Presence of heavy metals in the Obizi river of Awka and its implications for domestic use

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Abstract
In recent years, human activities have had a considerable impact on the world's water resources, resulting in substantial water supply and drinking water quality challenges. Heavy metal poisoning of drinking water is a worldwide concern that can lead to toxicity and sickness in humans and animals when consumed. Nigeria is Africa's most populous country, with an estimated population of 182 million people. People are subjected to environmental contamination as a result of excessive levels of heavy metal buildup in the environment and tainted drinking water. The occurrence of heavy metals in the Obizi river was studied. *Lead* (Pb), *cadmium* (Cd), *mercury* (Hg), *arsenic* (As), *copper* (Cu), *aluminum* (Al), *manganese* (Mn), and *iron* (Fe) were all tested, and the results were compared to the WHO permitted value for drinking water. When compared WHO criteria, the majority of the metal ions were at higher concentrations. Because, water quality of Obizi river has been determined to be unsafe and unfit for human consumption and irrigation, essential conservation and management actions should be implemented to enhance the Obizi river's declining water quality. Because of their uptake by plants and subsequent accumulation in food crops consumed by humans and animals, the high level of environmental contamination caused by these metals is detrimental to human and animal health. The earth, which releases dangerous metals into food, and water, as well as anthropogenic activities such as fertilizer application in agriculture, pesticide and herbicide use, sewage and waste disposal, and irrigation, are all known sources of toxic metals.

1. Introduction

Water is necessary for life to exist. Water is one of the most valuable natural resources on the earth, and its quality is vital to human survival. Human activities have polluted and destroyed water and land life, despite the fact that water is the most fundamental necessity [1]. Economic expansion brought about by industrialization and urbanization causes damage. Polluted water is a result of both household and human activity, lowering water quality. Water pollution is a global problem that has a negative impact on aquatic life quality [2]; [3]; [4]. One of the most harmful contaminants is heavy metals (HM). Although there isn't a clear definition of "heavy metal is but, in most cases, density is widely employed as a criterion. Elements with a specific density more than 5g cm-3 are classified as heavy metal. The 19 heavy metals that are harmful to human health are zinc, platinum, thallium, tin, vanadium, uranium, silver, cerium, tellurium, iron, manganese, nickel, copper, cobalt, chromium, gold, bismuth, gallium, and antimony.

All of these elements are important for a healthy metabolism, but their levels can become dangerous if they get too high [4]; [6]. Heavy metal is present in small levels in our surroundings and diet, and some of it is even necessary for good health. Living creatures, for example, require varying levels of heavy metals including iron, cobalt, copper, manganese, molybdenum, and zinc, which are also required by humans. Because heavy metals accumulate in aquatic animals and permeate the food chain, they cause health problems and even mortality in some organisms when they are present in high amounts [7]. The toxicity of metals is influenced by their composition. When metals become soluble in water, they can become dangerous. Other metals are hazardous because they are not required for any biological function, therefore even a small amount can cause harm. Metal toxicity varies, too, depending on the type of metal. Furthermore, as the oxidation state of a metal changes, it becomes dangerous; for example, when the oxidation state of chromium increases to 4, it becomes carcinogenic [7]. Heavy metal is dangerous because it promotes mutagenesis and affects metabolism. Toxic effects can cause decreased fitness, limited reproductivity, and, in the worst-case scenario, death of the organism. Industrialization and economic advancement are inextricably linked, but they have detrimental consequences for the environment. Throughout history, hazardous metals have wreaked havoc on ecosystems, such as the Hg poisoning of water in Japan, which resulted in neurotoxicity and the "Hunter Russell syndrome." In addition to these direct effects, heavy metal intoxication can cause a fetus's growth to be retarded [8]; [9]. Heavy metal is dangerous because it promotes mutagenesis and affects metabolism. Toxic effects can include diminished fitness, limited reproductivity, and, in the worst-case scenario, death of the organism. Industrialization and economic advancement are inextricably linked, but they have detrimental consequences for the environment.

