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Heavy Metals and Physico-Chemical Properties of *Clarias Gariepinus* from Five Water Bodies in South East Nigeria

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Abstract

This study was conducted to evaluate the concentration of lead (Pb), copper (Cu) and zinc (Zn) of *clarias gariepinus* from three rivers (Uwana, Oziza, Akpoha,) and two aquaculture fish farms (PolyUwana and Ngwo) in the south-eastern part of Nigeria. Samples of fish species and water were obtained in triplicates from fishermen and aquaculture sellers. The fish samples were digested and analyzed. The physico-chemical properties of the water samples were also determined. The result showed that Pb concentrations (ppm) in the fish samples were 0.000 ± 0.001 (Uwana river), 0.014 ± 0.041 (Ngwo), 0.022 ± 0.026 (Akpoha river), 0.043 ± 0.057 (Oziza river) and 0.047 ± 0.063 (PolyUwana). Cu concentrations were 0.020 ± 0.027 (Uwana river), 0.028 ± 0.026 (Oziza river), 0.029 ± 0.023 (PolyUwana), 0.038 ± 0.021 (Ngwo) and 0.048 ± 0.071 (Akpoha river). Zn concentrations were 0.366 ± 0.178 (Uwana river), 0.458 ± 0.323 (PolyUwana), 0.467 ± 0.356 (Akpoha river), 0.486 ± 0.245 (Oziza river) and 0.492 ± 0.161 (Ngwo). There were significant ($p < 0.05$) differences between the river sources for Pb. There was no significant difference between the river sources for Zn and Cu. The physicochemical properties of the water showed low levels of the elements studied and the highest concentration of metals was in Oziza river while the lowest concentration was in Ngwo Aquaculture. There were no significant ($p > 0.05$) differences in Pb, Cu and Zn concentrations of the water samples. Water sample from Oziza river was also found to have the highest turbidity (15.20), highest titrable acidity (0.95) and lowest pH (5.47). In all cases, the heavy metal concentrations were lower than the maximum limit set by FAO/WHO.

Keywords: Heavy metals; *clarias gariepinus*; Physico-chemical, Aquaculture

1. Introduction

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 run offs in addition to sewage effluents, supply to water bodies huge quantities of inorganic anions and heavy metals (ECDG, 2002). The sources of water can beconstantly polluted with a series of metals (as well as with other pollutant) which can be sources of intoxication for man, depending on the dose of metals that exists in the water.

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms (Jarup, 2003). These metals are essential for the maintenance of various biochemical and physiological functions in living

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organisms in very low concentrations, however they become harmful when they exceed certain threshold concentrations. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Jaishankar *et al*., 2013; Nagajyoti *et al*., 2010). The most commonly found heavy metals in waste water include arsenic, cadmium, chromium, copper, lead, nickel, and zinc, all of which cause risks for human health and the environment (Lambert *et al*., 2000). Heavy metals enter the surroundings by natural means and through human activities. Various sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops, and many others (Morais *et al*., 2012). Trace metals such as Zinc (Zn), Copper (Cu) and Iron (Fe) play a biochemical role in the life processes of all aquatic plants and animals, therefore, they are essential in the aquatic environment in trace amount. Extensive research programs have been carried out to investigate the fishes in the inland waters of Egypt, including the northern Delta Lakes (Shakweer and Abbas, 1996; Khallaf *et al.*, 1998; El-Moselhy, 1999; Elghobashy *et al*., 2001).

The most anthropogenic sources of metals are industries, petroleum contamination and sewage disposal (Santos *et al.*, 2005). Metal ions can be incorporated into food chains and concentrated in aquatic organisms to a level that affects the physiological state. Metals have both benefits for the human body when they act as mineral substances and also toxic effects when they reach a certain high concentrations. One group of the effective pollutants is heavy metals which have drastic environmental impact on all organisms (Samir and Ibrahim, 2008).

Since fish is known for the bioaccumulation of heavy metals in its body, it is an important biomonitor of the presence of heavy metal (lead, zinc and copper) in their water. In rural areas, fish is an important source of food for the human population and its procurement is not always controlled, therefore, there is more often a risk for those people who consume contaminated fish.

