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Assessment of some Selected Heavy Metals Content of Soil, Water, Plants and Fish from Igbeti Dam Area of Oyo State, Nigeria

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Abstract: Heavy metals are potential environmental contaminants that can cause health problems if present in excess in the food we eat. This study investigates the level of concentrations of nine heavy metals (Ni, Mn, Zn, Cu, Fe, Co, Pb, Cr, and Cd) in water, soil, plant, and fish samples collected from Igbeti Dam in Oyo State, Nigeria. Using a combination of chemical treatments and filtration, the heavy metal concentrations were analyzed using Atomic Absorption Spectroscopy (AAS) and compared with the World Health Organization's (WHO) maximum tolerable limits. The results revealed that while concentrations of Ni, Mn, Zn, Fe, and Cu in the samples were within acceptable limits, significant concerns were identified with Cr, Pb, and Cu levels. Notably, cobalt concentrations exceeded WHO standards across all sample types, while lead and chromium were also found in excess in the plant and fish samples, with fish(0.179mg/kg) exceeding the standard (0.001mg/kg), Lead levels were highest in plant (0.968mg/kg) as against the standard (0.1mg/kg). Chromium also exceeded its limits in soil (0.099mg/kg) as against the standard (0.05mg/kg). These high levels of Pb, Cr and Co suggest potential risks for human and environmental health,

Keywords: Heavy metals, Soil, Water, Plant, Fish

1. Introduction

Heavy metals are naturally occurring trace elements characterized by high densities—typically five times that of water—and have been associated with various health hazards. These metals can enter the environment through multiple channels such as air, food, water, and chemical usage, eventually finding their way into the human body via ingestion or dermal absorption. Without proper detoxification, accumulation of these metals can result in toxic effects (Girigisu et al., 2020).

Increasing concerns about heavy metal contamination in environmental compartments—soil, water, and air—have prompted widespread interest in monitoring their levels in commonly consumed food products. These concerns are fueled by past incidents of environmental poisoning, such as the 2010 lead contamination in Zamfara, northwestern Nigeria, which tragically resulted in numerous child fatalities (Udiba et al., 2019).

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Heavy metals such as Fe, Cu, Zn, Co, and Mn play essential roles in human nutrition. However, metals like As, Cd, Pb, Hg, and Al, which are non-essential, pose significant health risks even at trace concentrations. Exposure to any heavy metal—essential or non-essential—above physiological thresholds is potentially harmful (Iwegbue et al., 2008). Singh et al. (2021) further categorize these metals into toxic, essential, hazardous, and valuable classes based on their biological and industrial relevance.

While trace elements like Cu, Zn, and Ni contribute to human health as micronutrients, highly toxic metals such as Pb, Hg, Cd, and As are detrimental even at low levels. Vulnerable populations, including pregnant women and children, are particularly at risk. Cadmium, known for its mobility in soils and plants, is easily transferred through the food chain. Chronic exposure to cadmium can impair the liver, kidneys, lungs, and skeletal system, and has been linked to conditions like pulmonary adenocarcinoma and immune dysfunction. Lead toxicity, on the other hand, may lead to endocrine disruption and elevated blood pressure (Gao et al., 2021).

Agricultural crops are sensitive to elevated heavy metal concentrations, with elements like Cu, Ni, and Co identified as particularly toxic. These metals, including both essential (Fe, Zn, Cu) and non-essential types (Hg, Pb, As, Cd), naturally occur in soil, water, and air but may enter the food chain through environmental contamination (Gbaruko and Friday, 2007).

Due to widespread pollution of environmental media, food and beverages are increasingly contaminated with heavy metals. Even at minimal concentrations, these metals pose serious health threats, justifying global concern. Numerous studies have linked excessive intake to organ dysfunction, developmental disorders, and other health issues. Understanding the heavy metal composition of food is therefore crucial, as many of these elements are essential in trace amounts but toxic when consumed in excess (Musa and Lai, 2018).

Major sources of water pollution include inadequately treated wastewater, industrial discharges, and agricultural runoff. Among these, industrial effluents are recognized as leading contributors to waterborne heavy metal contamination. Such pollutants, often persistent and highly toxic, threaten aquatic ecosystems even at low concentrations (Shahadat and Ismail, 2018). Investigations have consistently found higher levels of heavy metals in food items from industrialized areas compared to those from less polluted environments (Abdullahi et al., 2008).

Soil and water contamination with heavy metals contributes significantly to their bioaccumulation in plants and eventual entry into the food web. The risk of contamination escalates with increasing urbanization, industrial activity, and modern farming practices (Liang et al., 2019). Although anthropogenic activities are the primary drivers of surface soil contamination, natural geological factors also play a role. The mineral composition of parent rocks, which weather into soils, largely determines the native heavy metal content (Ahmad et al., 2021).