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Throughout history, hazardous metals have wreaked havoc on ecosystems, such as the Hg poisoning of water in Japan, which resulted in neurotoxicity and the "Hunter Russell syndrome." In addition to these direct effects, heavy metal toxicity can cause a fetus's growth to be stunted [2]; [9]. Toxic heavy metal levels vary by age, physiological state, and developmental stage, but fish remains the principal source of heavy metals such as arsenic and mercury in human's uptake [8]; [10]. As a result of urbanization and industrialization, heavy metal has polluted the aquatic system, harming the ecosystem's balance and diversity of aquatic life. Arsenic is a carcinogen that is most plentiful in saltwater and is regarded to be most hazardous in the +3-oxidation state. Chromium is widely used in the paint and electroplating industries, and industrial effluents carry it into the aquatic system. The most toxic form of chromium is hexavalent chromium, which is regarded to be the most detrimental to animals' health. Mercury is also introduced into the aquatic system by the coal industry as absorbed emissions, which have a profound impact on aquatic life.

Access to safe drinking water is critical for human survival, health, and happiness. Surface water bodies, on the other hand, which are the most important sources of water for human activities, are sadly under severe environmental stress and are under threat as a result of anthropogenic activity. Since Obizi communities depend majorly on Obizi river for drinking and other domestic purposes and because they do not have other sources of drinking water, and cannot afford the water treatment plant, poor water quality contributes to health disparities. Water source protection, and water management can all be used to improve the quality of drinking water. The rules must be appropriate for regional and local circumstances, which necessitates adaptation to environmental challenges, as well as social, economic, and cultural factors, as well as prioritization [2]; [11].

Water contamination has a bigger impact on human health. Pathogens are disease-causing bacteria that propagate disease directly among humans. Some pathogens are present all throughout the world, whereas others are restricted to a specific geographical area [5]; [12]. Many water-borne diseases are being passed from person to person [13]. Floods and heavy rains are linked to extreme weather, resulting in a variety of diseases in both developed and developing countries [14]. Food and vegetables cultivated in contaminated water are consumed by 10% of the population [15]. Many aquatic infectious diseases are linked to fecal contamination of water sources, which leads to infection via the fecal-oral route [16]. Different ailments such as respiratory disease, cancer, diarrheal disease, neurological condition, and cardiovascular disease are among the health risks connected with polluted water [17]. Cancer and blue baby syndrome are caused by nitrogenous substances [18]. Cancer mortality is higher in rural locations than in urban ones because urban residents consume treated water, but rural residents do not have access to treated water and must rely on unprocessed water. Because of poor sanitation, hygiene, and water availability, poor people are more susceptible to disease [19]. Contaminated water has serious consequences for pregnant women who are exposed to chemicals; it increases the rate of low birth weight, which has a detrimental impact on fetal health [20]. Water of poor-quality damages crop production and infects our food, posing a threat to aquatic and human life [21]. Pollutants disrupt the food chain, and heavy metals, particularly iron, have an impact on fish respiratory systems [13]. When an iron clog forms in the gills of fish, it is harmful to the fish, and when these fish are consumed by humans, it causes a serious health problem [22]. Hair loss, liver cirrhosis, and renal failure are all symptoms of metal-contaminated water and a neurological condition [23]; [24].

The most common cause of diarrhea is a bacterial infection caused by untreated drinking water and fecal contamination of water. Campylobacter jejuni causes diarrhea in 4% to 15% of the world's population. The most common symptoms of diarrhea include fever, stomach pain, nausea, and headache. This disease can be avoided by following good hygiene measures and using antibiotics. Cholera is a disease caused by polluted water. This sickness is caused by Vibrio Cholerae. In the digestive tracts, this bacterium creates poisons. Watery diarrhea, nausea, and vomiting are symptoms of this disease, and watery diarrhea can lead to dehydration and renal failure. To get rid of this disease, antimicrobial treatment is needed. Shigellosis is an infection caused by the Shigella bacteria. Humans' digestive tracts are affected, and the intestinal lining is damaged. Symptoms include watery or bloody diarrhea, abdominal pains, vomiting, and nausea, which can be treated with antibiotics and excellent hygiene. The digestive system is infected with salmonellosis. Salmonella bacteria can be detected in contaminated water, causing intestinal irritation and, in some cases, death. This disease is treated with antibiotics (https://www.nps.gov).

Hepatitis is a viral infection of the liver caused by polluted water. Hepatitis symptoms include jaundice, loss of appetite, weariness, pain, and a high temperature. If it continues over an extended period of time, it may be deadly and result in death. Hepatitis vaccine is available, and by following proper hygiene practices, one can avoid contracting the disease (https://www.nps.gov). Encephalitis is an inflammatory disease spread by mosquito bites. The eggs of the Culex mosquito are laid in contaminated water. The majority of patients show no symptoms, but some people experience headaches, high fevers, muscle stiffness, and convulsions, which can lead to coma and paralysis in extreme cases. This disease has no vaccination available (http://www.in.gov/isdh/22963.htm). Poliomyelitis is caused by the poliomyelitis virus. Poliomyelitis causes a sore throat, fever, nausea, constipation, diarrhea, and sometimes paralysis. This disease has a vaccine available (http://www.in.gov/isdh/22963.htm). Viruses such as rotaviruses, adenoviruses, caliciviruses, and the Norwalk virus cause gastroenteritis. Vomiting, headaches, and fever are all signs of gastroenteritis. After

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infection, symptoms occur 1 to 2 days later. Infants, small children, and disabled people are especially vulnerable to illness (http://www.in.gov/isdh/22963.htm).