Fish is a worldwide distributed food commodity. It is regarded as a potentially cheap source of protein, especially in developing countries such as Nigeria and India where problems of nutritional deficiencies persist (Mandakini and Gaihiamngam, 2010).

The level of heavy metals in the fish flesh is of interest because of potential risk to humans (Ashraf, 2005; Barbieri *et al*., 2010). This present work is a public health study aimed at investigating the heavy metal concentration of the most popularly consumed fresh water fish (*Clarias Gariepinus)* in south east Nigeria. The broad objective of this study was to investigate the level of heavy metals in *Clarias gariepinus* in some water bodies in South East Nigeria. The specific objectives were to:

1. Evaluate the heavy metal content of *Clarias gariepinus* from three rivers and two aquaculture fish ponds.
2. Evaluate the heavy metal content of the water body
3. Evaluate the physico-chemical properties of the water bodies.

Clarias gariepinus also known as African catfish is generally considered to be one of the most important tropical catfish species for aquaculture. It has an almost Pan-African distribution, ranging from the Nile to West Africa and from Algeria to Southern Africa. They also occur in Asia Minor (Obaroh *et al*., 2015). C. gariepinus is hardy and tolerates adverse water quality conditions. It can be raised in high densities, resulting in high net yields. It grows fast and feeds on living and dead animal matter. It is also able to swallow relatively large prey whole, because of its wide mouth. This species is of major economic importance and also an important aquaculture species thus it was introduced all over the world for farming purposes in the early 1980s. Clarias gariepinus is also of high economic importance in many countries of the world especially African and Asian continents (Legendre *et al*., 1992; Adebayo and Fagbenro 2004; Olaniyi and Omitogun 2014); and also serve mainly as food in many homes and hotels (Omitogun *et al*., 2012). Recently, there has been an increase in the farming of Clarias and Heterobranchus spp and their hybrids in Nigeria based on their growth performance, short generation interval, and consumer preference or demand, among others.

Nutrient Composition of Fish

The major constituents of fish are moisture, protein and fat with minerals occurring in trace amount (Dhanapal *et al*., 2011).

Table 1: Proximate composition of *Clarias gariepinus*

Parameter (%)	Fresh Catfish
Protein	16.24
Carbohydrate	0.92
Moisture content	78.70
Fat	0.50
Ash	1.33
NFE	2.31

Source: Olayemi *et al*., 2011

The protein content of *Clarias gariepinus* varies up to 20%, depending upon the species and the season of the year. When compared to other animal protein source like goat and chicken meat, it is safer, healthier and also known to be excellent source of protein from its amino acid composition (Emmanuel *et al*., 2011). *Clarias gariepinus* has high moisture content. High moisture content increases susceptibility to microbial spoilage, oxidative degradation of polyunsaturated acids and consequently decreases in the quality of the fishes for longer preservation time (Omolara and Omotayo, 2008). Fish meat contains significantly low lipids and higher water than beef or chicken and is preferred over other white or red meat (Nestel, 2000). Fish contains a considerably lower fat content than beef (Ndome *et al*., 2010; Al-Ghanim, 2016; Tsironi and Taoukis, 2017). The Ash content is a measure of the mineral content of food item. It is the inorganic residue that remains after the organic matter has been burnt off (Olagunju *et al*., 2012). The high value of ash in the fish species is an indication of its high mineral content like magnesium, calcium, potassium, and zinc (Emmanuel *et al.*, 2011). The total lipid and ash content of fish vary with the increasing weight or length of the fish. It may also vary with the season and habitats (Hassan, 1996).

Effect of Heavy Metals on Humans

There are 35 metals that are of great concern to humans because of residential or occupational exposure, out of which 23 are heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc (Mosby *et al.,*1996). These heavy metals are commonly found in the environment and diet. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long-term exposure can lead to gradually progressing physical, muscular, and neurological degenerative processes that imitate diseases such as multiple sclerosis, Parkinson's disease, Alzheimer's disease and muscular dystrophy. Repeated long-term exposure of some metals and their compounds may even cause cancer (Jarup, 2003).