Developing nations often report higher incidences of heavy metal contamination than their developed counterparts. As a result, continuous monitoring of metal levels in frequently consumed agricultural produce remains imperative (Mawari et al., 2022). This study, therefore, aims to evaluate the concentrations of selected heavy metals in soil, water, plants, and fish from the Igbeti Dam region in Oyo State, Nigeria, to assess potential health risks to humans and aquatic life.

2. Materials and Method

2.1 Samples Collection

The soil, fish (gill), water and plant samples used in this research were collected from Igbeti dam, Igbeti, Oyo state with GPRS coordinates 8^{o}45'N, 4^{o}9'E.

2.2 Water Sample Preparation

The water sample was collected from the Dam with the aid of a plastic bottle. It was placed in an ice bath to maintain the temperature using a thermometer and subsequently analyzed for its metal content in the laboratory. 10mL of water sample was weighed and poured into a beaker, and 30mL of concentrated Hydrochloric acid (HCl) was added to it and placed on the hot plate that boiled for 30 minutes, this was removed and allowed to cool. Thereafter, 20mL of de-ionized water was added to it and then filtered into a clean sample bottle for onward analysis using an Atomic Absorption Spectrophotometer (AAS).

2.3 Soil Sample Preparation

10g of soil sample was weighed and poured into a beaker, 30mL of concentrated Hydrochloric acid (HCl) was added to it and placed on the hot plate to boil for 30 minutes till the solution became almost clear and near dry, this was allowed to cool for 5 minutes. 20 ml of de-ionized water was added to the solution and then filtered into a clean sample bottle.

2.4 Plant Sample Preparation

The plant was air dried at room temperature and pounded into powder form with mortar and pestle. Then 20g of the plant sample was weighed and transferred into a crucible and placed in a furnace at 450^{o}C for one hour to burn into ashes. Then it was cooled and 30mL of distilled water was added to it and then filtered into a clean sample bottle, and was later made up to 100ml before analysis.

2.5 Fish (Gill) Sample Preparation

The fish was killed and the gill was removed, cleaned and oven dried. This was ground into powder form with mortar and pestle. Then 20g of the sample was weighed and poured into a crucible and set in the furnace at 450^{o}C for 1 hour. The resulting ashes were left to cool down and then 30ml of de-ionized water was added. This was filtered into a clean sample bottle and analyzed for its metal content.

3. Results and Discussion

From the Tables 1, 2 and Figure 1, it could be observed that the concentrations of Nickel in the fish, water, plant and soil samples were all below the standard set by the WHO, meaning that the samples analyzed do not pose the risk of Nickel poisoning.

Table 1: Heavy metals concentration in fish, plant, sand and water samples from Dam, Igbeti, Oyo State.

Sample	Ni	Mn	Zn	Cu	Fe	Co	Pb	Cr	Cd
Fish (mg/kg)	0.037	0.125	0.433	0.043	0.209	0.179	0.355	0.010	0.055
Water (mg/l)	0.007	0.005	0.046	0.018	0.229	0.050	0.020	0.039	0.003
Plant (mg/kg)	0.055	0.058	0.402	0.066	0.512	0.014	0.968	0.053	0.002
Sand (mg/kg)	0.015	0.018	0.083	0.089	0.216	0.015	0.054	0.099	0.002

Table 2: Nickel (Ni) Concentration

Sample	Average	Standard Permissible Limit	Reference
Fish	0.037	0.50	WHO 2018
Water	0.007	0.07	WHO 2017
Plant	0.055	0.50	WHO 2018
Soil	0.015	0.35	WHO 2018

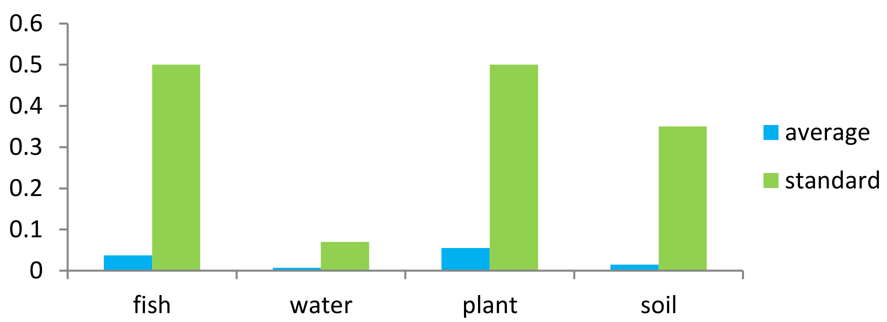

Figure 1: Nickel (Ni) Concentration

In all four (4) samples, i.e. fish (gill), water, plant and soil, the average manganese concentration was lower than the maximum tolerable limit set by the WHO. This means that the concentration level of manganese in this sample cannot be harmful to humans if consumed.