The parasitic disease cryptosporidiosis is caused by the cryptosporidium parvum. Diarrhea, loose or watery bowls, stomach cramps, and upset stomach are symptoms of this widespread disease (http://www.in.gov/isdh/22963.htm). Cryptosporidium is a bacterium that is resistant to disinfection and affects the immune system, causing diarrhea and vomiting in humans [25]. Entamoeba histolytica causes galloping amoeba, which attacks the stomach lining. This parasite has two forms: cyst and non-cyst. When a cyst is ingested after being detected in polluted water, infection follows. Fever, chills, and watery diarrhea are symptoms (https://www.nps.gov). According to WHO, there are approximately 4 billion diarrheal cases worldwide, with 2.2 million deaths [26]. Giardia lamblia is the organism that causes giardiasis. Intestinal lining cells may be damaged. Giardia is resistant to wintry temperature and disinfectant. It's also known as traveler's illness. Bloating, increased gas, watery diarrhea, and weight loss are all indications of giardiasis (http://www.in.gov/isdh/22963.htm).

Although heavy metal has many negative effects on animals, some of it is important for their systems to function properly, therefore it is naturally found in small concentrations in aquatic organisms that aren't hazardous [9]; [27]. Some of the most important responsibilities include: Iron is found in peroxidase, catalase, cytochromes, and hemoglobin; cobalt is found in vitamin B12; chromium regulates metabolism, redox processes and influence cartilage development; copper regulates respiration; and chromium is found in vitamin B12. Manganese, which aids in urea synthesis, the citric acid cycle, and protects mitochondria from free radical damage, is an important transition metal. Nickel is a growth-stimulating element that is found in many enzymes. Molybdenum is found in the enzymes that produce uric acid and fatty acids. Selenium, a mineral, is involved in tissue oxidation and cardiomyopathy. Tin is required for growth and is found in gastric enzymes. Vanadium is necessary for both bone mineralization and lipid metabolism. Zinc is found in a variety of enzymes that are necessary for protein synthesis, metabolism, and fertilization, among other functions [28].

The leading negative effect of heavy metal contamination is domestic garbage that finds its way into the river water and pollutes it [29]; [30]; [31]. Zinc is a necessary element, but its pollution is estimated to be higher in rivers, with the cause being the existence of dust particles that dissolve in water and contaminate it [32]. Zinc pollution is caused by volcanic eruptions, fires, and fertilizers, in addition to dust particles. Furthermore, residential trash contributes significantly to heavy metal poisoning of water [33]. Lead is another significant pollutant that enters waterways near mining locations since the fuel used in mining is high in lead. Lead is also introduced into water by airborne particles and climate changes. Humic compounds in the soil are said to be a major source of water pollution because they act as a carrier of heavy metals from the soil to the water [34]. According to the studies, nickel is sourced from both point and non-point sources in the water [35]. while iron is mostly sourced through redox reactions occurring in the water at the sedimentary level [36].

Heavy metals are naturally occurring elements in the earth's crust that are persistent environmental contaminants. They are not biodegradable and enter the body through food, air, and water, where they bioaccumulate over time [37]. Natural and manmade sources can both release them into the environment. Agricultural operations such as pesticide and herbicide application, contaminated irrigation water, municipal garbage used for fertilization [38], and even mineral fertilizer containing concentrations of heavy metals are all anthropogenic sources of heavy metal contamination [39]. Additional anthropogenic sources of heavy metals include direct waste disposal on farmland [40], mining, use of lead as an antiknock additive in gasoline, traffic emissions, cigarette smoking, metallurgy and smelting, aerosol cans, sewage discharge, and building materials such as paints [41]. The disintegration of applied waste materials, which progressively release the heavy metals in them, might pollute the environment with heavy metals. However, long-term farming causes lead accumulation in Nigerian soil [42], whereas manure application causes a considerable rise in zinc concentration in pasture lands [2]. Heavy metals have apparently been added to the soil in Nigeria's savannah region through farmyard and chemical fertilizer application [43].

