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Heavy Metal Contamination and Physiochemical Parameters of Water, Fishes and Sediments in Jos South Plateau State, North Central, Nigeria using X-Ray Fluorescence (XRF) Spectrometer

[1]Bello, A. A., *[2]Ewuga, U. J., [3]Orkaa, S. M. and [4]Dlama, J. Z.

[1]Physics Department, Federal University of Lafia, Nasarawa State.
[2]Physics Department, Karl Kumm University Vom, Plateau State.
[3]Department of Radiography and Radiation Science, Rev.Fr. Moses Orshio Adasu University, Makurdi.
[4]Department of Radiography, Federal University of Lafia, Nasarawa State.

*Corresponding author's email: uluewuga@gmail.com

ABSTRACT
Consumers health may be in danger if exposed to heavy metals, particularly in food. Water, biota, and sediments in and around abandoned mining ponds could be polluted with heavy metals which may impact the well-being of fish consumers from these ponds. This study aimed to determine the physiochemical parameters of water samples and the level of heavy metals in two abandoned mining ponds in Jerek community, Jos South Local Government Area of Plateau State, Nigeria. Water samples were collected from two ponds (Ponds 1 and 2) and analyzed to measure the concentrations of five heavy metals (Ni, Mn, Pb, Cd and Fe) using an XRF spectrometer (Model AA240FS). The results of the water quality assessment showed that the water samples in Pond 1 had a Pb and Cd contamination value of 2.2 mg/L and 2.0 mg/L respectively, which is above the WHO (World Health Organization) acceptable limit of 0.03 – 0.5mg/L, while Pond 2 had higher contamination of Pb (2.4mg/L) and Cd (2.6mg/L) which also are above the WHO acceptable limit. The catfish in pond 2 had the highest concentration of Cd (5.08mg/L) which signifies a toxic level of concentration when compared with (Federal Environmental Protection Agency) FEPA and WHO acceptable limit. The concentration levels in the sediment were high in Cd (1.55mg/L) in Pond 1 and Cd (1.703mg/L) in Pond 2 as compared to other heavy metals of interest. These values however fall within the WHO, 2018 and FAO, 2019 acceptable limits. The physiochemical properties: pH, Salinity, Turbidity, Dissolved Oxygen (DO), total dissolved solids (TDS) and Electrical Conductivity, were all within the FEPA and WHO permissible limits. The study concludes that the fish from the selected ponds especially catfish are potentially harmful to consumers' health. Hence a need for regular monitoring and evaluation of water, sediments and fish in these ponds.

Keywords:
Fish,
Heavy metals,
Jerek,
Physiochemical,
Pollution,
Pond,
Sediments,
Water.

INTRODUCTION

The dumping of mine waste, acid deposition, sewage, sludge, and other human activities have an impact on the soils and aquatic habitats in many developing nations, including Nigeria. Radioactive materials can find their way into water through a variety of means, including airborne deposition in surface water, seepage or erosion into ground or surface water from the ground, and human activities like farming, mining, and industrial processes. They can also dissolve as water passes through subterranean mineral deposits.

The water-soil interface and the water-atmosphere interface are the medium through which the heavy metals travel (Ali et al., 2018; Varol, 2011). Both anthropogenic activities and geochemical processes are responsible for heavy metal contamination in ecosystems (Li et al., 2007). Elements that have high density and are less noxious are known as heavy metals. Examples of heavy metals are lead, iron, mercury, cadmium, zinc, arsenic, copper, and chromium and the actual volume of these heavy metals is more than 6 gm^{-3} (Tavakoli et al., 2018).

These metals can be found on the layer of the earth in their regular form, they have the property of environmental persistence, they cannot be degraded or decomposed, and they can bioaccumulate (Baby et al., 2010). They could enter the aquatic system and ecosystem through various pathways from the air, via drinkable water, or through multiple chemicals and products that are manmade. Their route of administration is via inhalation, ingestion, and skin absorption. They impair the quality of the aquatic ecosystem and human health (Meng et al., 2023; Sharma et al., 2009). These heavy metals get into the biosphere via human activities, which include industrial production, mining, agriculture, and transportation (Sardar et al., 2013).