Table 4: Cobalt (Co) Concentration

Sample	Average	Standard permissible limit	Reference
Fish(mg/kg)	0.125	0.14	WHO 2018
Water (mg/l)	0.005	0.4	WHO 2017
Plant(mg/kg)	0.058	0.14	WHO 2018
Soil(mg/kg)	0.018	0.14	WHO 2018

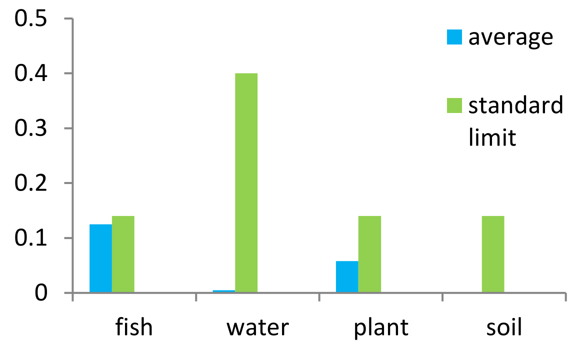

Fig 2: Manganese (Mn) Concentration

In all four (4) samples, (fish, water, plant and soil) the average manganese concentration was lower than the maximum tolerable limit set by the WHO. This means that the concentration level of manganese in this sample cannot be harmful to humans if consumed.

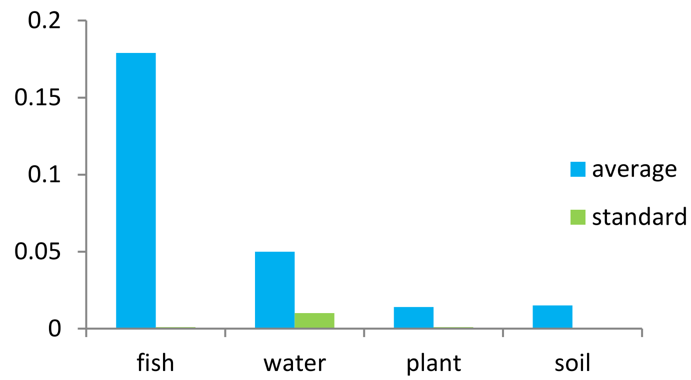

Fig 3: Cobalt (Co) Concentration

From the table and chat above, it is clear that all four samples analyzed (fish, water, plant and soil) had Cobalt concentrations higher than the standard limits set for the samples by the WHO. This simply means all samples are potent sources for Cobalt poisoning, this is even more pronounced in the fish sample than all others, therefore it's a red flag to consume products from this source especially fish as cobalt has been identified as a precursor to lung cancer (Leyssens *et al*., 2017).

Table 5: Zinc (Zn) Concentration

Sample	Average	Standard permissible limit	Reference
Fish (mg/kg)	0.433	0.50	WHO 2018
Water (mg/l)	0.046	3.0	WHO 2017
Plant (mg/kg)	0.402	0.50	WHO 2018
Soil (mg/kg)	0.083	0.30	WHO 2018

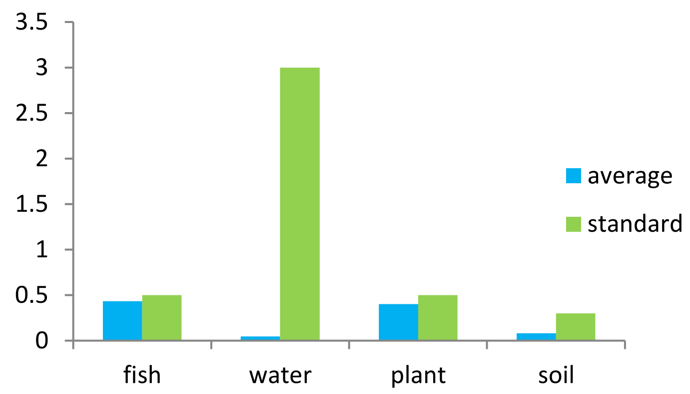

Fig 4: Zinc (Zn) Concentration

Zinc concentrations in the analyzed samples were all below the maximum standard limits set by the WHO as illustrated in the chart above. The samples are therefore safe from excess zinc ingestion.