Excessive quantities of trace metals can arise in nature due to geological occurrences such as volcanic eruptions, rock weathering, and water leaching into rivers, lakes, and seas [44]. Anthropogenic activities like mining and uncontrolled smelting of vast quantities of metal ores in open fires, small amounts of heavy metals are emitted [45]. Metals were collected from natural resources and processed in industries, where heavy metals were released into the atmosphere, thanks to the industrial revolution [46]. Similarly, traces of heavy metals are released into the environment as a result of trash disposal, both home and agricultural, as well as motor exhaust. The following list illustrates how heavy metals enter the environment through numerous human activities: metal ores are smelted or processed, the mining industry, Fossil fuels such as coal, gasoline, and kerosene oil are burned, agricultural waste disposal, disposal of industrial waste, disposing of household garbage, emissions from automobile exhaust systems, using insecticides containing heavy metal compounds like salts [47].

Lead, cadmium, mercury, arsenic, selenium, iron, copper, manganese, zinc, and other heavy metals have atomic numbers greater than 20. Metals like iron, copper, zinc, and a few others, in low amounts, are necessary

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for organisms. Trace metals are what they're called. Metals such as lead, mercury, cadmium, and others, on the other hand, are hazardous to organisms above a specific concentration [46]. A trace metal is one that occurs in the earth's crust in concentrations of 1000 parts per million (mg/lit) or less. Although mining poses a considerable risk of heavy metal pollution, it is not the only source of pollution in the industrial sector. Heavy metal contamination can be caused by a variety of industrial processes and in a variety of ways [46]. Clearly, certain industries will pollute at a higher rate than others.

Activities in the mining industries cause heavy metals to infiltrate water resources through natural processes since they are found in the earth's geological structures. Both direct extraction procedures (which often entail size reduction, considerably increasing the surface area for mass transfer and generating effluents) and leaching from ore and tailings stockpiles can result in significant heavy metal pollution from mineral processing operations [9]; [45]. Heavy rains or flowing water, for example, can drain heavy metals from geological formations [45]. When this geology is affected by economic activity such as mining, such processes are intensified. Acid mine drainage (AMD) is a result of these processes, which expose the mined-out area to water and air [46]. Heavy metals, especially radio nuclides, are mobilized by the low pH conditions associated with AMD.

Electronic products manufacturers must legally ensure that their product's disposal methods are mentioned in the user manual. Because electronic-waste is a known main source of heavy metals, toxic compounds, and carcinogens, disorders of the skin, respiratory, digestive, immunological, endocrine, and neurological systems, as well as malignancies, can all be averted by effective electronic-waste management and disposal. Because of the exponential development in the usage of electrical and electronic equipment to bridge the digital gap, there is a worrisome effect on the environment and human health when ICT wastes are not disposed of scientifically [5]; [48]. It produces enormous volumes of metal-rich effluents, making it a more likely polluter than, instance, the food processing industry. However, it is in the electroplating business's best economic interests to reduce metal discharges, as they are inversely proportional to resource efficiency. Reduced metal discharges, for example, can be achieved by reducing losses by limiting drag-out from plating baths. Another example of a sector that can produce metal-rich effluents as well as airborne lead pollution that might end up in surface water resources is the lead-acid battery manufacturing industry (and of course on land). So, it's evident that when heavy metals are used as significant input materials in a manufacturing process, pollution concerns rise [9].

Coal-fired power generation is a significant non-point source of heavy metal pollution, and mercury discharged from boiler flues can affect water supplies. The industry also produces a lot of ash, which contains a lot of heavy elements, including uranium [44]. Production of fertilizers by industries adds a substantial amount of these heavy metals which occurs naturally within the raw ore, cadmium is an unavoidable byproduct of zinc (and rarely lead) processing. Cadmium, on the other hand, is reasonably easy to recycle after it has been collected. Cadmium is most commonly used in nickel/cadmium batteries, which are rechargeable or secondary power sources with high output, long life, little maintenance, and strong resistance to physical and electrical stress. Cadmium coatings provide good corrosion resistance, especially in high-stress situations like maritime and aerospace applications where high safety and reliability are essential; but, if the coating is broken, it will degrade preferentially. Cadmium is also used in pigments, PVC stabilizers, alloys, and electronic compounds. Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and petroleum products that have been refined [49].

