IMPACT OF URBAN RUNOFF ON BENTHIC AND PELAGIC FISH FAUNA IN IKPOBA RIVER; HEAVY METALS IN MUSCLE.

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FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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AN UNDERGRADUATE PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA; IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.SC.) DEGREE IN ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY.

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this research titled "**IMPACT OF URBAN RUNOFF ON BENTHIC AND PELAGIC FISH FAUNA IN IKPOBA RIVER; HEAVY METALS IN MUSCLE"** was carried out by **"OMOZUSI EMMANUEL EGUAGIE"** with matriculation number **"LSC1705398"** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc.) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

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Dr. (Mrs) G. Ogbeide **Date**

Project Supervisor

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Prof. A. A. Enuneku **Date**

Head of Department

DECLARATION

I "**OMOZUSI EMMANUEL EGUAGIE**" declare that "**IMPACT OF URBAN RUNOFF ON BENTHIC AND PELAGIC FISH FAUNA IN IKPOBA RIVER; HEAVY METALS IN MUSCLE**" is my own work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

OMOZUSI EMMANUEL EGUAGIE

…………………………

Date

DEDICATION

To my family, for their financial and moral support and encouragement which helped make this possible. To the Enehizenas, I'm eternally grateful for everything.

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ABSTRACT

Aquatic ecosystems are often subject to contamination by heavy metals due to human and natural activities. This study was conducted to determine the concentrations of heavy metals present in water, sediment and fish samples collected from Ikpoba River, Benin City, Nigeria. Samples were collected over from June to August 2023 and analysed using standard methods. The findings showed that while Cd and Pb were not detected in the water, Ni and Cr exceeded permissible limits. However, the concentrations of Co were within limits. Sediment samples had comparatively low heavy metal content. Benthic fish were found to have higher concentrations of heavy metals than pelagic fish. However, the concentrations of these metals in the samples were below the recommended limits for heavy metals in food. Therefore, it was concluded that the fish in the study area are safe for consumption but the water is not. Hence, routine surveillance and implementation of measures to protect water quality such as prevention of waste discharge are recommended.

CHAPTER ONE

INTRODUCTION

1.3 Background to the Study

Over the course of time, sources of water have been centres of life with services such as the provision of habitats and sustenance for plant and animal communities. While it is crucial in the continuance of human existence, industries and agriculture, freshwater is finite and without it being present in adequate quality and quantity, it is impossible for sustainable development to occur (Soltaninia *et al.,* 2022). Pollution in water bodies comes from various point and non-point sources. Such point sources include industrial effluent discharge, releases from wastewater treatment plants and refineries. The non-point sources include contaminants from soils and groundwater flow system, precipitation and urban runoff (Olal, 2015).

Urban runoff encompasses the clean rain falling on landscape which then flows away, the rain water which falls on a catchment collecting air pollutants, on roadway and storm drains and is then considered to be another form of wastewater (Muller *et al.,* 2020). Urban runoff is composed of a number of contaminants from different sources and these contaminants are harmful to the quality of receiving water bodies, as well as the aquatic organisms in these systems (Chow *et al.,* 2019). Additionally, such contamination leads to problems with the aesthetics and productivity of water and may eventually threaten developmental projects and increase the difficulty and costs of water treatment (Harding *et al.,* 2020).

The structures and functions associated with freshwater ecosystems have been and still being significantly altered by the growth of the human population, and the continual expansion of metropolitan areas and cities in a phenomenon which is referred to as urban stream syndrome (Soltaninia *et al.,* 2022). Primary drivers of this phenomenon are land use and land cover changes. An example of this is the increase in impervious surfaces which results to modifications to natural processes in the physical habitat which are well documents, such as increases in sedimentation, bank erosion, scouring of streambeds and extreme instream flows. These changes are driven by runoff of urban stormwater (Yadzi *et al.,* 2021).

