BIOACCUMULATION AND RISK ANALYSIS OF HEAVY METAL POLLUTANTS IN TILAPIA ZILLI AND CLARIAS GARIEPINUS FISH SPECIES FOUND IN RIVERS DILIMI AND TUDUN WADA OF JOS, PLATEAU STATE, NIGERIA

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ABSTRACT: Heavy metal content (Cd, Cr, Cu, Hg, Mn, Ni and Pb) in two fish species (Tilapia zilli and Clarias gariepinus), collected from the two major rivers within the Jos urban city were assessed using atomic absorption spectrophotometer (AAS). The highest oncentration range of 4.26 – 5.22 mg/Kg and mean value of 4.06±0.20 in tilapia liver was recorded for Cr, the least concentration range of ND – 0.16 was recorded in the kidney. The least detectable concentration, ND - 0.17 mg/Kg was measured for Ni in Clarias gariepinus (Cat fish), while the highest concentration of 3.84 – 5.18 and mean value 0f 4.06±0.81 was recorded for Cr in the liver. Most of the heavy metals were not within the recommended maximum guidelines except for manganese. The concentration of Cd, Cr, Cu, Hg, Mn, Ni and Pb measured in all the samples however, exceeded the FAO/WHO maximum limit. Similarly, the concentration of Mn measured in all the fish samples exceeded the WHO limit of 0.5mg/L in drinking water but fall within the limit for liquid and solid foods, with the bioconcentration patterns follows: liver > gills > muscle > kidney, particularly for Cd and Cr, while for Cu, Mn and Ni, muscle and gill show more bioaccumulation. The mean of the total concentration of each metal in all the samples indicate that the concentrations of the heavy metals in the samples are generally well above the respective recommended guidelines. Thus fish species harvested from the Dilimi and Tudun-Wada Rivers, are unsafe for human consumption and so eating fish from this area may pose health hazards for humans and thus can create an upsetting situation.

Keywords: Dilimi, Tudun-Wada, Heavy Metal Pollutants, Tilapia zilli and Clarias gariepinus

1. INTRODUCTION

Globally, aquatic systems are polluted through anthropogenic activities with chemical pollutants from domestic, agricultural and industrial wastes, which are finally absorbed by aquatic plants and animals. According to [1] heavy metal pollution in aquatic systems is an important environmental problem, since heavy metals are among some of the most dangerous toxicants that bioaccumulate in aquatic plant and animal tissues. [2] reported that the consumption of food such as fish with high levels of heavy metals such as lead (Pb), can induce convulsion, abdominal pains, drowsiness, vomiting, kidney and reproductive system malfunction in humans. In pollution studies, sediment quality is used as an indicator by contaminants including trace metals because it provides a deeper insight into the long-term pollution state of the aquatic environment [3]. Sediment being the loose sand, clay, silt and other soil particles which settle at the bottom of body of water [4] is a major habitat and major nutrient source for aquatic organisms such as fish, micro-invertebrates and macroinvertebrates [5]. Sediments have been described as a ready sink of pollutants where they concentrate according to the levels of pollution [6]. Pollution of the aquatic environment by inorganic chemicals has been considered a major threat to the aquatic organisms including fishes. The agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals [7]. Rapid industrialization and urbanization has led to increased disposal of pollutants such as heavy metals, radio-nuclides, various types of organic and inorganic compounds into the environment [7]. The rapid build-up of toxic pollutants in soil, surface water, and ground water affects natural resources, besides causing major strains on ecosystems and thus pose serious risks to human health. Sewage and industrial disposal has greatly increased the addition of heavy metals in the aquatic ecosystems.