Biological methods are another natural source of mercury addition in water including degassing of the Earth's crust, volcanic emissions, and evaporation from natural bodies of water. Mining of the metal on a global scale results in indirect emissions into the atmosphere. Mercury is widely used in industrial processes and in a variety of products (e.g. batteries, lamps and thermometers). It's also commonly utilized in dentistry and the pharmaceutical business as an amalgam for fillings [50].

Food, water and air exposure to humans are also ways of acquiring heavy metal because when mined ores are placed on the ground surface for manual dressing, heavy metal pollution of surface and subsurface water sources results in significant soil pollution, and pollution grows. Surface dumping exposes metals to air and rain, resulting in a lot of Acid Mine Drainage. These metals are taken up by plants and accumulate in their tissues when agricultural soils are polluted [51]. Animals that graze on contaminated plants and drink polluted water, as well as marine life that spawn in heavy metal-polluted waters, acquire heavy metals in their tissues and milk if breastfeeding [51]. Humans are exposed to heavy metals through the consumption of contaminated plants and animals, which has been linked to a variety of metabolic problems. In conclusion, all living creatures within a given ecosystem get contaminated in various ways throughout their food chain cycles [51].

Heavy metal toxicology occurs when heavy metals are absorbed by the body and accumulate in the soft tissues, they become poisonous [5]. Toxicity of heavy metals refers to the negative consequences of excessive exposure or ingestion of levels that exceed the daily recommended limits. When vapours and fumes of cadmium, lead, arsenic, mercury, zinc, copper, and aluminium are inhaled, symptoms include gastrointestinal disorders,

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diarrhoea, stomatitis, tremor, hemoglobinuria, ataxia, paralysis, vomiting, convulsion, depression, and pneumonia [52]. Lead poisoning can harm a child's brain, kidneys, bone marrow, and other systems if they ingest or inhale it. In infants and children, blood lead levels as low as 5 g/dL are linked to developmental problems like impaired cognitive function, behavioral disorders, impaired hearing, and stunted growth [2]; [53], while levels above 75 g/dL cause coma, convulsions, and even death is a possible neurotoxicant, according to studies on the effects of prenatal and postnatal cadmium exposure on intelligence quotient impairments [53]; [54]. In laboratory animals, developmental exposure has been shown to have a deleterious impact on operant performance and conditioned avoidance. Cadmium appears to pass the placental barrier and accumulate in the fetus, causing neurological diseases in the fetus [54]. Nickel is a trace element that is typically linked to chronic bronchitis, emphysema, reduced pulmonary function, and fibrosis in animals. Copper and chromium are crucial necessary elements; however, they can be harmful if consumed in excess [55]. While copper is a component of iron-metabolizing enzymes, and its shortage causes anemia [55], chromium aids in blood glucose control and is commonly utilized in diabetes treatments [56]. When copper and chromium are consumed in excess, they cause acute and chronic. Nausea, vomiting, jaundice, liver necrosis, damage to the proximal tubules of the kidney, and anemia are all symptoms of acute copper intoxication. Wilson's illness is a type of chronic copper toxicity that causes mental and motor impairments, dysphagia, ataxia, hemolytic anemia, renal dysfunction, kidney stones, and hepatic failure in humans. Chromium poisoning is usually caused by physical contact with contaminated dust or soil, which causes allergic dermatitis, which is characterized by eczema [57].

Other sources of heavy metal emissions have been found, including old automotive tires and brake linings, roofs, and food remains in residences, as well as other domestic wastes, such as garbage [9], because of their instability and solubility, which leads to a high bioavailability, heavy metals originating from anthropogenic sources are more harmful [47]. Because this work contains original material, it addresses a knowledge gap by contributing to the original data-driven method for water pollution and management. To the best of the authors' knowledge, this is the first study on heavy metal contamination of the Obizi river in Awka town, Anambra state's awka-south local government area.

2. Method

2.1. Materials

Water samples, refrigerator, membrane filters, weighing balance, beaker, conical flask, measuring cylinder, sampling bottles, test tubes/stand, pipettes/filters, bijou bottles, forceps, atomic absorption spectrometer, autoclave, pH meters, nitric acid (HNO_3), centrifuge, iron stock solution, deionized water, volumetric flasks, manganese stock solution, metallizer, AS50 standard, inductively coupled plasma optical emission spectrometer, cotton wools and aluminum foil.