Table 6: Iron (Fe) Concentration

Sample	Average	Standard permissible limit	Reference
Fish (mg/kg)	0.209	1.4	WHO 2018
Water (mg/l)	0.229	0.5	WHO 2017
Plant (mg/kg)	0.512	1.4	WHO 2018
Soil(mg/kg)	0.216	1.59	WHO 2018

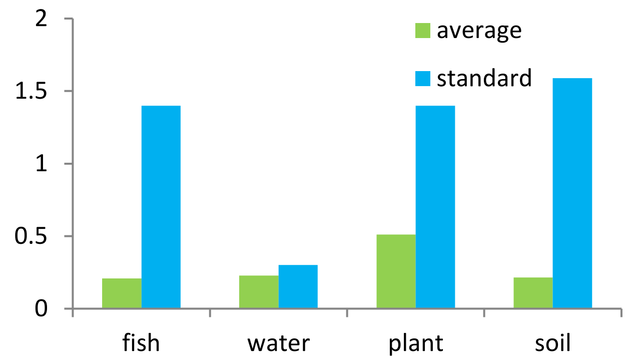

Fig. 5: Iron (Fe) Concentration

Although iron is an essential mineral for both humans and animals, excessive levels in the body can become toxic. As illustrated above, the level of iron concentrations in the samples analyzed from the Igbeti Dam area are all below the maximum tolerable limits set by the WHO.

Table 7 :Chromium (Cr) Concentration

Sample	Average	Standard permissible limit	Reference
Fish (mg/kg)	0.010	0.1	WHO 2018
Water (mg/l)	0.039	0.05	WHO 2017
Plant (mg/kg)	0.053	0.1	WHO 2018
Soil (mg/kg)	0.099	0.05	WHO 2018

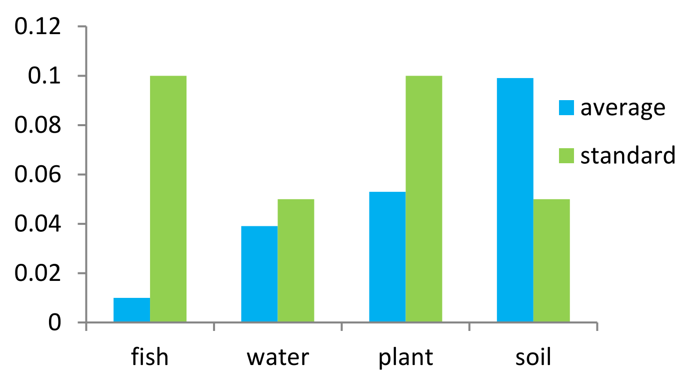

Fig. 6: Chromium (Cr) Concentration

All the samples except the soil, showed levels of Chromium concentrations that are below the set tolerable limits. Interestingly, the results obtained show a descending order in Chromium concentrations from the soil, to the plant, to the water and the fish. This means that the chromium moves primarily from the soil into the plant and water body; and subsequently into the fish and other consumers of the plants and water. This trend therefore needs to be checked to be sure of the main source of chromium.

Table 8 :Lead (Pb) Concentration

Sample	Average	Standard permissible limit	Reference
Fish (mg/kg)	0.355	0.1	WHO 2011
Water (mg/l)	0.020	0.01	WHO 2017
Plant (mg/kg)	0.968	0.1	WHO 2011
Soil (mg/kg)	0.054	0.025	WHO 2018

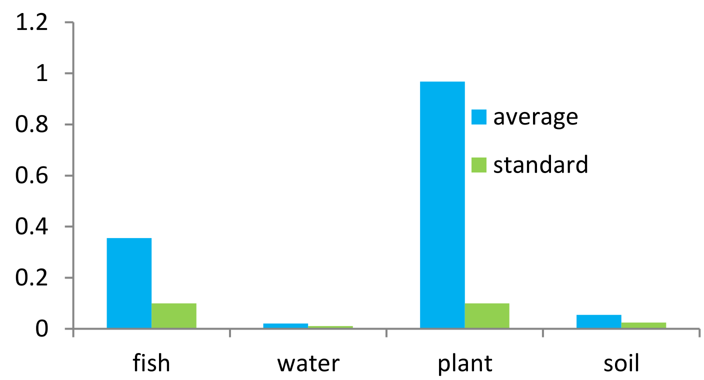

Fig. 7: Lead (Pb) Concentration

Again, the results on table and chat show disturbing concentrations of lead in all four samples analyzed from the Igbeti dam area as they are all above the standard limits. As previously discussed, lead is a poisonous metal that is responsible for about 1.5% of the total fatalities worldwide each year, with a total number of 900,000 deaths, which is approximately equal to the (954,000) total victims caused by HIV/AIDS. Once Pb reaches the body via the gastrointestinal or respiratory system, it is distributed by the blood to other organs and poisons the blood, thereby suffocating its host (Alalwan *et al.*, 2020).