Few studies have been carried out on the impact and health risk of waste disposals Dilimi and Tudun Wada Rivers of Jos City on humans through the food chain. It influences the productivity and health status of water bodies as abnormal changes in physicochemical conditions and other quality parameters have their impact on biodiversity. Heavy metals such as nickel, copper, zinc and lead, generally are toxic substances that pose a great risk to living organisms in our environment due to their inevitable existence [8].Metals can cause serious health effects with varied symptoms depending on the nature and quantity of metal ingested [9]. The most common metals that humans are exposed to are: aluminium, arsenic, cadmium, lead and mercury. Aluminium has been associated with Alzheimer's and Parkinson's disease, senility and pre-senile dementia. Arsenic exposure can cause among other illnesses or symptoms, cancer, abdominal pain and skin lesions. Cadmium exposure produces kidney damage and hypertension. Lead is a cumulative poison and a possible human carcinogen [10] while for mercury, toxicity results in mental disturbance and impairment of speech, hearing, vision and movement [11]. In addition, lead and mercury may cause the development of autoimmunity in which a person's immune system attacks its own cells. This can lead to joint diseases and ailment of the kidneys and circulatory system and neurons. At high concentrations, lead and mercury can cause irreversible brain damage. Mercury (Hg) is one of the most hazardous environmental pollutants due to its toxicity and its accumulation in aquatic organisms. The relative toxicity of mercury depends on its chemical form, methyl mercury being one of the most toxic substances existing in the environment. The consumption of fish is the main route of exposure of humans to monomethylmercury, which represent the main form of mercury in fish due to biomagnification in the marine food chain [12, 13]. According to [14, 15], the order of mercury concentrations in tissues of the fish species was as follows: liver>gill>muscle and in tissues of the kingfisher species was as follows: feather>liver>kidney>muscle. Therefore, liver in fish and feather in kingfisher exhibited higher mercury concentration than the other tissues [16]. There was a positive correlation between mercury concentrations in fish and kingfisher species with size of its food items.

2.MATERIALS AND METHODS

Study area and sampling locations

The present study was carried out in 2013 through 2014 in the two major rivers that pass through the city center of Jos, the capital of Plateau State, Nigeria.

