kg in Karu, 0.78 mg/kg in Keffi, 2.67 mg/kg in Kokona pond, and 1.67 mg/kg in Nasarawa river. Manganese was consistently the most prevalent heavy metal in all locations, with Lead showing the lowest bioaccumulation index in Karu ponds. Elevated metal concentrations in these fish are likely linked to mining, pesticide usage, and local irrigation practices, particularly in Karu. Chromium, Nickel, and Lead concentrations adhered to WHO/FAO recommendations. However, some samples exceeded permissible limits for Manganese and Copper, posing potential risks to human consumption, except for Cadmium, which was solely found in Kokona pond samples.

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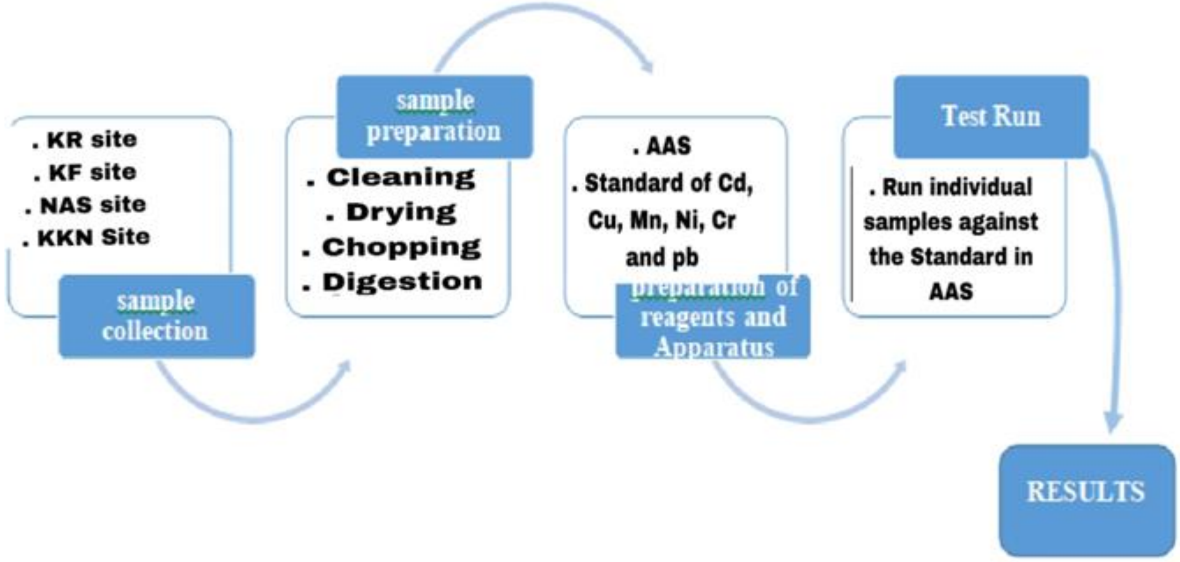
GRAPHICAL ABSTRACT



1. INTRODUCTION

Heavy metals refer to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentration [1].

Heavy metals are natural component of the earth crust, they cannot be degraded or destroyed, to a small extent they enter our bodies via food, drinking water and air as trace elements. Some heavy metals (e.g copper, selenium and zinc) are essential to maintain the metabolism of the human body. However, at higher concentration they can lead to poisoning. Heavy metal poisoning could result, for instance from drinking water contamination (e.g lead pipe), high ambient air concentration near emission source or intake via the food chain. Heavy metals are dangerous because they tend to bio accumulate. Bioaccumulation means an increase in the concentration of chemicals in a biological organism overtime, compared to the chemical's concentration in the environment [2]. Trace metal pollution originates from natural and human activities, including industrial effluent discharges, atmospheric deposition, mining, agricultural runoffs, and urbanization [3]. The contamination of these heavy metals in food is a matter of great concern for human health because they are toxic in nature even at relatively low concentration can cause adverse effects. The metals that are particularly concern in relation to harmful effect on health are mercury, lead, cadmium, tin, arsenic [4].