Scholz and McIntyre (2016) posit that stormwater is a top factor in the loading of pollution from non-point sources into urban waterways. It has long been understood that runoff from roads with high traffic volumes is hazardous to aquatic life. As a result of tyre and brake pad wear, crankcase oil and gearbox fluid leaks, and tailpipe emissions, motor vehicles discharge a wide variety of chemicals into the environment (Peter *et al.,* 2018). These pollutants, the majority of which have not yet been examined, build up on roads, other impermeable surfaces, and when it rains, they become mobile and enter stormwater runoff. Their toxicity to aquatic creatures remains mainly unclear in the absence of definite identification (Chow *et al.,* 2019).

Entry of urban runoff into water bodies is associated with a number of changes in the receiving water body. Examples of these changes include reduction in dissolved oxygen levels due to decomposition of organic wastes, eutrophication and algal blooms as a result of increased levels of nutrients in water, toxicity of water due to presence of toxic compounds which are non-biodegradable, deterioration of the quality of water by suspended solids, presence of immiscible liquids, increased temperature and impartation of taste, odour and colour (Backhaus *et al.,* 2019). There may be inputs of microorganisms which may be parasitic to aquatic organisms or may cause disease in humans who consume products from affected water bodies. Some of these may include pathogenic bacteria, coliforms, viruses, protozoans and helminths (Bashir *et al.,* 2020).

Heavy metals are among the contaminants which are added to water bodies via urban runoff. The menace of heavy metal pollution in the environment is critical due to the fact that they are not biodegradable and hence are persistent in the environment. Their total removal after entry into the environment is very difficult if not impossible (Aderinola *et al.,* 2009). In water, heavy metals cause diverse adverse effects among which loss of biodiversity ranks highly (Oluyemi and Olabanji, 2011). The suspension of heavy metals in water exposes swimming and floating aquatic organisms to heavy metals while their sedimentation exposes benthic organisms to these hazardous elements (Tchounwou *et al.,* 2012). Aquatic plants also take up and store heavy metals in their tissues. Heavy metals may cause behavioural and reproductive alterations in aquatic organisms. Bioaccumulation and build-up of heavy metal concentrations through aquatic food chains also occurs (Ali *et al.,* 2019). Human exposure to heavy metals from water bodies is often through the ingestion of contaminated seafood and water, inhalation of aerosols from contaminated water bodies and dermal absorption during bathing or recreational activities (Nkwunonwo *et al.,* 2020).

Against this background, this study intends to determine the impacts which urban runoff has on benthic and pelagic fish from an urban river in Nigeria.

1.4 Aim and Objective of the Study

The aim of this study is to evaluate the impacts of urban runoff on benthic and pelagic fish from Ikpoba River, Nigeria.

The objectives of the study are to:

1. Heavy metal concentrations in water
2. Heavy metal concentrations in sediment
3. Heavy metal concentration in benthic and pelagic fish muscles

CHAPTER TWO

LITERATURE REVIEW

2.1 Pollution of Water Bodies

One of the main types of environmental pollution, along with air and water pollution, is water contamination. When substances or chemicals that have the potential to lower water quality are put into a body of water or a body of water, water pollution results. There are two main types of pollution that affect aquatic ecosystems: point sources and non-point sources (Chaudhry and Malik, 2017). While non-point sources are diffuse sources of pollutants that cannot be identified and are thus frequently hard to manage, point sources are those that can be tracked to their direct origins and controlled. Human activity is the main cause of water pollution. The discharge of untreated industrial effluents into water, the entrance of human and animal wastes, the disposal of solid waste in bodies of water, the introduction of agro-pesticides and fertilisers from agricultural fields are a few examples (Kumar *et al.,* 2019). Contamination of water usually has negative effects. One of them is the potential for contaminants to bioaccumulate in aquatic creatures exposed to them and travel up food chains until they reach humans. A rise in the danger of water-borne illnesses, modifications in the dynamics of aquatic ecosystems, aquatic animal toxicity and death, and eutrophication brought on by excessive nutrient intake are some additional effects of water pollution (Simon and Joshi, 2021).