2.2. Description of study area

Awka is located in latitude 6.333 N and longitude 7.000 E, and it is part of the rainforest climatic region, with an average annual temperature of 330°C and annual rainfall ranging from 1,400 mm in the north to 2,500 mm in the south. It has a total area of 613 square kilometers, including 15% highland and 21% plainland. The rainy season and the dry season are the two seasons that it endures throughout the year. The rainy season lasts from march to October, while the dry season lasts from November to April and lasts around 4-5 months [58]. It's a typical grass-covered savanna.

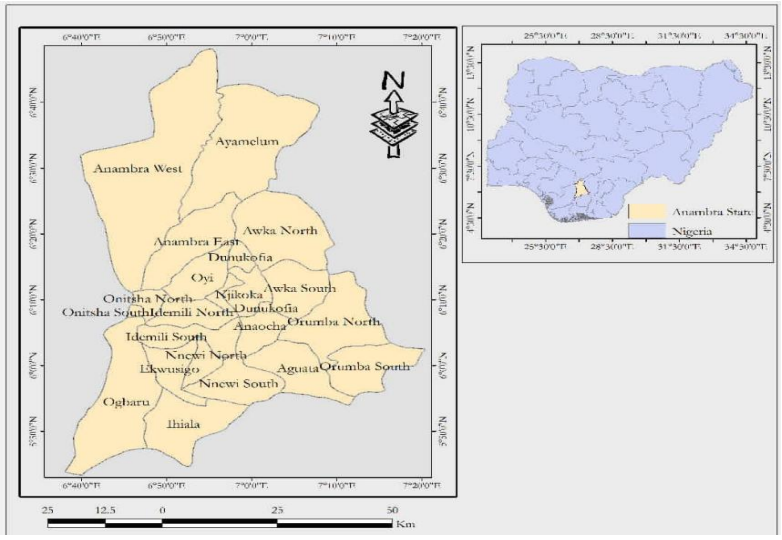

Figure 1. Map of Nigeria Showing Anambra State

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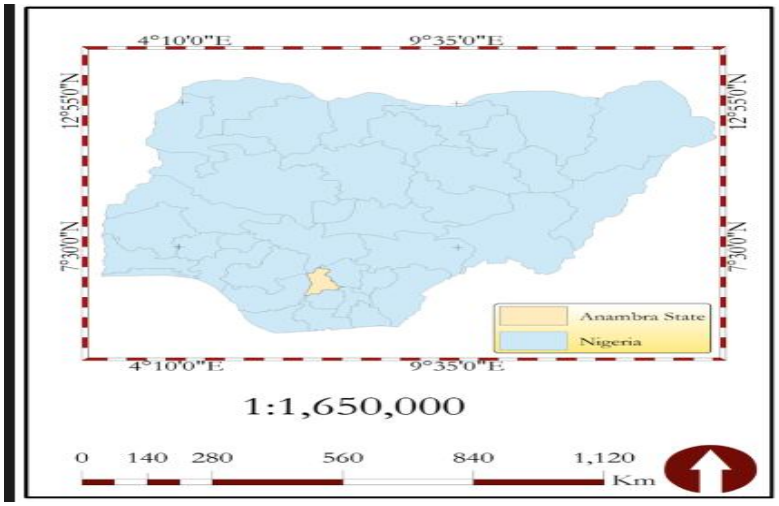

Figure 2. Expanded Map of Nigeria Showing Anambra State

2.3. Sample collection

Water for heavy metal analysis was collected aseptically using 250ml sampling bottles (screw capped) from the Obizi River in the Awka South Local Government Area of Anambra State, according to the protocol described by APHA (1985).

The samples were placed on ice in a cooler to keep the water samples cool while being transported to the lab for analysis. Within 24 hours of collection, the material was examined. All glassware used to collect water samples was sterilized in an autoclave for 15 minutes at 120°C.

2.4. Analysis

2.4.1. Determination of Iron

The atomic absorption spectrometer (AAS) was used to determine the amount of iron in the sample (Pg. Instrument AA 500). The apparatus was calibrated using 0.5 mg/l, 1.0 mg/l, 1.5 mg/l, and 2.0 mg/l concentrations of industry manufactured standards before the fe determination. To make a 100ppm solution, 10ml of the iron stock solution was pipetted into a 100 ml volumetric flask and filled to the mark with deionized water. Volumes of 0.5, 1.0, 1.5, and 2.0 ml of this solution were pipetted into four distinct 100ml volumetric flasks in that order and filled to the mark with deionized water to generate 0.5 ppm, 1.0 ppm, 1.5 ppm, and 2.0 ppm working solutions, which were run on the AAS after water samples.