Some primary sources of metal pollution are fossil fuel burning, smelting of different waste from the municipality, fertilizers, pesticides, and sewage (Nriagu, 1979; Kabata-Pendias,1984; Rai, 2009). The toxicity of heavy metals in the human body reduces energy levels; disrupts brain functioning; disturbs the functioning of various other organs such as the brain, lungs, liver, and kidney; and hinders blood composition. If the contact with these metals continues, then it can hinder physical, neurological, and muscular functioning which could lead to diseases like multiple sclerosis, Parkinson's disease, muscular dystrophy, and Alzheimer's disease. Chronic exposure to some of the heavy metals and their compounds may even cause cancer (Ghosh et al., 2017).

Pollution of heavy metals into the river may cause distressing effects on the ecological balance of the aquatic environment, and with the extent of contamination, the diversity of aquatic organisms becomes limited (Ayandiran et al., 2009). The fish in the aquatic ecosystem can be used to examine the well-being of biota. Due to pollutants in the food chain of organisms, harmful effects can be seen and the aquaculture can become dead (Sankhla et al., 2020). These heavy metals are neurotoxins for the fish living in the aquatic environment.

When these heavy metals enter the fish body, they interact with them to generate biochemical reactions inside the fish, which makes it difficult for fish to communicate with their surroundings (Baatrup, 1991). Illnesses such organic mercury poisoning (Minamata) are brought on by these metals. If heavy metals are present in the water, they may bioaccumulate in the fish that inhabit it, endangering people and other animals when ingested (Sonone et al., 2020). There are three pathways through which humans get exposed to trace metals, which include directly ingesting, inhaling through the mouth or nose, and via skin absorption when it gets exposed. From the water, the heavy metals usually enter through ingestion and dermal absorption. The average daily dose is measured for pollutants through different identified paths to assess exposure. In a dose-response assessment for no carcinogens, reference doses (RfD) are calculated, and for carcinogens, slope factors (SF) are obtained by the United States Environment Protection Agency (USEPA) Integrated Risk Information System (IRIS) database.

Table 1: The Permissible Limit of Heavy Metal Ions in Water

Heavy metal ions	WHOs Permissible Limit (mg/L)
Se	0.02
Hg	0.001
Mn	0.02
Ag	0.1
Cd	0.05
Cr	0.003
Pb	0.01
Zn	3.00
Fe	0.30
Cu	0.02
As	0.01

Source : (Meng et al., 2023; Wu et al., 2009)

Recent study by (Dabak et al., 2019) assessed the levels of some heavy metals in water and fish from Plateau State. The results showed the concentrations of Mn and Ni in water sources were higher than World Health Organisation (WHO) maximum permissible limits of 0.05mg/L and 0.06mg/L respectively. Also, Petrocephalus bovei recorded the highest mean concentration of Mn and Ni, while Co was highest in Clarias gariepinus species.

Gungsat, 2020 assessed heavy metals in water and fish samples of abandoned mining ponds in Barkin Ladi. Results obtained indicates that the abandoned tin mining ponds are somewhat polluted with toxic heavy metals which can bioaccumulate or bioconcentrate in aquatic lives. Therefore, the concentrations of Cd and Pb in the fish species were higher than recommended national and international recommended values. These studies mentioned above focused on water and fish species without considering other factors of bioaccumulation of elements like sediments.

This study assessed the physiochemical parameters water and also the heavy metal concentration (Ni, Cd, Mg, Fe and Pb) in water, sediment and fish species in some abandoned mining ponds in plateau state. The Enrichment Factor (EF), Pollution Index (PI) and the Contamination Factors (CF) of heavy metals in water, sediment and fish samples were also determined. Findings from this study will be beneficial to the economy in areas of water resource management and treatment. In the health sector in the areas of water borne disease prevention and food poisoning and water waste treatment. This study will help in scientific research advancement, policy development and community engagement towards a better and sustainable environment.