Inspite of the various health benefits and pleasure associated with the consumption of fish particularly with the awareness of its nutritional and therapeutic benefits which include healthy development of human brain [5], reduction in the incidence of premature birth, heart diseases and stroke [6], fish are at a higher level of the food chain, and they are also widely used to biologically monitor the degree of metal pollution in aquatic ecosystems [7], as fish may concentrate large amounts of some metals from the water [8]. Fish in heavy metal polluted water are susceptible and vulnerable to toxicological problems because of their feeding habits and location in water environments [9] and the issue of these heavy metal intake in these fishes has become a global concern that require an immediate attention [10]. The toxicity of heavy metals has two main aspects; the fact that have known metabolic function but when present in the body they distribute normal cellular process, leading to toxicity in a number of organs also the potentials of the so called heavy metals. Mercury and lead to accumulate in biological tissues a process known as bioaccumulation, this occurs because the metals once taken up into the body, is stored in particular organs [11]. For examples the liver or the kidney and is excreted at a low rate, compared with it uptake [12]. Though individual metal exhibit specific signs of toxicity. Many illnesses like gastrointestinal disorders, diarrhoea, stomatitis, depression, pneumonia and many others have been reported as general signs associated with Cd, Pb, Cr, Cu, Mn and Ni consumption. In addition, young children are considered to be at greatest risk due to their ability to effectively absorb metal and thereby suffer physiological development retardation [13]. In this study the objective is to determine the concentration of heavy metals in fish obtained from river and pond of different local government area (Karu, Keffi, Kokona and Nas) under Nasarawa west region and the result is aimed at providing information of five heavy metals (Cd, Pb, Cu, Cr, Mn and Ni) obtained in fish from the river and pond of these areas.

Some metals are essential for life, but if an individual's intake exceeds a certain threshold, toxicity may develop. Thus, minerals and heavy metals in food for human being and animals are of great interest because of their potential effects on human and animal health [14].

Some have no beneficial biological function and expose may be harmful to health. Thus, expose to lead can be harmful to neurophysiological development; inorganic arsenic is a human carcinogen, organic mercury compounds are neurotoxins and cadmium can affect renal function. Element, such as cobalt, iron and copper are essential to health; but may be toxic at high levels of exposure [15].

To limit the possibilities of food poisoning in human cause by ingestion of excessive amounts of trace elements via food and water, highest allowed concentration of trace element is fixed. The accumulation of heavy metals in the body of human through fish intake is of great concern due to the probability of food contamination through these fishes. Heavy metals have great significance due to their tendency to accumulate in the vital human organs over a prolong period of time [16]. Heavy metal pollution is raising environmental problem, which requires immediate attention. The health risk from certain elements in food can be evaluated by comparing estimates of dietary exposures with the provisional Tolerable Weekly Intake (PTWIs) and Provisional Maximum Tolerable Daily intake (PMTDIs) recommended by the Joint Expert Committee on Food Additives (JECFA) of food and Agriculture Organization (FAO) and World Health Organization (WHO) programs on chemical safety [17]. The details of these potential health risks are presented in Table 1 as reported by Rilwan et al. (2020f) [18].

This study assessed the level of concentration in fishes across the investigated areas, contributing to the understanding of heavy metal contamination in fish from multiple regions, highlighting variations, prevalence, and potential risks associated with specific heavy metals.

These findings have implications for both environmental conservation and public health awareness.

2. MATREIALS AND METHODS

2.1. Study Areas

The study was carried out in four different Local Government Area (Karu, Keffi, Kokona and Nasarawa) in Nasarawa State, Nigeria. Karu is located at 9º 2´49N, 7º.45´49E with an area of 2, 640 Km^2 and estimated population 205, 477(according to 2006 census) and it is close in proximity to the Federal capital Territory of Nigeria. Keffi is located at 8º 50" 17N, 7º 49´38"E with an area of 138 Km^2 and the population of about 85,911(2016).

Kokona is located at 8.85 25ºN, 8.13´64ºE with an area of 1,844 Km^2 and the population of 146,500 (march 2016). Nasarawa has an area of 5,704 Km^2, its located at 8º32´N, 7º 42´E with the estimated population of 30, 949 (as of 2016) inhabitants [19].

Table 1: Potential Health Effects of Excess Exposure

Metals	Potential Health Effects of Excess Exposure
Ni	Dermatitis, respiratory issues, lung and nasal cancer, gastrointestinal effects, organ and skin allergic reactions, kidney and liver damage, neurological effects
Cu	Gastrointestinal symptoms, liver damage, kidney damage, neurological effects, hemolysis, Wilson's disease.
Cd	Kidney damage, bone health, respiratory problems, lungs cancer, cardiovascular effects, gastrointestinal effects, reproductive and developmental effects, neurological effects.
Pb	Neurological effects, hematological effects, renal effects, cardiovascular effects, reproductive and developmental effects, gastrointestinal effects, bone health, immunological effects, behavioral and emotional effects, developmental delays, dental effects.
Co	Hypothyroidism, cardiovascular effects, neurological effects, gastrointestinal effects, thyroid gland enlargement, hematological effects.