Table 9: Cadmium (Cd) Concentration

Sample	Average	Standard permissible limit	Reference
Fish (mg/kg)	0.055	0.05	WHO 2011
Water (mg/l)	0.003	0.003	WHO 2017
Plant (mg/kg)	0.002	0.05	WHO 2011
Soil (mg/kg)	0.002	0.025	WHO 2018

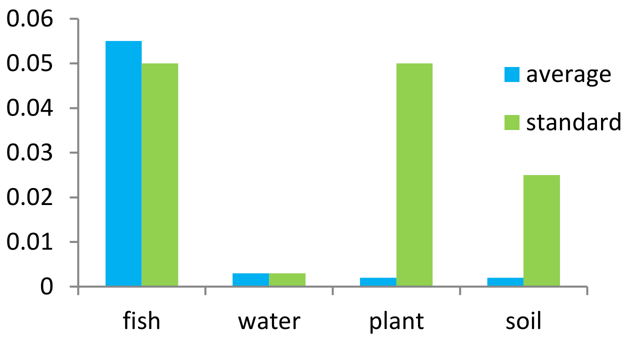

Fig. 8: Cadmium (Cd) Concentration

The results obtained from the table and chat show intolerable cadmium concentrations for both water and fish samples which are above the WHO set limits, but tolerable cadmium concentrations were recorded for plant and soil samples. It is to be noted that cadmium is a toxic element regarded as one of the leading hazardous contaminants in water. Therefore, cadmium metal accumulates mainly in the human kidneys, with a comparatively lengthy half-life of 10 to 35 years. Thus, kidneys are the main organ affected by cadmium poisoning as a water contaminant. Cadmium accumulation also impacts the bones and promotes cancer at high levels. However, the most serious kind of Cadmium exposure seems to be intense bone pain which is known as "itai-itai" illness in Yoruba language. In addition, cadmium has been linked to liver disease and high blood pressure. Moreover, cadmium in polluted water may disrupt many body functions which can cause short-term and/or long-lasting issues (Richter *et al.*, 2017).

Table 10: Copper (Cu) Concentration

Sample	Average	Standard permissible limit	Reference
Fish	0.043	0.1	WHO 2018
Water	0.018	2.0	WHO 2017
Plant	0.066	0.1	WHO 2018
Soil	0.089	0.05	WHO 2018

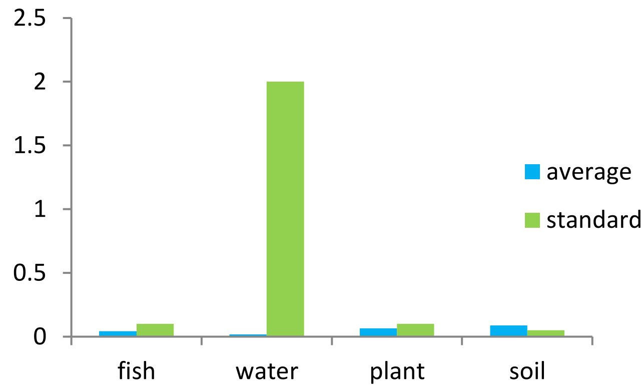

Fig. 9: Copper (Cu) Concentration (mg/ kg)

The result of the analysis for copper shows that the copper concentrations were lower in the fish, water and plant samples but greater than the tolerance limit set by WHO in the soil sample. Copper metal is regarded as an extremely hazardous element in water, and the only element more harmful when compared with copper is mercury. Even though copper is important to mammals' metabolic processes, excess copper intake causes severe side effects such as elevated blood pressure, rapid breathing, renal and liver damage, seizures, cramping, sickness, and potential mortality. Cu (II) ions typically build up in various body parts like the brain, skin, and pancreas, causing major health issues especially in the liver, kidneys, and respiratory system. In addition, Wilson's illness and Menkes syndrome appear to be significantly impacted by unusual copper amounts linked to proteins (Abbas *et al.*, 2016).

4. Conclusion

In conclusion, proactive steps must be taken to stem the observed trend in heavy metal concentrations. Chromium, lead, cobalt, and copper need to be properly monitored to avoid food poisoning. This trend has only been noticed in the rainy season, so similar research will also be needed during the dry season to establish and ascertain the causes and average trend of these metals.

Authors' Contributions

All authors have participated in conceptualization, analysis and interpretation of the data;

Declaration of Competing Interest

The authors declare no competing interests

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