In comparison to rivers, where the water flows and has a flushing effect that transports the pollutants away, lakes have been shown to be more vulnerable to pollution and its detrimental impacts on ecosystems and human health. This is because the water in most lakes is static. Industrial and sewage runoff, agricultural effluents, seepage from landfills containing household and commercial trash, and runoff from metropolitan areas are all examples of pollutants that can affect aquatic ecosystems. The issue with these contaminants is that they alter the properties of aquatic ecosystems (Chaudhry and Malik, 2017; Kumar *et al.,* 2019). Examples of these changes include a decrease in the amount of dissolved oxygen due to the breakdown of organic waste, eutrophication and algal blooms brought on by an increase in nutrients in the water, water toxicity caused by the presence of toxic, non-biodegradable compounds, degradation of water quality due to suspended solids, the presence of immiscible liquids, an increase in temperature, and the imparting of taste, odour, and colour. Microorganisms may enter the system and cause sickness in individuals who ingest goods derived from contaminated water sources or act as parasites on aquatic organisms. Pathogenic bacteria, coliforms, viruses, protozoans, and helminths are a few examples of these (Schweitzer and Noblet, 2018).

2.2 Stormwater/Urban Runoff

Urban runoff is more complicated than just rain that falls on an urban area and then drains away. When rain falls on a catchment, pollutants from the air, roadways, other catchment surfaces, and storm drains are collected, and the pollutants are then converted into a specific type of municipal wastewater (Zhang *et al.,* 2020). According to a number of research, runoff from urbanised regions is the main factor affecting the water quality of assessed estuaries and the third greatest factor affecting the water quality of examined lakes. The natural systems of the receiving water bodies have undergone major alterations as a result of rising urbanisation. The hydrologic flow regime, as well as the chemical and biological composition of storm water runoff from these emerging areas, have changed as a result of these changes (Yang and Lusk, 2018). As a region is developed, the catchments' innate capacity to resist natural hydrologic fluctuation is lost. Increased impermeable surface area, together with disturbed native soils and vegetation, reduce infiltration capacity. Additionally, anthropogenic activity exposes the catchment to new chemical and biological elements. In general, urbanised and urbanising areas have higher concentrations of trace metals, suspended solids, nutrients, pesticides, petroleum products, *E. coli*, and faecal coliform bacteria than natural systems do. This is because there are more people, cars, roads, and building materials in these areas. These elements are shown to be a significant cause of contamination for the quality of surface water and groundwater resources that storm water runoff conveys (Hwang *et al.,* 2016; Yang and Toor, 2017).

2.2.1 Properties of stormwater

2.2.1.1 pH

It is a gauge for the amount of hydrogen ions (H^+) in water. Because of organic acids in the sediment and atmospheric acids that have seeped into the water, groundwater is acidic. Water that is unpolluted has a pH level that is close to neutral (pH 7). Rainwater has a pH of 5.7 or so. The oxidation of sulphur compounds in sediment is another factor contributing to the rise in acidity. The chemical kinetics of significant components are affected by the pH, which has an impact on the solubility and toxicity of metals (Gustafsson and van Schaik, 2003).

2.2.1.2 Turbidity

Water clarity is measured by turbidity. It is an optical property that gauges how much light is reflected or dispersed as light passes through water. The turbidity rises as the amount of dispersed light does. According to Fakayode (2005), dissolved coloured compounds, organic and inorganic particles, clay, silt, tiny organisms, and inorganic and organic particles can all contribute to turbidity in water.

2.2.1.3 Electrical conductivity

The capacity of water to convey an electric current is measured by its conductivity. It is correlated with the ion content in the water. According to Fakayode (2005), conductivity is expressed in milliSiemens or millimhos per centimetre.

2.2.1.4 Ammonia

Nitrogen and hydrogen are combined to form ammonia. The organic breakdown of proteins in water produces ammonia as a by-product. It can exist in water in two different forms: unionised as ammonia (NH3) or ionised as ammonium (NH_4^+) (Fakayode, 2005).

2.2.1.5 Chloride

The anion Cl^- is the chloride ion. It is created when an electron is added to a chlorine atom or when a substance, such hydrogen chloride, is dissolved in water or another polar solvent. Sodium chloride and other chloride salts are frequently extremely soluble in water. It is a vital electrolyte that is present in all bodily fluids and is in charge of controlling fluid flow into and out of cells, conveying nerve impulses, and keeping the acid/base balance (Wetzel, 2001).