These LGA´s were selected for their fish production. These four local government areas have diverse range of ethic group, an estimated population of 468,859 and full of hospitable and culturally rich people [20].The ethic group in karu Local Government area is Gbagyi, Gwandara and Gade, that of Keffi Local governments are Hausa-Fulani, Eggon, Korowachi, Mada, that of Kokona are Gwandara; madaFulani, Hausa; Eggon While that of Nasarawa Local Government area are EgburaAgatu; Eggon, Gade; Fulani, Hausa. Fig 1a and 1b depict the map of Study Area and sampling local government in Nigeria

2.2. Sampling

Fish sample from four rivers and rearing ponds were randomly taken for a week, at each location the samples were taken from two different sources (rivers and ponds) in that area. In all, eight (8) samples were collected and labelled accordingly. All the fish samples were then separately stored inside a deep freezer at about 100ºc till they were all collected complete and taken to the laboratory.

2.3. Sample collection and preparation

Sampling was carried out during dry season (February, 2023).The Samples were collected from four locations namely: Karu river and pond(Location A), Keffi river and pond(Location B), Kokona river and Pond(location 3) and Nasarawa river and pond (location 4).Total of 8 individual samples were collected, The fish species (Catfish) were purchased from the fishermen at the four locations, all in same season and captured fish were labelled accordingly and placed in an ice chest before transported to the Scientific and Basic Research Laboratory Department: Sheda Science and Technology Complex 10 km lokoja road away from gwagwalada, Abuja Nigeria. where its being washed with clean water and the fish were properly dissected to remove the existing required organ (gill, liver and muscle) then chopped into halves and the gill. liver and muscle taken from each fish samples and then digested.

The digestion was performed in 250cm^3 glass conical flask covered with watch glass. The fish samples of 3g was digested in 20cm^3 of Conc. Nitric (HNO_3) on a hotplate for 1hr at 95^{o}C. After evaporation to near dryness as a result of heating until a clear solution was obtained., the sample was diluted with 20cm^3 of 2% (v/v with H_2O) nitric acid and transferred into a 100cm^3 volumetric flask after filtering through Whatman no. 42 filter paper and diluted to 100cm^3 with deionized water [21].