Lead

Human activities such as mining, manufacturing and fossil fuel burning has resulted in the accumulation of lead and its compounds in the environment, including air, water and soil. Lead is used for the production of batteries, cosmetics, metal products such as ammunitions, solder and pipes, *etc.* (Martin and Griswold, 2009). Lead is highly toxic and hence its use in various products, such as paints, gasoline, *etc.* The use of lead has considerably reduced lately. The main sources of lead exposure are lead based paints, gasoline, cosmetics, toys, household dust, contaminated soil, industrial mining and emissions (Gerhardsson *et al.*, 2002). Lead poisoning was considered to be a classic disease and the signs that were seen in children and adults were mainly pertaining to the central nervous system and the gastrointestinal tract (Markowitz, 2000). Lead poisoning can also occur from drinking water. The pipes that carry the water may be made of lead and its compounds which can contaminate the water (Brochin *et al.*, 2008). According to the Environmental Protection Agency (EPA), lead is considered a potential carcinogen. Lead has major effects on different parts of the body. Lead distribution in the body initially depends on the blood flow into various tissues and almost 95% of lead is deposited in the form of insoluble phosphate in skeletal bones (Papanikolaou, 2005). Toxicity of lead, also called lead poisoning, can be either acute or chronic. Acute exposure can cause loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations etc. Acute exposure mainly occurs in the place of work and in some manufacturing industries which make use of lead. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death (Martin and Griswold, 2009). Although lead poisoning is preventable it still remains a dangerous disease which can affect most of the organs. The plasma membrane moves into the interstitial spaces of the brain when the blood brain barrier is exposed to elevated levels of lead concentration, resulting in a condition called edema (Teo *et al.*, 1997). It disrupts the intracellular second messenger systems and alters the functioning of the central nervous system, whose protection is highly important. Environmental and domestic sources of lead ions are the main cause of the disease but with proper precautionary measures it is possible to reduce the risk associated with lead toxicity (Brochin *et al.*, 2008)

Copper

Electroplating and metalworking industries discharge large amounts of heavy metals, including copper (Cu) and nickel (Ni) ions, in their effluents (Ting-Chu, 2009). Environmental contamination due to copper is caused by mining, printed circuits, metallurgical, fiber production, pipe corrosion and metal plating industries. The other major industries discharging copper in their effluents are paper and pulp, petroleum refining and wood preserving. Agricultural sources such as fertilizers, fungicidal sprays and animal wastes also lead to water pollution due to copper. Copper may be found as a contaminant in food, especially shell fish, liver, mushrooms, nuts and chocolates. Any packaging container using copper material may contaminate the product such as food, water and drink (Pamar and Thakur, 2013). Copper has been reported to cause neurotoxicity commonly known as “Wilson’s disease” due to deposition of copper in the lenticular nucleus of the brain and kidney failure. In some instances, exposure to copper has resulted in jaundice and enlarged liver. It is suspected to be responsible for one form of metal fume fever (Pamar and Thakur, 2013). Copper containing sprays are linked to an increase in lung cancer among exposed workers (Onundi *et al*., 2010).

Zinc

Zinc is the 23rd most abundant element in the Earth's crust and its concentrations are rising unnaturally, due to addition of zinc through human activities (Nasernejad *et al*., 2005). Zinc is a lustrous bluish-white metal. It is brittle and crystalline at ordinary temperatures, but it becomes ductile and malleable when heated between 110°C and 150°C. It is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen. Most zinc is added during industrial activities, such as mining, coal and waste combustion and steel processing (Raut *et al*., 2012). Zinc is widely used in industries such as galvanization, paint, batteries, smelting, fertilizers and pesticides, fossil fuel combustion, pigment, polymer stabilizers, etc, and the wastewater from these industries is polluted with zinc, due to its presence in large quantities (Holdren *et al*., 1991: Pamar and Thakur, 2013). During washing of the electroplating tanks, considerable amounts of the metal ions find their way into the effluent (Al-Asheh and Duvnjak, 1997). When it is present in less quantity in human’s body, it affects the human’s health. Although humans can handle repeated exposure to zinc, accumulation of it can be hazardous to human health (Khan and Wahab, 2006).