MATERIALS AND METHODS

Description of Study Area

Figure 1: Map of the study Area (Source: GPS)

Jerek Village is one of the oldest tin mining areas in Plateau State. Tin mining activities have created over ten mining ponds. The area has an elevation of 1,298 meters (4,259 feet) and lies on latitude 90 54' 54'' N and longitude 80 54' 35''E respectively in Jos South Local Government Area of Plateau State, North Central, Nigeria.

Preliminary Survey

In carrying out this study, a reconnaissance survey of the study location was carried out in June 2024 to select the appropriate sites for the investigation. Information collected during this survey aided the choice and mapping of the various abandoned mining sites, and abandoned ponds for sampling.

Water Sample Collection and pre-Treatment

To assess the water quality and the concentration of heavy metals in the study area, two (2) water samples were collected from two abandon mining ponds. The collected water samples were preserved by acidifying with concentrated HNO_3 to keep the metal ions in the dissolved state and slow down microbial activities (Boamponsem et al., 2010) and were stored in the ice chest at 4 °C before taken to the laboratory for heavy metal analysis.

Digestion of water samples for heavy metal analysis

Exactly 5 ml of water samples was digested by the addition of exactly 10 ml of concentrated nitric acid and 10 ml of hydrogen peroxide. This was heated on a hot plate to about half the original volume. The flask was collection and preservation of all water samples was carried out according to the methods of American Public Health Association (APHA, 2005). Well-labelled and preserved polyethylene sampling bottles (2 dm^3) were cleaned by washing in detergent, rinsed with tap water and later be soaked in 10% HNO_3 for 24 h and finally rinsed with distilled water before being used for sampling. At each sampling point, the bottle was rinsed three times with the water before the collection of a 15-ml water sample. All the water samples collected were filtered into polyethylene sampling bottles that were prewashed with de-ionized water. During the sampling times, parameters such as pH, electrical conductivity, temperature, and total dissolved solids were measured on-site using a portable PCSTestr pH/conductivity meter (Model: PCSTestr 35 multi-Parameter), and turbidity was measured using a portable Hanna digital turbidity meter while the dissolved oxygen level was measured using a Biocotek portable DO analyze. The pH meter was calibrated with pH 4 and 7 standards. The allowed to cool and its contents filtered into a 25-ml standard volumetric flask and made up to the mark with distilled water according to (Popoola et al., 2011). The digest was then filtered into a 25-ml standard flask and cooled and diluted to mark. To rule out experimental bias or some random error, triplicate digestion of each sample was carried out and a portion of the solution was used for heavy metal determination. The analysis was conducted using an XRF spectrometer (model AA240FS).

Sediment Samples Collection and Preparation

Sediment samples were collected from the ponds and were dried in an oven at a temperature of around 60^0C for 24hours to remove moisture. The dried sediment samples were grinded into fine powder using a grinding mill to ensure homogeneity. The samples were then sieved through a fine mesh 200µm size holes to remove any coarse particles. Pellets were then prepared from the powdered samples using a pellet press. The pellets were typically 30 – 40mm in diameter and 10mm thick.

Fish Samples Collection and Preparation

Fish samples were collected and stored in a clean environment. The fish samples were then taken to the laboratory where they were dissected and the need quantity of muscles were obtained. The muscles were freeze-dried to remove moisture after which they were grind into fine powder using grinding mill. Pellets were then formed from the powdered muscles using a pellet press.

Quality assurance and quality control

To ensure that the results were authentic and correct, strict quality assurance and control protocols were rigorously adhered to. All the chemicals and reagents used were of analytical grade. All polyethylene sampling bottles and glassware used in the laboratory were cleaned by washing with detergent, rinsed in tap water, later soaked in 10% HNO_3 for 24 h, and then finally rinsed with distilled water before use for sampling (APHA, 2005).

Contamination Factor

The contamination factor (CF) was obtained by using the following equation by (Boamponsem et al.,2010);

$$CF=\frac{Concentration\ of\ metal\ in\ sample}{Concetration\ of\ metal\ in\ background} \quad (1)$$

In this research work, the (WHO, 2004) guidelines for drinking water quality was used as the background level for the calculation of the contamination factor of the water samples.