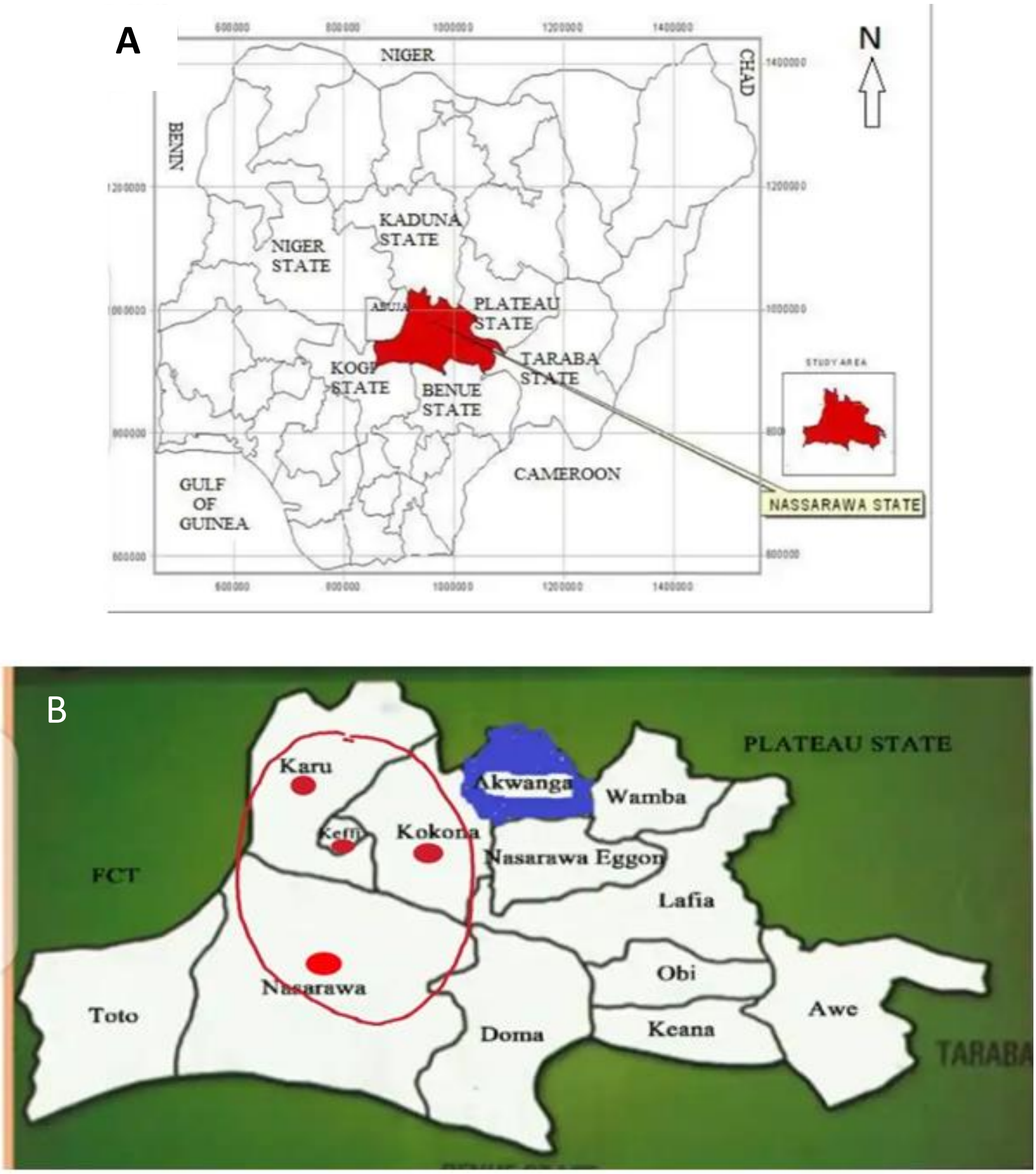


Fig1. (A&B) A map of Study Area and sampling local government in Nigeria

A blank was also prepared and sample solution including the blank and standard solution were analysed for each of the heavy metals.

The AAS Aanalyst 400 model was utilized for the determination of heavy metal content in previously digested fish samples. The setup process involved fixing the nitrous oxide, acetylene gas, and compressor. The compressor was then activated, and the liquid trap was purged to eliminate any trapped liquid. Following this, both the Extractor and the AAS control were switched on.

To ensure the precision of the analysis, meticulous cleaning procedures were performed. The slender tube and nebulizer piece were thoroughly cleansed using a purifying wire, and the burner's opening was cleaned using an arrangement card. Subsequently, the AAS programming worksheet on the connected PC was opened, and the empty cathode light was inserted into the light holder. The light source was turned on, and the cathode beam was carefully adjusted to precisely target the arrangement card, ensuring optimal light throughput. Once this was achieved, the machine was ignited. In preparation for analysis, amount of the sample was placed in a 10 ml graduated cylinder containing deionized water, and the aspiration rate was measured. An analytical blank was meticulously prepared, followed by the creation of a series of calibration solutions with known quantities of the analyte element (standards). These standards, along with the blank, were atomized sequentially, and their respective responses were recorded. Calibration curves were constructed for each standard solution, enabling the subsequent atomization and measurement of the sample solutions. Finally, the concentrations of various metals within the sample solution were determined by referencing the absorbance values obtained for the unknown sample against the calibration curves. This methodology allowed for the accurate quantification of heavy metal concentrations in the soil samples [22, 23]. The Limit of Blank (LOB), Limit of Detection (LOD), and Limit of Quantitation (LOQ) were evaluated which are important parameters in analytical chemistry, particularly in the context of analytical method validation. These parameters help determine the sensitivity and reliability of an analytical method as pointed out by David & Terry in 2018 [24].

Limit of Blank (LOB) as in Equation (1), represents the highest apparent analyte concentration that is expected to be indistinguishable from the background signal (blank) with a certain level of confidence. It is typically calculated according to David & Terry (2018) [25] as:

OB=Mean signal of blank + k × (Standard Deviation of blank) (1)

Limit of Detection (LOD) as in Equation (2), represents the lowest concentration of an analyte that can be reliably detected but not necessarily quantified. It is typically calculated according to David & Terry (2018) [25] as:

LOD= LOB + k × (Standard Deviation of low concentration sample) (2)

Where k is a constant that depends on the desired level of confidence. Common values for k include 1.645 for a 95% confidence level and 2.33 for a 99% confidence level when assuming a normal distribution.

Repeatability and reproducibility are important measures of the precision or variability of an analytical method. These measures help assess how consistent the results are when the same analyst repeats the analysis (repeatability) or when different analysts or laboratories perform the analysis (reproducibility). They are often expressed as standard deviations or coefficients of variation. Here are the formulas for calculating repeatability and reproducibility:

Repeatability (R) as in Equation (3), also known as intra-laboratory precision, assesses the precision of results obtained within the same laboratory by the same analyst or instrument on different days or under different conditions. It is typically calculated according to David & Terry (2018) [25] as the standard deviation (SD) or coefficient of variation (CV) of a series of replicate measurements on the same sample:

$$R = \sqrt{\left[\frac{\Sigma(x_i - \bar{x})^2}{(n - 1)}\right]} \qquad (3)$$

Reproducibility (Rp) as in Equation (4), also known as inter-laboratory precision, assesses the precision of results obtained by different analysts or different laboratories using the same method. It is typically calculated similarly to repeatability according to David & Terry (2018) [25], but it involves measurements from multiple laboratories or analysts. The formula for reproducibility standard deviation (RSDR) is similar to repeatability:

$$\boldsymbol{R_P} = \sqrt{\left[\frac{\boldsymbol{\Sigma(x_i - \bar{x})^2}}{\boldsymbol{(m - 1)}}\right]} \qquad \mathbf{(4)}$$

Where x_i equals each individual measurement, $\bar{x}$ equals the mean of the measurements n is the number of replicates and m is the number of laboratories or analysts.