Toxic Effect of Heavy Metals on Aquatic Organisms

Aquatic organisms are adversely affected by heavy metals in the environment. The toxicity is largely a function of the water chemistry and sediment composition in the surface water system (Volesky, 2003). The metals are mineralized by microorganisms, which in turn are taken up by plankton and further by the aquatic organisms. Finally, the metals by now, several times biomagnified is taken up by man when he consumes fish from the contaminated water. Slightly elevated metal levels in natural waters may cause the following sublethal effects in aquatic organisms:

i. Histological or morphological change in tissues
ii. Changes in physiology, such as suppression of growth and development, poor swimming performance, changes in circulation
iii. Change in biochemistry, such as enzyme activity and blood chemistry
iv. Change in behaviour
v. Changes in reproduction (Pamar and Thakur, 2013).

2. Methods

The samples were digested using the aqua regia digestion method as described by AOAC (2010). The digested samples were analysed according to standard methods using the Atomic Absorption Spectophotometer (Shimadzu model AA7000) as described by AOAC (2010). The physicochemical properties were determined according to standard methods (AOAC, 2010).

Techniques

The samples were left to thaw and three grams of each of the samples were weighed into digestion flasks containing 28 ml aqua regia (21 ml HCl and 7 ml HNO_3) fitted with water condenser. The mixture was kept overnight at room temperature. It was then boiled for 2 hours on an electrothermal heater. The content of the flask was allowed to cool then filtered using the whatman filter paper and diluted to 100 ml with deionised water.

Determination of Heavy Metals

The various standards of the metals were prepared from 1000 ppm stock solution of each metal using the formular: $P_1V_1 = P_2V_2$

The system was put on and allowed to initialize. The various standards were aspirated into the flame and got atomized by the flame. The graph of the standard was plotted and displayed on the monitor. The various samples were aspirated and analysed and the heavy metal concentrations displayed on the screen. The procedure was repeated for each of the elements and the result was printed out.

Studied Material

Samples of *Clarias gariepinus* were collected in triplicates from each collection spot. The raw samples were collected from fishermen and women fish sellers at Akpoha, Oziza and Unwana fresh water ecosystem. The samples were kept in an ice pack temporally from the sampling site and later stored frozen until the analysis took place. Water samples were also be collected for analysis alongside the fish samples at Akpoha, Oziza, and Uwana rivers and analysed in the laboratory

Samples of *Clarias gariepinus* were also collected from a fish pond at Uwana Polytechnic and another fish pond at Ngwo, Enugu State and these served as control samples. The water samples from these aquaculture sites were also collected for analysis

The fish samples were dissected and the gills, viscera and muscle parts of each of the three species were collected, duely labeled and stored in the freezer. Also labeled and stored were samples of the rivers and aquaculture ponds.

Area Description

South East Nigeria is one of the six geopolitical zones in Nigeria. Southeast Nigeria is a region of Nigeria that borders Cameroon to the east and the Atlantic ocean to the south. The dominant language of this region is Igbo. Southeastern Nigeria is also where the oil wealth of Nigeria originates from, which has led to environmental degradation of its extreme south in the mangroves, rivers, and swamps facing the Atlantic. Although southeastern Nigeria is often referred to as a region by Nigerians, it stopped being an official region in 1967 after Nigeria switched to states.

3. Result and Discussion

Heavy Metal Concentration of Clarias Gariepinus obtained from South East Nigeria.

Table 2 shows the result of analysis of heavy metals of *Clarias gariepinus* obtained from south east Nigeria. From Table 2, Pb concentration (ppm) in the fish samples ranged from 0.000 ± 0.001 (Uwana river) to 0.047 ± 0.063 (Poly Uwana fish pond). There were significant differences between the sources for Pb ($p < 0.05$). The value obtained in this research work is similar to the values obtained by Babatunde *et al.* (2012) whose values ranged from 0.01 ± 0.00 to 0.25 ± 0.20. These findings were lower when compared with the findings of Doherty *et al. (*2010) (0.395 – 0.62 ppm) and Okoye *et al.* (1991) (9 ppm) who researched on lead in some fishes from Lagos Lagoon. Farombi *et al.* (2007) had the values that ranged from 0.73 to 4.12 ppm in *C. gariepinus* from Ogun state Nigeria. Obasohan *et al. (*2006) also had the values that ranged from 0.10 to 0.83 ppm in some fishes from Ogba River. Oronsaye *et al.* (2010) obtained values of 2.67 to 3.53 ppm in *Mormyrops delicisus* and *Mormyrus macrophthalmus* from Ikpoba river dam. However, the data from this research work were lower than the standard permissible limit for lead (< 0.5 ppm) in fish food (FEPA, 2003).