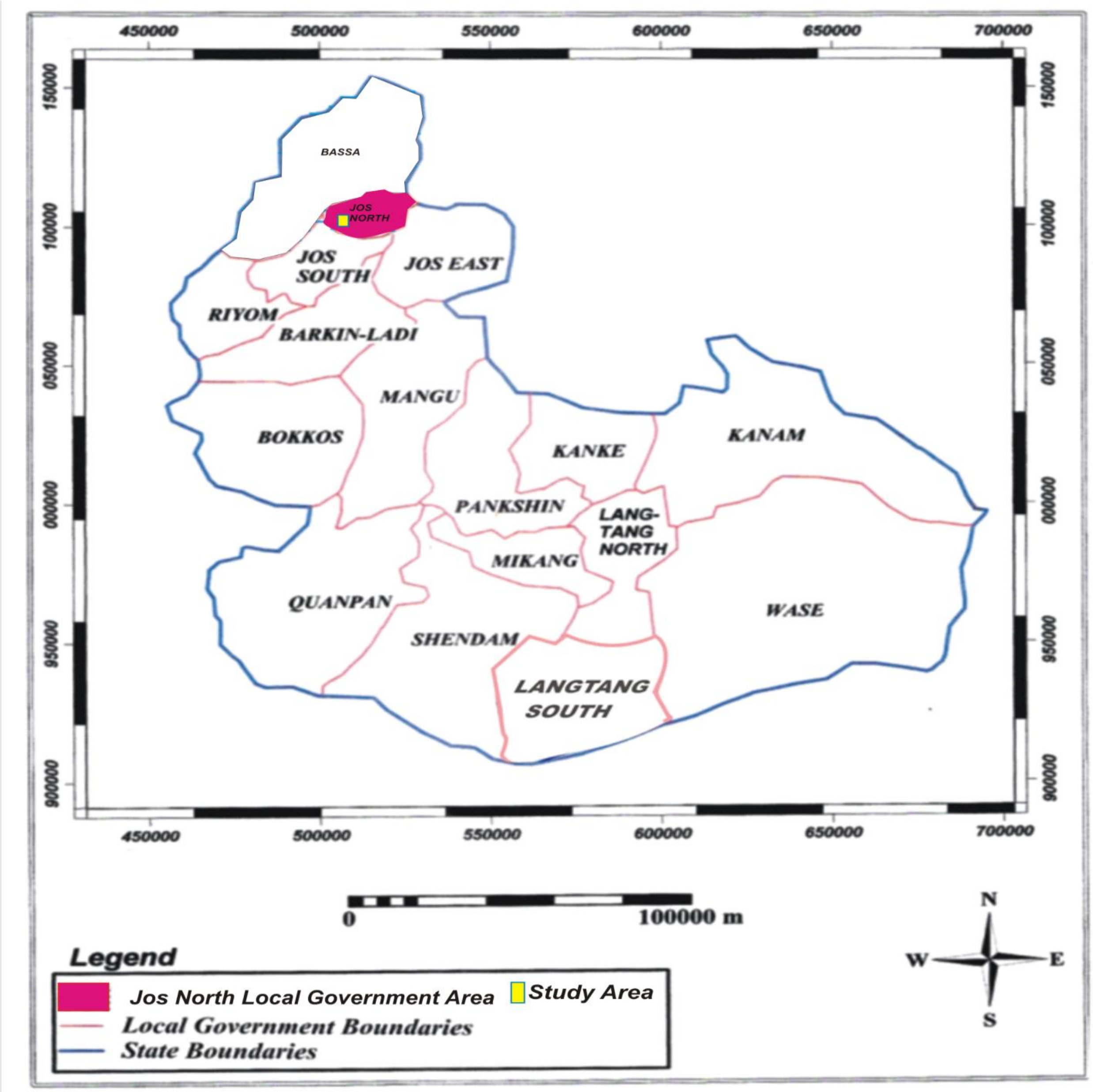

Fig. 1: Political Map of Plateau State Showing Local Government Area and Sampling Site