The pollution Load Index (PLI) of Heavy Metals

This index was used for pollution assessment of heavy metals in the water samples within the area of study (Bhupander et al., 2011). The pollution load index for each site was calculated using the following relation:

$$PLI=\sqrt[n]{CF1 \times CF2 \times CF3 \times - - CFn} \quad (2)$$

where CF is the contamination factor of each metal that was examined, and n equals the number of contamination factor. A PLI value > 1 indicates pollution whereas a PLI value< 1 indicates no pollution (Ong et al., 2013).

Enrichment Factor (EF) of Heavy Metals

An enrichment factor is a parameter that is used to evaluate natural or anthropogenic sources of heavy metal content in the soil and water (Ayandiran et al., 2009). This index was used to distinguish between natural and anthropogenic sources. To calculate the enrichment factors for the entire element, iron (Fe) was used as a reference element. Reference elements are mostly conservative ones, such as the most commonly used elements which include Fe, Sc, and Ti (Hernandez et al.,2003; Ayandiran et al., 2009).

RESULTS AND DISCUSSION

Physiochemical Properties of water samples and quality assessment of pH

Table 2a: Physiochemical Properties of Water Sample in Pond 1

Parameters	Pond 1	WHO	FEPA
pH	8.2±0.01	6.5 -8.5	6-9
Salinity(mg/L)	39.2±0.01	0 – 1,000	0.00-0.10
TDS (mg/L)	64.0±0.01	500	-
Temperature(^{0}C)	28.0±0.5	25 – 30	<40
EC(µS/cm)	91.4±0.01	300	20 – 150
Dissolved Oxygen(mg/L)	2.2±0.73	5	8.0
Turbidity (NTU)	18.8±2.8	5-25	1-150

Table 2b: Physiochemical Properties of water sample in Pond 2

Parameters	Pond 2	WHO	FEPA
pH	8.4±0.01	6.5 -8.5	6-9
Salinity(mg/L)	26.2±0.01	0 – 1,000	0.00-0.10
TDS (mg/L)	68.0±0.01	7.5	-
Temperature(^{0}C)	27.0±0.5	25 – 30	<40
EC(µS/cm)	95.4±0.01	300	20 – 150
Dissolved Oxygen(mg/L)	2.4±0.73	5	80
Turbidity (NTU)	18.2±2.8	5-25	1-150

Table 2a and 2b shows the physiochemical properties of water samples collected from ponds 1and 2.

pH Values

According to (Evans et al., 2009), the pH of a water body determines the quality because it affects the solubility and toxicity of metals. The pH of both ponds in the study area were slightly alkaline with values of 8.2±0.01 and 8.4±0.01 respectively. During the present investigation, the mean pH of the water samples was observed to be within the (Wetzel, 2006) permissible range of 6.5- and 9.2-units, tables 2a and 2b. It is important to note that the alkalinity levels of both ponds can be attributed to geology of the areas as the soil and sediments may contain minerals like limestone, dolomite or serpentinite which can dissolve in water (Osibanjo et al., 2012). Also, biological activities by certain microorganism can also contribute to alkalinity through their metabolic processes National Research Council (NRC, 2007). Alkaline conditions (pH 8-9) can precipitate Pb out of solution, reducing its toxicity (NRC, 2007). It can also increase the solubility of Cd, making it more mobile and toxic (McBride, 1980).

Electrical Conductivity

Tables 2a and 2b shows the Electrical Conductivity (EC) of the water samples collected from pond 1 and 2 respectively. The results show that the EC of all the water samples were below the (WHO, 2004) permissible limits of 300μS/cm and 20- 150 μS/cm respectively.

Electrical conductivity (EC) measures the ability of water to conduct electricity, which is related to the amount of dissolved minerals in the water without an indication of which element is present or absent. A high value of EC is an indication of the presence of sodium, potassium, chloride, or sulfate contaminants (Orebiyi et al., 2010). Electrical conductivity is a good way to measure the total dissolved ions as it has a direct relationship with the total amount of solids in the water samples. This then means that a high number of dissolved ions in water translates to a greater number of ions in water (Adewoye et al., 2021).

Total Dissolved Solid (TDS)

Table 2a and 2b also shows the values of the total dissolved solid (TDS) in pond 1 and 2.