Table 2: Pb, Cu and Zn content of Clarias Gariepinus

River	Pb(ppm)	Cu(ppm)	Zn(ppm)
Akpoha	$0.022^{ab} \pm 0.026$	$0.048^{a} \pm 0.071$	$0.467^{a} \pm 0.356$
Uwana	$0.000^{b} \pm 0.001$	$0.020^{a} \pm 0.027$	$0.366^{a} \pm 0.178$
Oziza	$0.043^{ab} \pm 0.057$	$0.028^{a} \pm 0.026$	$0.486^{a} \pm 0.245$
Poly Uwana aquaculture water	$0.047^{a} \pm 0.063$	$0.029^{a} \pm 0.023$	$0.458^{a} \pm 0.323$
Ngwo aquaculture water	$0.014^{ab} \pm 0.041$	$0.038^{a} \pm 0.021$	$0.492^{a} \pm 0.164$

Note: Values presented are means from triplicate samples and standard deviation. Means with same superscript in the same column are statistically similar (p > 0.05)

Cu concentration ranged from 0.020 ± 0.027 (Uwana river) to 0.048 ± 0.071 (Akpoha river). There was no significant difference between the river sources (p > 0.05). The values obtained in this research work were similar to the findings of Olaifa *et al*. (2004) who obtained a Cu concentration of 0.0125 (ppm) and 0.0072 (ppm) in the gills during the rainy and dry seasons respectively, 0.16 ppm in the intestine for both seasons as well as 0.05 and 0.07 (ppm) in the muscle for rainy and dry seasons, respectively. The values obtained in this research work were lower than the standard permissible limit of < 2ppm (FEPA, 2003).

Zn concentration ranged 0.366 ± 0.178 (Uwana river) to 0.492 ± 0.161 (Ngwo fish pond). There was no significant difference between the river sources (p > 0.05). The values obtained in this report were lower than that reported by Olaifa *et al.* (2004), who obtained a range between 0.1104 and 2.25 ppm. The values obtained were less than the WHO (1994) standard permissible limit of 3 ppm.

The trend for Pb concentration was Uwana<Ngwo<Akpoha<Oziza<Poly. There was no significant difference between the river sources (p > 0.05). The trend for Cu concentration was <Uwana<Oziza<Poly<Ngwo<Akpoha. The trend for Zn concentration was Uwana<Poly<Akpoha<Oziza<Ngwo. Generally fish samples from Uwana recorded the least accumulation of these three metals while fish samples from Akpoha river recorded the highest accumulation. This could be attributed to the fact that Akpoha river is the closest river to the major quarrying site (Julius Berger) in Afikpo while Uwana river is the farthest river from this major quarrying site.

Properties of Water Bodies where Fish Samples were obtained

Table 3 shows the level of metals in the 5 water bodies and their physicochemical characteristics. The range of Pb (ppm) in the water body was 0.0 ± 0 in Ngwo fish pond to 0.036 ± 0.062 in Akpoha river. This report is in line with the report of Nwani *et al*. (2010) who obtained a Pb concentration of 0.05 in Afikpo fresh water ecosystem. There were no significant (p > 0.05) differences in the Pb concentration of the water bodies. This could be attributed to the fact that the rivers are from the same geographical location (Adefemi *et al*., 2007). Cu was not detectable at Akpoha, Poly fish pond and Uwana river. This report is in line with the findings of Olaifa *et al.* (2004) who reported that Cu was not detectable in Eleiyele lake and Zartech fish pond. The mean values of copper concentration were 0.01 ± 0.01 and 0.05 ± 0.06 from Oziza river and Ngwo fish pond. There were no significant differences (p > 0.05) in the Cu concentration of the water bodies. Zinc concentrations in the water bodies ranged from 0.006 ± 0.006 in Akpoha river to 0.018 ± 0.001 in Ngwo river. There were no significant differences in the Zn concentration of the water bodies (p > 0.05). This report is also similar to the findings of Olaifa *et al.* (2004) who reported a Zn concentration of 0.0024 in Eleiyele lake. The findings from this research work were less than the FEPA, (2003) and WHO, (1994) standard permissible limit for Pb, Cu and Zn in drinking water.