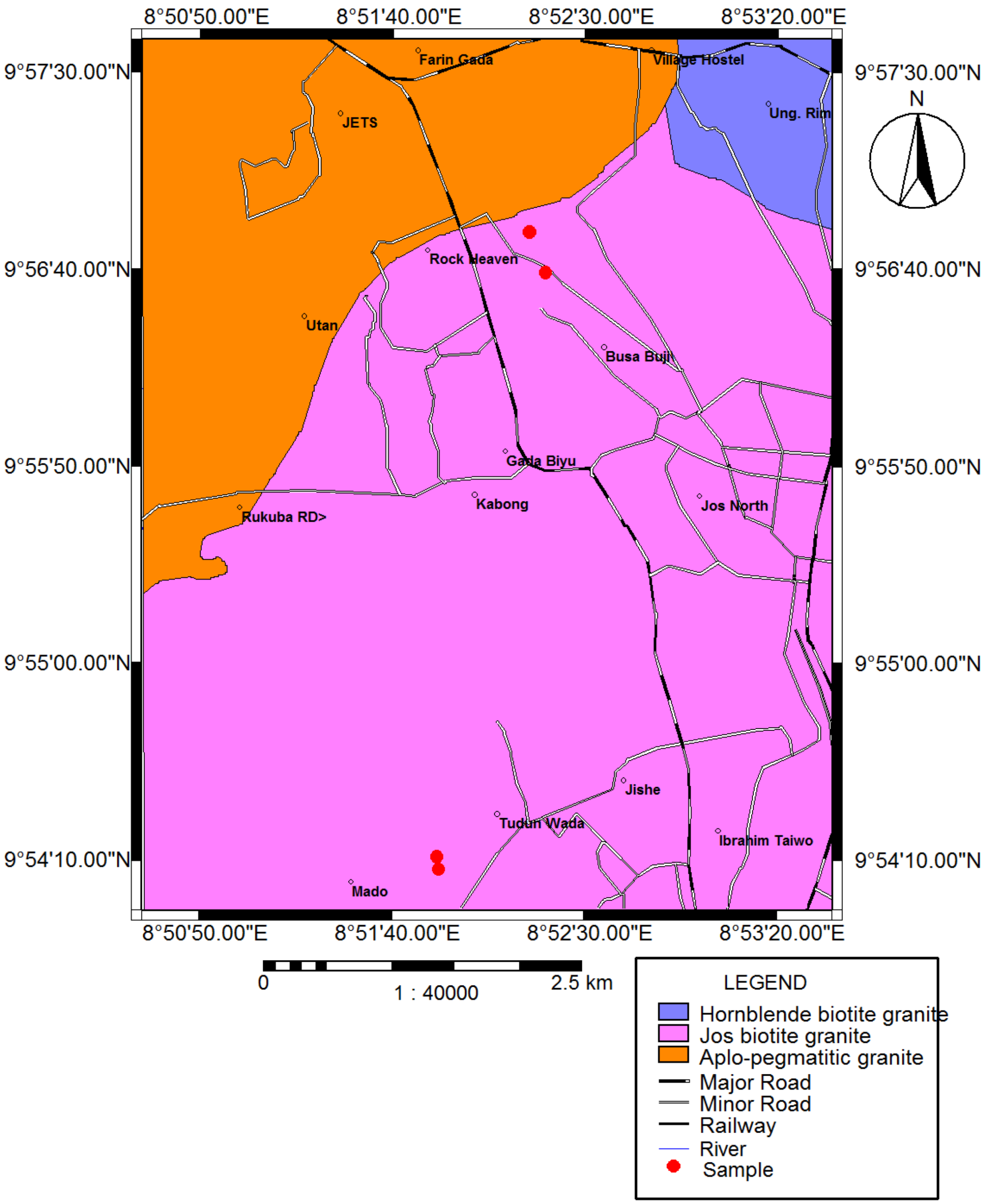

Fig. 2: Geologic Map of Sample State Showing Sampling Points

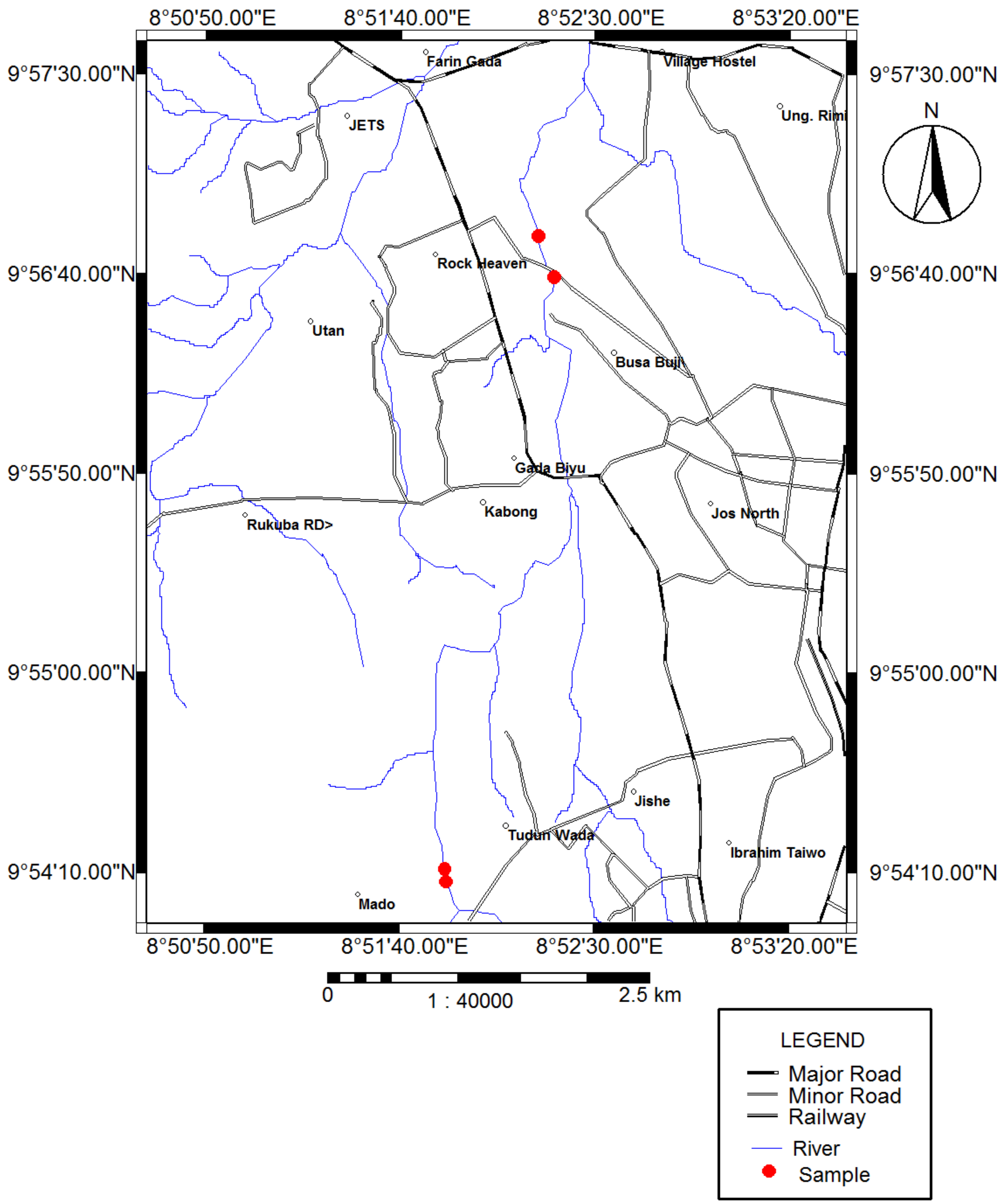

Fig. 3: Hydrologic Map of Sample Site Showing Sampling Points Collection of samples

Sample collection and treatment

A total of 120 samples of different types of common fish species, meat and meat products were collected in 2013 through 2014. These samples classified into common fish species (Tilapia zilli and Clarias gariepinus) were bought from local fishermen onsite. All collected samples were stored in clean polythene bags according to their type and brought to the laboratory for preparation and treatment. Sample fish species were then dissected using clean ceramic knife to remove the organs of interest. Sample organs were dried in an oven at 110^{o}C for two weeks to ensure complete dryness. After drying, the samples were grained into a fine powder using a ceramic mortar and stored in polyethylene bags until used for acid digestion.

Preparation and treatment of samples

The collected samples were washed with distilled water to remove any contaminated particles.

Acid digestion of samples:

Acid mixture (10 mL, 70% high purity HNO_3 and 65% $HClO_4$, 4:1 (v/v) was added to the beaker containing 2 g dry sample according to [15]. The mixture was then digested at 80^{o}C till a transparent solution was achieved. After cooling, the digested samples were filtered using Whatman no.42 filter paper and rinsed