These formulas as reported by David & Terry (2018) [25] provide quantitative measures of the precision within a single laboratory (repeatability) and the precision between different laboratories or analysts (reproducibility). The choice of whether to use standard deviation or coefficient of variation depends on your preference and the reporting requirements of your analytical method validation or quality control procedures.

Fig 2a: Karu location; Pond and River

Fig 2b: Kokona location; river and pond

Fig 2c: Nasarawa location; pond and river

Fig 2d: Keffi location; pond and river

2.4. Sample location

Four sampling sites were selected, two from each Local Government area of study (Karu, Keffi, Kokona and Nasarawa) it's being known for its proficiency in good fishing grounds around the rivers. Fig 3 shows the map of Nasarawa state indicating the sample points with a red dot

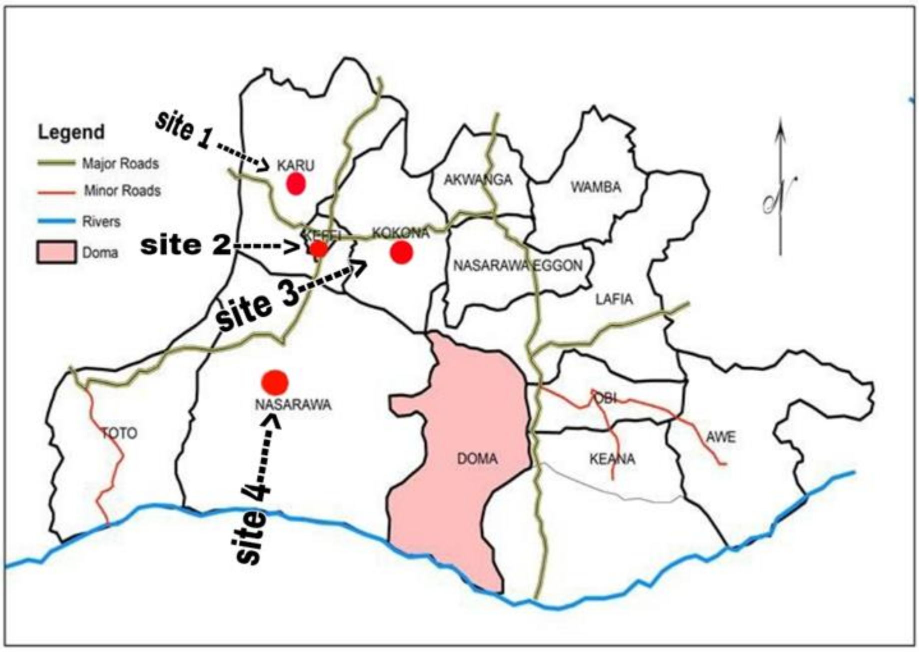


Fig 3: A map of Nasarawa state indicating the sample points with a red dot

3. RESULTS AND DISCUSSION

3.1. Results

Concentrations of the heavy metals (Cd, Ni, Cu, Cr, Pb) After digestion were analysed using Atomic Absorption Spectrometer (iCE 3000). The results from the AAS were expressed as mg/l which was converted to mg/kg in the results obtained. All reagents used were of analytical grad. Fig 1 depict the illustration of the analysis processes and the results of the analysis was presented in Table 1.