Table 3: Properties of five water bodies studied.

River	Pd (ppm)	Cu (ppm)	Zn (ppm)	Turbidity	Titrable acidity	Ph
Akpoha	$0.036^{a} \pm 0.062$	$0.0^{a} \pm 0.000$	$0.006^{a} \pm 0.006$	$2.06^{d} \pm 0.150$	$0.66^{c} \pm 0.010$	$7.17^{b} \pm 0.06$
Uwana	$0.033^{a} \pm 0.060$	$0.0^{a} \pm 0.000$	$0.014^{a} \pm 0.015$	$4.53^{c} \pm 0.060$	$0.67^{c} \pm 0.020$	$7.0^{b} \pm 0.100$
Oziza	$0.036^{a} \pm 0.060$	$0.01^{a} \pm 0.010$	$0.014^{a} \pm 0.015$	$15.20^{a} \pm 0.400$	$0.95^{a} \pm 0.010$	$5.57^{c} \pm 0.060$
Poly	$0.033^{a} \pm 0.057$	$0.0^{a} \pm 0.000$	$0.011^{a} \pm 0.006$	$1.10^{e} \pm 0.000$	$0.86^{b} \pm 0.020$	$7.0^{b} \pm 0.200$
Ngwo	$0.0^{a} \pm 0.000$	$0.05^{a} \pm 0.06$	$0.018^{a} \pm 0.001$	$8.37^{b} \pm 0.110$	$0.93^{a} \pm 0.015$	$7.50^{a} \pm 0.100$

Note: Values presented are mean values from triplicate samples with the standard deviation. Means with same superscript in the same column are statistically similar ($p > 0.05$).

Turbidity values of the water bodies ranged from 1.10 ± 0.0 in Poly fish pond to 15.20 ± 0.40 in Oziza river. There were significant differences in the turbidity of the water samples. Titrable acidity ranged from 0.66 ± 0.01 in Akpoha river to 0.95 ± 0.01 in Oziza river. There was a significant ($p > 0.05$) difference in the titrable acidity of the water samples. pH of the water samples ranged from 5.57 ± 0.06 in Oziza river to 7.50 ± 0.10 in Ngwo fish pond. The pH of Oziza river is lower than the findings of Olaifa *et al.* (2004) who obtained a pH of 6.5 to 7.2.

The findings from this report is in line with the report of Oyeku and Eludoyin (2010) who obtained a pH of 5.4 on Heavy metal contamination of ground water resources in a Nigeria urban settlement. The pH report was also lower than the findings of Adefemi and Awokunmi (2010) 6.87-7.68 who researched on Determination of physicochemical parameters and heavy metals in water samples from Itaogbolu area of Ogun State Nigeria. There were significant ($p < 0.05$) differences in the pH of the water samples. pH is considered as an important biochemical and ecological factor and provides an important information in many types of geochemical equilibrium, solubility and concentration calculations. It is an important parameter in water body since most of the aquatic life are adapted to an average pH and do not withstand drastic changes (Shyalama *et al*., 2008). Bioconversions of organic materials in the living system is achieved with the help of enzymes which are specific in action and work within a given pH range (Voet and Voet, 2004).The trend for concentration of metals in the water bodies is Cu<Zn<Pb.

It was observed that the results of the physicochemical properties were within the recommended levels for safe drinking or portable water by Environmental Protection Agency (EPA, 2003). The Environmental Protection Agency Standard for pH in drinking water is 6.5 – 8.5.

4. Conclusion

Aquatic organisms are adversely affected by heavy metals in the environment. The level of heavy metals in the fish flesh is of interest because of potential risk to humans. It is considered that the findings of the study will be a contribution to assess whether the mining and quarrying activities in south east Nigeria poses a risk for the water bodies studied, in terms of heavy metal content.

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6. Conflict of Interest Statement

None of the authors have any conflict of interest to declare.

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