severally to ensure complete washing of the filter paper. The filtrate was diluted to 50 mL with redistilled water. Determination of the heavy metals in the filtrate of the fish organ digests was achieved by atomic absorption spectrophotometer (Shimadzu Model 6800 with graphite furnace Model GFA 7000, Hydride unit was used for determination of mercury).

3.RESULTS AND DISCUSSION

The mean values ± standard deviation of Cadmium, Chromium , Copper, Mercury, Manganese Nickel and Lead in the organs of the studied two common fish species are as given in Tables 1 and 2 below:

Table 1: Levels of Heavy Metals in different organs of Tilapia Fish

	Kidney		Gill		Liver		Muscle		Standard
Element	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	FAO/WHO (mg/Kg)
Cd	0.86 - 1.77	1.23 ± 0.43	1.87 - 2.96	2.23 ± 0.15	2.78 - 4.04	3.28 ± 0.58	1.06 - 1.55	1.31 ± 0.20	<0.01
Cr	1.38 - 1.48	1.43 ± 0.50	2.29 - 4.33	3.66 ± 0.20	4.26 - 5.22	4.72 ± 0.20	0.98 - 1.20	1.17 ± 0.11	<0.01
Cu	1.22 - 2.64	1.88 ± 0.36	2.11 - 3.16	2.48 ± 0.21	1.16 - 2.28	1.38 ± 0.20	1.22 - 2.16	1.88 ± 0.08	0.01
Hq	ND - 0.11	0.08 ± 0.02	ND - 1.88	0.90 ± 0.80	ND - 0.21	0.17 ± 0.03	ND - 0.20	0.15 ± 0.02	0.05
Mn	1.68 - 2.11	1.86 ± 0.23	1.16 - 3.10	2.48 ± 0.23	1.78 - 2.13	2.05 ± 0.20	1.60 - 2.34	2.18 ± 0.08	5.0
Ni	ND - 0.30	0.21 ± 0.05	ND - 0.18	0.15 ± 0.10	0.11 - 0.71	0.53 ± 0.15	1.86 - 4.44	2.77 ± 0.20	0.02
Pb	ND - 0.16	0.10 ± 0.02	0.16 - 0.23	0.18 ± 0.10	0.17 - 0.28	0.21 ± 0.07	0.07 - 0.21	0.16 ± 0.05	0.05