All the water samples from the two ponds analyzed from the study area were found to be below the (WHO, 2004) permissible limits of 500 mg/L. However, the TDS level of pond 2 is higher than pond 1 because agricultural activity is intensive as well as industrial activities. This may be responsible for the higher values.

Total dissolved solids refer to the inorganic and small amounts of organic matter present in solution in water (WHO, 2004). High TDS levels can be toxic to aquatic and human lives, causing osmotic stress, respiratory distress, and even death (NRC, 2007). Also, elevated TDS levels can reduce growth rates and reproduction in aquatic species (Li et al., 2007). The effects in humans includes gastrointestinal problems such as nausea, vomiting and diarrhea when the water is being consumed Standard Organisation of Nigeria (SON, 2007). Again, long-term consumption of water with high TDS levels can lead to kidney problems, as the kidneys have to work harder to process the excess minerals (SON, 2007).

Turbidity

Table 2a and 2b shows the values for the turbidity of the two ponds. The turbidity values of all the water samples analyzed were within the (WHO, 2004) permissible limit of 5-25 NTU and (SON, 2007) permissible limit of 1- 150NTU.

Water turbidity is very important because high turbidity is often associated with a higher level of disease-causing organisms such as bacteria and other parasites (Shittu et al., 2008). High turbidity can reduce light penetration, affecting photosynthesis and primary production (Covich et al., 1999). Also, it can lead to increased mortality rates among aquatic organisms especially those with gills (e.g fish and other invertebrates) (Bruton, 1985) and it can also alter habitats making it difficult for aquatic organisms to find food. shelter and breeding grounds (Abraham et al., 2018).

Dissolved Oxygen (DO)

The values for the DO of the two ponds are in Tables 2a and 2b. The DO levels recorded at the mining ponds were 2.2±0.73mg/L and 2.4±0.73 mg/L for pond 1 and pond 2 respectively. For all the water samples analyzed, the values were below the 5-mg/L minimum standard limit (Wetzel, 2006).

Dissolved oxygen is one of the most important parameters used to measure water quality and to determine the degree of freshness of a river (Fakayode et al., 2005). It is also used to indicate the level of organic pollution in a water body (Wetzel, 2006). It is important to note that there is a direct relationship between the amount of dissolved oxygen and temperature as well as biological activities (Chapman and Kimstach, 1992). According to (Brett, 1979), DO levels ranging from 2 – 4 mg/L will cause stress to aquatic life, reduce growth and reproduction. The high value recorded in surface water may be attributed to the open-source of the water and is highly enriched with oxygen from the atmosphere.

Salinity

It is a measure of the concentration of dissolved salts in water bodies, typically measured in parts per thousand (ppt) or milligrams per litre (mg/L). Salinity affects the balance of essential ions, potentially leading to respiratory distress, nerve damage or even death (Evans et al., 2009). Increased salinity can lead to a decline in species diversity, as some organisms are more tolerant than others (Bruton, 1985). The salinity levels of the two water bodies recorded were 39.2±0.01 and 26.2±0.01mg/L respectively as recorded in Tables 2a and 2b. It therefore shows that it is within the (WHO, 2004) permissible limit for salinity of water bodies of 0 – 1,000mg/L.

Concentration of Heavy Metals in water

Table 3: Heavy metals concentration in water of Pond 1 and Pond 2

Parameters	Pond 1(mg/L)	Pond 2 (mg/L)
Nickel (Ni)	0.013±0.001	0.023±0.001
Manganese (Mn)	0.008± 0.001	0.033±0.001
Lead (Pb)	0.022± 0.002	0.024±0.002
Cadmium (Cd)	0.006 ±0.001	0.008±0.001
Iron (Fe)	0.033±0.002	0.045±0.002

Table 3 shows the values of water contamination by heavy metals (Ni, Mn, Pb, Cd, and Fe) from pond 1 and pond 2. The concentration of Nickel (Ni) was 0.013±0.001mg/L in pond 1 and 0.023±0.001 in pond 2. This is in line with the (WHO, 2004) permissibly limit of 0.025 – 0.1mg/L. Ni toxicity can affect growth, reproduction and survival.