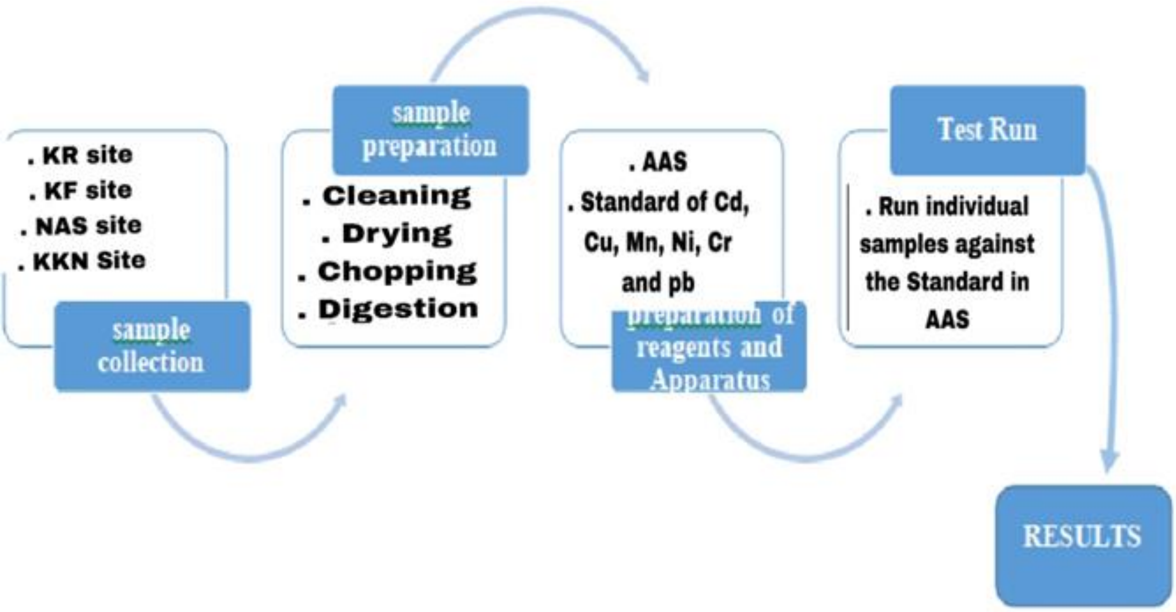


Fig 4: An illustration of the Analysis processes

Table 1: Results Concentration (mg/kg) in All Local Governments

Metals		KR	KF	KKN	NAS	FAO/WHO, 2020	LOB	LOD × 10^{-4}	R × 10^{-4}	Rp × 10^{-3}
Cr	River	6.99	3.39	5.17	6.86	20	0.29×10^{1}	*0.033*	1.00	0.11
	Pond	2.31	2.02	5.00	2.92		0.12×10^{1}	4.290	1.81	0.06
Cd	River	ND	ND	ND	ND	0.5	4.14×10^{-4}	4.290	0	0.01
	Pond	ND	ND	0.06	ND		4.14×10^{-7}	4.290	1.81	0.20
Mn	River	127.60	78.52	33.74	24.52	20	1.92×10^{1}	5.280	2.77	0.15
	Pond	73.62	85.47	14.86	3.85		0.27×10^{1}	8.580	3.52	0.20
Cu	River	61.15	16.92	33.74	24.52	20	1.44×10^{1}	13.20	3.54	0.30
	Pond	18.82	8.48	14.86	3.85		0.22×10^{1}	19.80	3.54	0.31
Ni	River	3.36	ND	ND	1.67	10	0.11×10^{1}	8.250	0.35	0.18
	Pond	2.48	0.78	2.67	ND		2.09×10^{1}	16.50	2.88	0.36
Pb	River	0.48	0.08	0.93	0.21	0.3	2.10×10^{-3}	19.80	2.69	0.01
	Pond	0.01	ND	1.93	0.003		2.97×10^{-4}	1.980	0.57	0.11

D = Not detected; KR = Karu; KF = Keffi; KKN = Kokona; NAS = Nasarawa

The calibration curve of heavy metals (Cr, Cd, Pb, Cu, Mn and Ni) is presented in Figure 5.