Table 2: Levels of Heavy Metals in different organs of Cat Fish

	Kidney		Gill		Liver		Muscle		Standard
Element	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	Concentration	Ave (µg/g)	FAO/WHO
Cd	0.79 -1.12	0.97 ± 0.20	1.86 - 3.44	2.19 ± 0.24	2.82 - 4.86	3.16 ± 0.55	1.12 - 1.67	1.42 ± 0.30	<0.01
Cr	1.32 - 1.57	1.38 ± 0.05	2.89 - 4.44	3.05 ± 0.23	3.84 - 5.18	4.06 ± 0.81	0.76 - 1.26	1.17 ± 0.18	<0.01
Cu	1.76 - 2.86	1.86 ± 0.30	2.11 - 3.77	2.56 ± 0.30	1.22 - 1.72	1.50 ± 0.07	2.34 - 3.12	2.54 ± 0.30	0.01

Hg	0.11 - 0.32	0.22 ± 0.10	ND - 1.22	1.07 ± 0.04	0.11 - 0.21	0.16 ± 010	ND - 0.16	0.10 ± 0.15	0.05
Mn	1.78 - 3.21	1.87 ± 0.15	1.78 - 3.21	1.85 ± 0.20	1.68 - 3.12	1.98 ± 0.30	1.11 - 3.32	1.28 ± 0.70	5.0
Ni	ND - 0.26	0.18 ± 0.08	ND – 017	0.12 ± 0.05	0.12 - 0.33	0.23 ± 0.10	ND - 0.17	0.08 ± 0.10	0.02
Pb	ND - 0.32	0.21 ± 0.27	ND - 0.22	0.16 ± 0.05	0.10 – 013	1.07 ± 0.12	ND - 0.24	0.17 ± 0.20	0.05

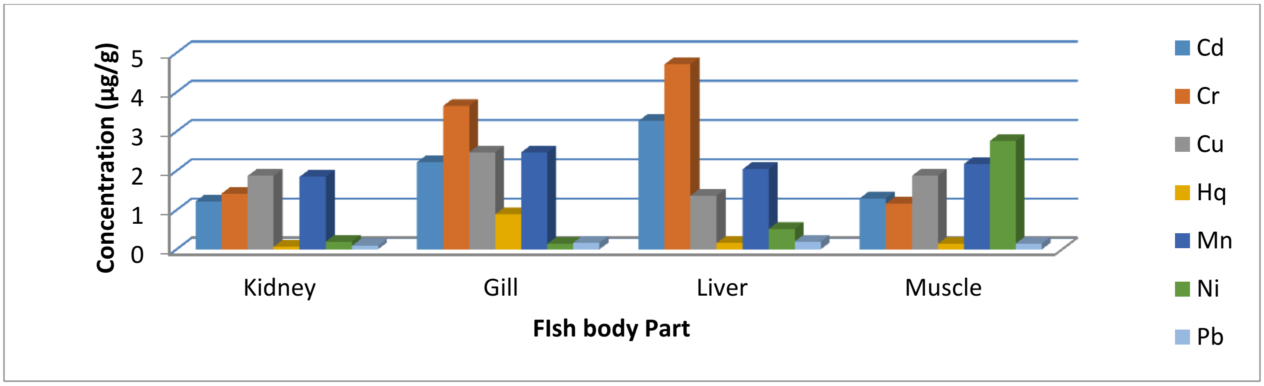

Fig. 4: Bar chart representing the concentration of each element in a particular organ of Tilapia Fish