High levels can cause bioaccumulation and biomagnification.

Cadmium is a known carcinogen, especially for lung cancer. It also causes kidney, intestinal, and lung damage. Cadmium is associated with behavioral and learning defects, low fetal weight, and skeletal deformation in pregnant animals. Research also suggests that low sperm count and low birth weight are caused by cadmium (Varol, 2001). In the study under review, cadmium was slightly above the national and international permissible limit meaning there is a risk of cadmium contamination in the two water bodies. This implies that vital humans' organs may end up being damaged if Cd is allowed to bioaccumulate. Fe is a necessary element found in nearly all living organisms and is considered at the border between macro and microelements. Iron-containing enzymes and proteins often contain heme-prosthetic groups that participate in many biological oxidations and transport (Chandra et al., 2009). The concentration of iron ranged from 0.033±0.002mg/L in Pond1 and 0.045±0.002mg/L in Pond 2. The iron (Fe) content of all the water samples was found to be below the (WHO, 2004) maximum permissible limit of 1 mg/L. Though an important component of human dietary requirement required by hemoglobin, a high concentration of iron is stored in the pancreas, heart, spleen, and the liver. This may end up damaging these vital organs. Furthermore, the presence of excess iron in water affects the taste as well as promotes the growth of iron bacteria that increases the rate of rusting (Chukwu et al., 2019). The level of manganese in all the water samples analyzed was below the maximum desirable limit as specified in the national and international standards. This means the people may not suffer from the problem of manganese, because excess manganese can increase bacterial growth, interfere with the ingestion of dietary iron, and cause hypertension in patients older than 40 years (Adewoye et al., 2021). Also, high manganese exposure can cause neurological damage, including Parkinson's disease-like symptoms, cognitive impairment and neuropsychiatric effects (WHO, 2004).

The most significant of all heavy metals are Lead (Pb) owing to its toxicity and abundance in the earth's crust (Gregoriadou et al., 2001). Lead is harmful even in the minutest quantity (Adewoye et al., 2021). Children are more susceptible to Pb exposure than adults; it has been shown to impair children's physical growth and lowering their intelligence (US Department of Health and Human Services, 2005). Exposure to lead has been associated with attention deficit, hyperactivity disorder, antisocial behavior, an endocrine disorder, and hormonal dysfunction. Furthermore, lead is a known carcinogen and a neurotoxin substance (Bellinger et al., 2008). All the water samples analyzed showed lead (Pb) concentration slightly above the maximum permissible limit as specified by the WHO, indicating a possibility of Pb contamination if not checked. Elevated levels of Pb in the water samples can be attributed to agricultural run-off from Lead-based pesticides and fertilizers which can contaminate soil and water(NRC,2007)

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Concentration of Heavy Metals in Sediments

Table 4: Heavy metals concentration in sediments of Pond 1 and Pond 2

Parameters	Pond 1(mg/L)	Pond 2 (mg/L)
Nickel (Ni)	0.770 ± 0.137	0.890±0.137
Manganese (Mn)	0.621 ±0.109	0.740±0.109
Lead (Pb)	0.194±0.024	0.230±0.024
Cadmium (Cd)	0.620 ± 0.109	0.681±0.109
Iron (Fe)	1.234±0.108	1.520±0.108