2.4.2. Determination of Manganese

Atomic absorption spectrometer was used to determine Mn (Pg. Instrument AAS 500). The equipment was calibrated using 1.0 mg/l, 1.5 mg/l, 2.0 mg/l, and 2.5 mg/l concentrations of industry manufactured standards before Mn determination. To make a 100-ppm solution, 10 ml of the manganese stock solution was pipetted into a 100 ml volumetric flask and filled to the mark with deionized water. Volumes of 1.0, 1.5, 2.0, and 2.5 ml of this solution were pipetted into four distinct 100 ml volumetric flasks in that order and filled to the mark with deionized water to generate 1.0 ppm, 1.5 ppm, 2.0 ppm, and 2.5 ppm working solutions, which were run on the AAS after water sampling.

2.4.3. Determination of Arsenic

Metalyser (MH 3000 METALYSER) was used to assess arsenic levels. One sachet of heavy metal 3 Buffer was added to the sample analysis beaker, followed by 70 ml of a sample AS50 standard before sample analysis.

2.4.4. Determination of cadmium, copper, aluminum, lead and mercury

Cadmium (Cd^{2+}), *copper* (Cu^{2+}), *aluminum* (Al^{3+}), l*ead* (Pb^{2+}), and *mercury* (Hg^{2+}) were all measured in each sample using a 5300 DV and 2100 DV inductively coupled plasma optical emission spectrometer (ICP-OES) (Perkin-Elmer). Heavy metal standard solutions in the range of 0.02 parts per million (ppm) to 0.35 parts per million (ppm) were generated in a final volume of 50 ml from 1000 ppm stock solutions of each metal (calibrated volumetric conical flask). Each multi-element standard solution was made by adding the appropriate amount of each heavy metal from their stock solutions (Merck CertiPUR) to sterile double distilled water in the volumetric flask to achieve the desired concentration, then adding a few drops of nitric acid (HNO_3) to preserve the metal. Thirty milliliters of each water sample was filtered via 0.45 m pore size membrane filters to remove any fibers

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that could cause a blockage in the ICP-OES autosampler and then transferred to centrifuge tubes. The calibration curves generated from the prepared heavy metal standard solutions were used to determine the concentrations of each metal in the water samples.

3. Results and Discussion

Table 1 presents the concentrations of selected heavy metals detected in the water samples and compares them with the maximum permissible limits recommended by the World Health Organization (WHO). This comparison was conducted to evaluate the water quality and determine whether the measured parameters comply with international safety standards. To provide a clearer visualization of the results, Figure 3 illustrates the concentrations of iron, manganese, arsenic, and cadmium in comparison with the WHO recommended limits

Table 1. Comparison of obtained results with WHO recommended limit

No	Parameter	Obtained result	Who limit
1	Iron mg/l	0.054	0.3
2	Manganese mg/l	0.039	0.3
3	Arsenic mg/l	0.00	0.00
4	Cadmium mg/l	0.112	0.003
5	Copper mg/l	0.031	1.0
6	Aluminum mg/l	0.01	0.02
7	Lead mg/l	0.069	0.01
8	Mercury mg/l	0.00	0.001

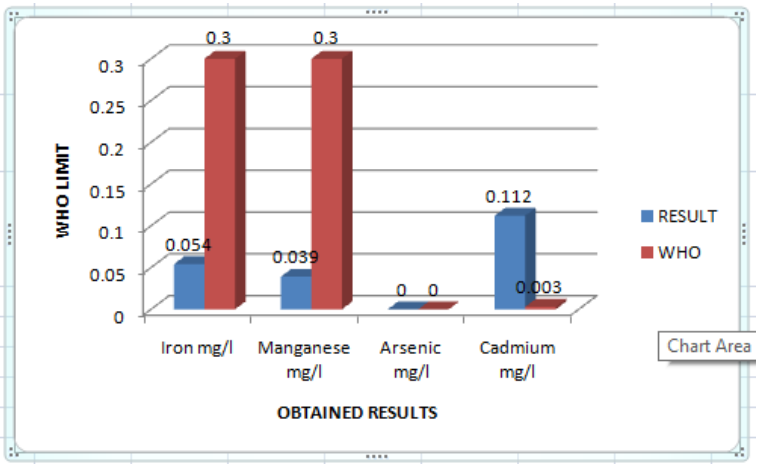

Figure 3. Graph of iron, manganese, arsenic and cadmium

The amount of iron in the water sample was below the WHO's recommended limit of 0.3 mg/l as seen in Table 1 and Figure 3. The iron concentration in the water sample was 0.054 mg/l. It is therefore suggested for human consumption and other home applications.