Figure 4 is the bar chart representing the concentration of each element in the various organs of the fish species with a standard error of 0.00. The bioaccumulation pattern shows that liver > gills > muscle > kidney, particularly for Cd and Cr, while for Cu, Mn and Ni, muscle and gill show more bioaccumulation, corroborating with the works of [17, 18 19]. In the tilapia fish sample, Cr, Cd, Mn and Cu bioaccumulate more in the organs of the fish with the muscle bioaccumulating the least in each case except for Cu, Mn and Ni. While concentration of Hg, Ni and Pb are low in all the organs studied except in muscles, these concentration are above the international maximum tolerable limits (MTL) as given FAO/WHO. The results also indicate that all the metal concentration in the fish organs are above international standards for safe consumption, except foemanganese

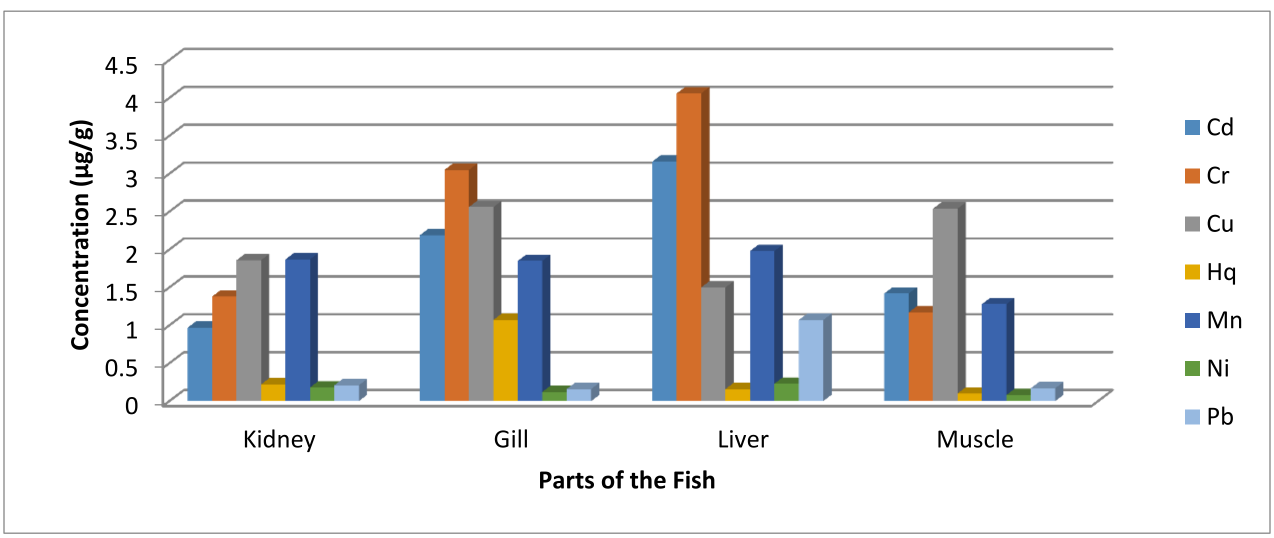

Fig. 5: Bar chart representing the concentration of each element in a particular organ of Cat Fish

Figure 5 is the bar chart representing the concentration of each element in the various organs of the cat fish species with a standard error of -0.5. The bioaccumulation pattern also shows that liver > gills > muscle > kidney, particularly for Cd and Cr, while for Cu, Mn and Ni, muscle and gill show more bioaccumulation. The concentrations of heavy elements in the selected studied species are quietly varied according to the fish species and organs. The liver bioaccumulates more of the heavy metals, followed by the gills in each case compared to the other organs, which corroborates the work of other researchers [12, 15, 17, 18, 19, 20]. This indicates the sample matrix is a good bioindicator environmental pollution, depicting the level of pollution in and within the rivers due to heavy anthropogenic activities.

4. CONCLUSION

The mean of the total concentration of each metal in all the samples indicate that the concentrations of the heavy metals in the samples are generally well above the respective recommended guidelines. Thus fish species harvested from the Dilimi and Tudun-Wada Rivers indicate the level pollution of these two rivers are therefore unsafe for human consumption and so eating fish from this area may pose health hazards for humans and thus can create an upsetting situation.

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