Table 4 shows level of heavy metals concentration in the sediment samples analyzed in ponds 1 and 2. The concentration of Nickel in the sediments was 0.770 ± 0.137mg/L and 0.890±0.137mg/L for pond 1 and pond 2 respectively. This shows that the level is below national and international standard level. High levels of Nickel can be toxic to aquatic organisms, causing mortality, growth inhibition and reproductive effects (WHO, 2004). Nickel is also classified as a carcinogen and exposure to high levels can increase cancer risk (Waste, 1991). Manganese in high levels in sediments can accumulate in aquatic organisms, potentially leading to biomagnification up the food chain and human exposure through consumption of contaminated seafood (WHO, 2004). From the study under review the concentration of Mn in the sediments were 0.621 ±0.109 and 0.740±0.109mg/L. However, these values are below the permissible limit of international standard. Cadmium concentration in sediments in high levels can be toxic to aquatic organisms, including fish, invertebrates and microorganisms even at low concentrations (Tavakoli et al., 2018). In humans, when consumed through seafood, Cd exposure can cause kidney damage and disease (NRC, 2007). The analysis of the sediment carried out revealed that the concentration level of Cd in the two sediment samples was above the permissible limit set by (NRC, 2007) of 0.025mg/L. The elevate values of Cd concentration in the sediments can be attributed to mining activities around the study area and also the use of Cd-containing fertilizers and pesticides (Chukwu et al., 2019). High Iron (Fe) concentration in sediments can have various effects on the environment, aquatic lives and invariably humans. This is because it changes the sediment chemistry by increasing its acidity (Chukwu et al., 2019) and reduces nutrient availability (APHA, 2005). Also, high level of Fe in humans causes gastrointestinal problems, liver and kidney damage and cancer (Chukwu et al., 2019).1.234±0.108 and 1.520±0.108mg/L were the levels of Fe concentration which are slightly above recommended limit of 1.0mg/L (APHA, 2005) and 0.5mg/L (WHO, 2004) Lead (Pb) in sediments can affect the ecosystem and humans entirely. Pb exposure can lead to toxicity of aquatic organisms by bioaccumulation and biomagnification in the food chain (APHA, 2005). It also impacts human health negatively; especially in children Pb exposure causes neurological and developmental effects (Dabak et al., 2019). The analyzed sediments samples for ponds 1 and 2 showed that the concentrations of Pb were 0.194±0.024 and 0.230±0.024mg/L respectively. Indicating that it's above the permissible limit of 0.015mg/L and 0.007mg/L (Gungsat, 2020)

Heavy Metals in Fish Samples

Table 5: Heavy metals concentration in fish species in ponds 1 and 2

Location	Species	Ni	Mn	Cd	Fe	Pb
	Tilapia	0.024±0.002	0.011±0.001	0.020±0.00	0.085±0.011	0.026±0.005
Pond 1	African Snook	0.028±0.003	0.021±0.001	0.013±0.001	0.235±0.041	0.041±0.004
	Catfish	0.145±0.001	0.230±0.001	0.230±0.00	0.450±0.001	0.320±0.001
	Tilapia	0.033±0.002	0.013±0.001	0.023±0.00	0.087±0.011	0.028±0.005
Pond 2	African Snook	0.027±0.003	0.024±0.001	0.030±0.001	0.244±0.041	0.051±0.004
	Catfish	0.160±0.002	0.300±0.001	0.254±0.00	0.470±0.001	0.340±0.001

Table 5. shows the concentrations of Ni, Mn, Cd, Fe and Pb in Tilapia, African Snook and Catfish from ponds 1 and 2. From the results, it can be seen that the highest concentration of Ni in ponds 1and 2 were in Catfish at 0.145±0.001 and 0.300±0.001mg/L. Both values are slightly below recommended national and international recommended standards of 0.5mg/L and 0.1mg/L (Meng et al., 2023). Mn concentration in the three fish species from ponds 1and 2 shows also the highest value in Catfish at 0.230±0.001 and 0.300±0.001mg/L. This shows an elevated value as when compared with 0.2mg/L (Nriagu, 1979) as recommended. The risk is even higher in pond 2 Total concentration of Cd was recorded highest in Catfish at 0.23±0.00 and 0.254±0.00mg/L. When compared to recommended guidelines of 0.01mg/L (Nriagu, 1979) and 0.003mg/L (WHO, 2004). Also, the concentration of Cd in Tilapia and African Snook in both ponds were slightly above the recommended standards. Fe concentration was recorded highest in Catfish from both ponds at 0.450±0.001 and 0.470±0.001 which is above national and international recommended standards of 0.3mg/L and 0.4mg/L (Orosun et al., 2023). The high level can lead to Fe overload causing liver damage, diabetes and cardiovascular disease (Orebiyi et al., 2010). Pb which is a very important heavy metal in this study was recorded highest also in Catfish at 0.320±0.001 and 0.340±0.001 in ponds 1 and 2 respectively. These values are above the recommended limits of 0.2mg/L (Sankhla et al., 2020; Orosun et al., 2023). High levels of Pb when consumed via food chain in humans can cause kidney damage (Chapman & Kimstach, 1992) and can affect human reproduction and development including reduced fertility and birth defects (WHO, 2004; Deutsch et al., 2011). From the results of heavy metals concentrations in the fish species, it can be observed that the highest concentration of Ni, Mn, Cd, Fe and Pb were in Catfish. This can be attributed to the fact that catfish is a benthic feeder. This could also be as a result of the high exposure to bottom feeding fish to the sediment which contains high concentration of heavy metals (Osibanjo et al., 2012). Also, the results show that the heavy metals concentrations are more elevated in pond 2. Possibly because of the ongoing farming and mining activities around the area. Meanwhile the Pollution Load Index (PLI) for pond 1 was 0.184 and pond 2 was 0.807 indicating a low contamination in pond 1 and moderate contamination in pond 2 (Sankhla et al., 2020; Shittu et al., 2008). The result of the Enrichment Factor, Contamination Factor (CF) of water, sediment and fish samples are presented in tables 6,7,8 and 9 respectively.