The manganese concentration in the water sample was below the WHO's recommended limit of 0.3 mg/l. Manganese concentration was found to be 0.039 mg/l as seen in Table 1and Figure 4. It is therefore recommended for human consumption. It is employed in metallurgical operations, dry cell battery manufacturing, and fertilizer production [59].

The amount of arsenic in the water sample was below the WHO's recommended limit of 0.00 mg/l as seen in Table 1 and Figure 3. The research revealed that arsenic levels of 0.00mg/l were found. It is therefore recommended for human consumption.

The amount of cadmium in the water sample was higher than the WHO's recommended limit of 0.003 mg/l. The study revealed a concentration of 0.112 mg/l of cadmium as seen in Table 1 and Figure 3. Electroplating, alkaline batteries, mining, and the plastics industry are all sources of cadmium in water. It disrupts metabolic processes and can bioaccumulate in aquatic creatures, making its way down to food source [59]. As a result, it is not advised for human consumption (Figure 4).

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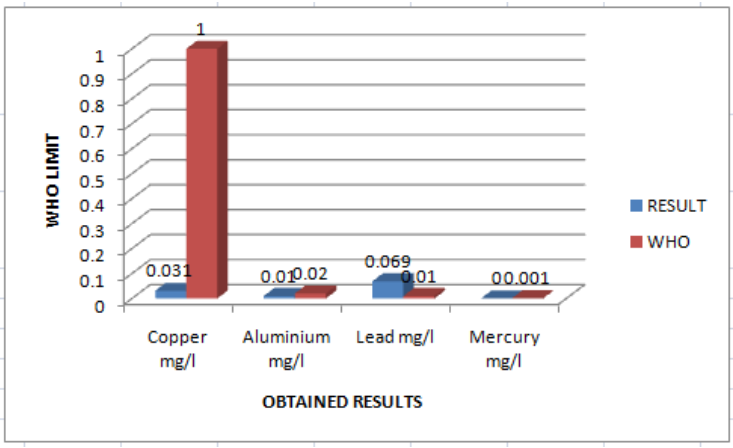

Figure 4. Graph of copper, aluminum, lead and mercury

Copper levels in the water sample were below the WHO's recommended limit of 1.0 mg/l. Copper concentrations of 0.031 mg/l were found in the analysis as seen in Table 1 and Figure 4. It is therefore recommended for human consumption. Copper comes from the mining, metal-making, storage-battery, and fertilizer-making businesses. Copper exposure poses a harm to aquatic creatures, hence mitigating measures are needed to limit copper influx into the river [59]. The amount of aluminum in the water sample was less than the WHO's recommended limit of 0.02 mg/l as seen in Table 1 and Figure 4. Aluminum concentrations of 0.01 mg/l were found in the research. It is therefore recommended for human consumption.

Table 1 and Figure 4 shows that the water sample contained lead levels that were higher than the recommended limit by WHO of 0.01mg/l and examination reveal an alarming concentration of 0.069mg/l, which is not safe for human consumption [60]. Heavy metals and pollutants in the aquatic and terrestrial environment are closely associated with anthropogenic activities and industrial expansion including the manufacture of paint, lead refining and production of lead-coated goods [61]. As of its toxic properties, lead can lead to several serious health issues [62]; [59] and the ongoing environmental contamination of lead presents significant health and ecological risks. The gradual elimination of lead from industrial activities and the implementation of better environmental management practices should, therefore, be tackled through innovative technologies and sustainable approaches [63]. The water sample had a lower concentration of mercury than the recommended limit by WHO which is 0.01 mg/l (Table 1 and Figure 4), a finding supported by research that reported that trace or zero level of concentration was detected [64]. Since these are safe threshold limits and reflect that anthropogenic contamination is minimal for this particular parameter, the water source is declared as being suitable and safe for human use [65].

4. Conclusion

Heavy metal poisoning of the Obizi river in the awka south local government area of Anambra state, Nigeria, for household uses, according to the study's findings. The results revealed that certain of the measured indicators, such as cadmium and lead, were greater than the WHO recommended limit for portable drinking water, indicating that the water is unfit for human consumption unless adequately treated. In general, the data reveal that drinking river water without treatment is the leading source of waterborne infections in this area. Good quality water, according to WHO (2010), should be devoid of harmful substances and organic materials.

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Data Availability

The datasets generated during and/ or analysed during the current study are available from the corresponding author on reasonable request.

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Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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