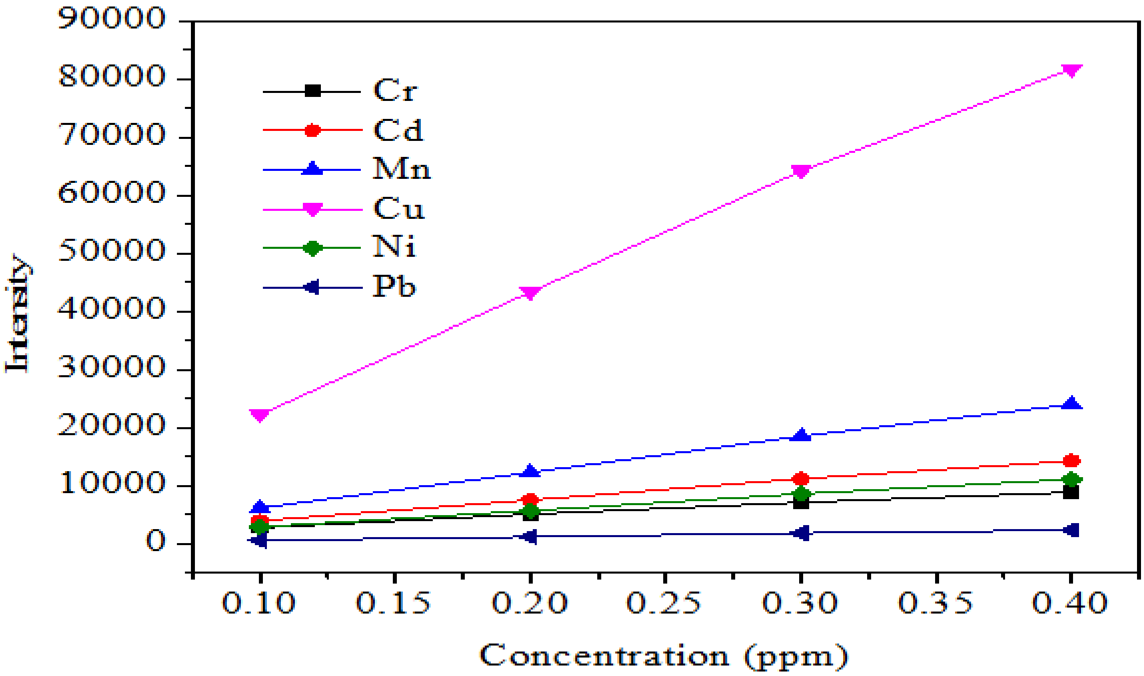


Figure 5: Calibration curve of heavy metals (Cr, Cd, Pb, Cu, Mn and Ni).

3.2. Discussion

The presence and concentrations of six heavy metals (Mn, Cu, Cr, Cd, Pb and Ni) were analyzed in the eight samples from four locations. The results are summarized in Table 1 above.

3.3. Concentration of Heavy metals in Karu L.G.A

From the table 1, however the values reported for Mn, Cu, Cr, Cd, Pb and Ni in both river and pond in this report is comparable to other values reported for same metals in river in Karu LGA, Nasarawa state [26]. The level of selected metals in this location, some are within the normal range while other are not for metals in fish especially for Mn which exceed the normal range set out by the international standard (FAO/WHO, 2015) [27]. The result of this study shows that Mn has high concentration (127.60 mg/kg) in the river as which might be as a result of several factor such as mining tailing, irrigation practice in this area which might flow to the river body. Fish are known to take up and accumulate heavy metals from contaminated water; especially if in high concentration [28]. If not for Mn and Cu whose concentration are high, other detectable metals are lower than toxic levels and are also within permissible limit set by the regulation bodies regulatory bodies as reported by Amir et al. (2017**)** [29]. The heavy metal levels in fish pond are lower than those in river samples, this is because it takes time before these factors have effect on the fish [30]. The metals level in the river is higher and this is because apart from waste water which is source of heavy metals, others such as sediments, pesticides and other irrigation practice too makes heavy metals to be in high concentration in the fish from this area. So lesser is available in the fish pond that is why the concentration in the fish pond is lower. Hence the level in the river fish is so surprising, When the level of metals in the two samples were compared, the highest variability was found in Mn while Pb was least Variable. The order of variation in descending order in Karu river(KR): Mn (127.60mg/kg) > Cu (61.15mg/kg) > Cr

(6.99mg/kg) > Ni(1.47mg/kg) > Cd (0.65mg/kg) >Pb (0.48mg/kg) and in Pond(KR): Mn (73.62mg/kg) > Cu (18.82mg/kg) > Cr (6.99mg/kg) > Ni(2.48mg/kg) >Pb (0.48mg/kg) (see Table 1).

3.4.. Concentration of heavy metals in fish of Keffi L.G.A

The levels of six heavy metals in fish sample that are consumed in keffi LGA, shown in table above, Mn had the highest concentration which ranges from 85.47mg/kg (in pond) to78.52mg/kg (in river), followed by Cu 16.92mg/kg (in river) to 8.48mg/kg in pond. For Cr in the fish been studied, the level of heavy metal ranges from 3.39mg/kg in river to 2.02mg/kg in pond, Ni ranges from 0.78mg/kg in pond to not detected in river. Pb ranges from 0.08mg/kg to not detected in pond while Cd was not detected in both the river and pond. The level of Mn, Cu, Cd, Cr, Pb and Ni in the sample are lower than central Nigeria [31]. However, the values reported for Mn, Cu, Cr, Cd, Pb and Ni in the present study is comparable to the value reported for sample same metals in fish in [32]. The levels of metals in the fish are within the range except for Mn which exceed the normal range. Mn concentration was high when compared to the standard set by regulatory agencies and reported by Usman et al. (2020c**)** [33] several factors such as mining tailing, sediments on the surface of the waste water, temperature and even the environment are the major contributing factor [34]. Therefore, because fish are known to take up and accumulate heavy metals from contaminated water and the environment, it easily takes up the Mn in higher concentration. The level of Mn in the pond is higher in this case than the river and this is because of some factors such as feeding habit, the environment and temperature which makes the metals available in high concentration but in the other hand it is available in low concentration in the river because it takes time before this factors have effect on the fish that is why it is available in lower concentration unlike the pond that accumulate faster because of its factor. When the levels of metals in the different river were compared, the highest variability was found in Mn (85.47mg/kg) in pond while Pb have the lowest variation (0.08mg/kg) in river. The order of variation in descending order Mn> Cu> Cr>Ni> Pb in both river and pond.