Table 6: Enrichment factor for water samples using Iron (Fe) as reference element for average

Location/Site	Enrichment factors (EF)			
	Ni	Mn	Pb	Cd
Pond	**10.577**	**0.456**	**1.030**	**2.10**
Pond 2	**0.826**	**0.722**	**2.563**	**2.46**

Table 7: Contamination Factors (CF) of Heavy Metals in Water Samples

Location/Site	Contamination Factors (CF)				
	Ni	Mn	Pb	Cd	Fe
Pond 1	**0.186**	**0.020**	**2.200**	**2.00**	**0.083**
Pond 2	**0.329**	**0.082**	**2.400**	**2.67**	**0.150**

Table 8: Contamination Factors (CF) of Heavy Metals in Sediments Samples

Location/Site	Contamination Factors (CF)				
	Ni	Mn	Pb	Cd	Fe
Pond 1	0.115	0. 0047	0.0146	1.550	0.00019
Pond 2	0. 134	0.0056	0.0172	1.703	0.00023

The enrichment factors (EF) calculated for Nickel (Ni) and manganese (Mn) for all the water samples in pond 1 and 2 were less than 1 showing no enrichment (background level).

The enrichment factor for Lead (Pb) and Cadmium (Cd) in pond 1 was 1.03 and 2.10 while pond 2 recorded a higher value for Pb and Cd of 2.10 and 2.46 respectively. These values indicate a minor – moderate enrichment (Waste, 1991). Generally, the presence of lead (Pb) and Cadmium (Cd) in the water samples of the study area may be due to industrialized and artisanal mining activities of tin, columbite and monazite.

The contamination factor (CF) for Pb and Cd in pond 1 water was 2.200 and 2.00 for pond 2 Pb and Cd have 2.4 and 2.67 respectively. This is an indication of high contamination as when compared with international acceptable limits (WHO, 2004).

Again, the contamination factor (CF) for sediments of the two ponds shows Cd was slightly high indicating a mild contamination (Tavakoli et al., 2018). For the contamination factor in fish samples, the result showed that the all the fish samples have a toxic value of Ni and Mn and a very toxic level of Pb and Cd especially in Catfish (Varol, 2011).

CONCLUSION

The physiochemical properties of water samples were generally within the national and international acceptable limits except for the elevated values of dissolved oxygen (DO) that can be attributed to agricultural and mining activities around the study areas. Furthermore, the water in pond 1 have a minor contamination with Pb and Cd whilepond 2 is having a moderate contamination of Pb and Cd. Also, the pollution load index in pond 1 is low while in pond 2 in moderate. The contamination factor is highest in pond 2 with the catfish having a very toxic contamination as when compared to acceptable limits. This therefore implies that fishes from these ponds especially catfish are potentially harmful to consumers health. The authors recommend the regular monitoring and evaluation of water, sediments and fishes in the ponds in Jerek community. Establishment and enforcement of regulations regarding resurfaced mining activities is highly recommended.

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