3.5. Concentration of heavy metals of fish in Kokona L.G.A

The cat fish consumed in Kokona local government shows some certain amount of heavy metals (shown in Table 1) Mn had the highest concentration (60.86mg/kg) in the pond followed by Cu (33.74mg/kg) in the river. For Cu in the fish been studied, the level of heavy metal ranges from 16.92mg/kg to 8.48mg/kg, Cr ranges from 5.17mg/kg to 5.00mg/kg, Pb is from 1.93mg/kg to 0.93mg/kg, for Ni the range is from 2.69mg/kg to not detected, while Cd was only detected in the pond with concentration 0.06mg/kg The level of metal in the sample are lower than the permissible limit set by the regulatory agencies and pointed out by WHO (2020**)**. [35] except Mn, Cu and Pb which exceed the limit and as such is said to be dangerous to the people of this area. However, the values reported for Mn, Cu, cr, Cd, Pb and Ni in the present study is comparable to the value reported for sample same metals in fish in [35]. When the levels of metals in the different river were compared, the highest variability was found in Mn (60.86mg/kg) while Pb have the least variation. The order of variation in descending order is Mn>Cu>Cr>Ni>Pb>Cd in pond while Cu>Mn>Cr>Pb in the river. Concentration of heavy metals in fish from keffi LGA

3.6. Concentration of heavy metals in Nasarawa L.G.A

The level of the six heavy metals in fish sample that are consumed in Nasarawa L.G.A as shown in table 1 indicates Mn to have the highest concentration (99.50 mg/kg) in river, followed by Cu with the concentration 24.59 mg/kg in the river too. These results agreed with report of [35] that river fish accumulate metals more. For Cu in the fish been investigated, the level of heavy metal ranges from 24.52 mg/kg in the river to 3.38 mg/kg in the pond. Cd ranges from 6.86 mg/kg to 2.92 mg/kg. for Ni it ranges from1.67 mg/kg to not detected. Pb ranges from0.21 mg/kg to 0.003 mg/kg Mn ranges from 60/86 mg/kg to32.07 mg/kg. Cd was not detected in both cat fish from pond and river. The levels of metals in the fish are within the range except for Mn and Cr which exceed normal range. Mn and Cu concentration was high when compared to the standard set by regulatory agencies and reported by Waida et al. (2023) [35]. The level of heavy metals in pond are lower than in the river, this is because of some factors such as temperature, feeding habit and the environment makes the metals available in high concentration but in this case, it is available in low concentration because it takes time before this factor have effect on the fish that is why it is available in lower concentration unlike river that accumulate more faster because of its factor. The metal level in pond are lower than those in the river sample and this is because apart from waste water which is a source of heavy metal, other such as the sediments, irrigation practice along this water side, and the feeding habit contribute in making heavy metal be in high concentration in river. So only a little is available in the pond. That is why the concentration in pond is lower than that in river. Hence the high level in river sample was not surprising. When the levels of metals in the different river were compared, the highest variability was found in Mn while Pb have the lowest variation. The order of variation in descending order is Mn > Cu > Cr > Cd > pb > Ni.

4. CONCLUSION

The comparison of the current study with global research indicates that the heavy metal concentrations in Catfish from Karu, Keffi, Kokona, and Nasasawa areas generally adhere to WHO/FAO (2020) [36, 37] permissible limits, except for Manganese (Mn) and Copper (Cu). Particularly, Mn levels are significantly higher in concentration than reported elsewhere, surpassing the standard limit for human consumption [38, 39]. The elevated metal levels in fish from these areas may be attributed to mining activities, as Nasarawa state is known for its solid minerals, pesticide use, and local irrigation practices. The determination of Cd, Mn, Cr, Cu, Pb, and Ni concentrations in Nasarawa west region provides crucial baseline data on river and pond pollution. This data serves as a valuable resource for researchers and environmental managers, aiding in the identification of future anthropogenic impacts and the assessment of the need for bio-accumulation remediation through monitoring. The high metal levels in fish samples suggest their capacity to absorb metals from the aquatic environment, highlighting the importance of further studies on metal incorporation into fish tissues. The low values of LOB, LOD, R, and Rp in our study indicate minimal variability and uncertainty in measurements, signifying a high level of precision in both the measuring instruments and the tested samples.

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HOW TO CITE THIS ARTICLE
Ibrahim Adamu Muhammed, Blessing Ifeyinwa Tabugbo, Usman Rilwan, Odih Christian,Assessment of Heavy Metal Content in Fish Obtained from Selected Rivers and Ponds of Nasarawa West Region, Nasarawa State, Ad. J. Chem. B, (2023) 244-260
DOI: 10.48309/pcbr.2023.409486.1270
URL: https://www.pcbiochemres.com/article_180247.html