2.2.1.6 Dissolved oxygen

The quantity of free, non-compound oxygen that is present in water or other liquids is referred to as dissolved oxygen (DO). Free oxygen (O_2), also known as non-compound oxygen, is oxygen that is not bound to another element. Oxygen bound in waters (H_2O) is part of a compound and is not included when calculating the concentration of dissolved oxygen. As it affects the aquatic life in a body of water, it is a crucial factor in determining the quality of the water. Dissolved oxygen is the second most important element in limnology after water itself (Wetzel, 2001).

2.2.1.7 Biochemical oxygen demand (BOD)

This is the quantity of dissolved oxygen (DO) required for aerobic organisms to decompose organic matter in a particular water sample during a predetermined time period and temperature. The BOD value, which is frequently employed as a gauge of the extent of water contamination by organic contaminants, is typically given in milligrammes of oxygen consumed per litre of sample over 5 days of incubation at 20°C (Miller, 2003).

2.2.1.8 Alkalinity

It gauges how well water can neutralise acids by absorbing hydrogen ions (H^+) and prevents abrupt changes in the acidity of the liquid. Two types of carbonate anions, HCO_3^-, CO_3^{2-}, and (OH^-), which function as a buffer system, are what give water its alkalinity. If present in groundwater, additional bases such as silicates, phosphates, and borates can contribute to alkalinity. Toxic free divalent metal ions like Cd^{2+}, Cu^{2+}, Pb^{2+}, Zn^{2+}, or methyl-metal complexes are eliminated when inorganic ligands (anions) combine with metals (cations). Metal complexes are not poisonous since they are not absorbed by living things. Alkalinity is a crucial characteristic for assessing whether water is suitable for various applications, such as irrigation, combining with pesticides, and treating polluted water (Hunt *et al.,* 2012).

2.2.1.9 Total Dissolved Solids

The concentration of all dissolved minerals in water is known as total dissolved solids (TDS). The Total Dissolved Solids in natural waters are made up of a range of ionic and non-ionic species in varying concentrations and ratios. When TDS is high (more than 1000 mg/L), the taste is frequently unpleasant or disagreeable. TDS depends on both pH and temperature. Groundwater dissolves more minerals at higher temperatures and lower pH levels. According to Agbaire and Oyibo (2009), the following are some sources of TDS: hard water ions, fertiliser in agricultural runoff, urban runoff and salinity from tidal mixing, minerals in irrigation water, and acidic rainfall.

2.2.1.10 Nitrate

The leaching of fertiliser, septic tank leachate, pit latrines, unsewered sanitation, the disposal of human or animal waste, and the mineralization or oxidation of decomposing substances by sediment bacteria are all sources of nitrate pollution of groundwater. Greater than 3 mg/L nitrate concentrations point to a rather close relationship between the source of pollution and the water. Because it is highly soluble and resistant to ion exchange, nitrate is easily transferred under the sediment zone. Nitrate may be transformed into nitrite by nitrification, which reacts with amines in the stomach to produce a number of N-nitroso compounds. According to Suthra *et al*. (2009) and USGS (2012), these substances are harmful to human health because they impair the blood's ability to carry oxygen, which can lead to Blue-baby syndrome or infantile methemoglobinemia, gastrointestinal cancer, Alzheimer disease, vascular dementia, multiple sclerosis, non-Hodgkin's lymphoma, and thyroid hypertrophy.

2.2.1.11 Total and Faecal Coliforms

The presence or absence of harmful microorganisms, which are indicated by the presence of coliforms, is used to determine the hygienic quality of water. At or near the earth's surface, nearly no geological setting has a pH that does not sustain some kind of organic life. At this level, water pressure is also insufficient to prevent microbial activity. The intestines of both humans and animals are home to a sizable group of disease-causing bacteria known as the coliform group of bacteria. According to the World Health Organisation, 0cfu/100 ml is the MPN (maximum permitted number) for total and faecal coliforms in potable drinking water (Burton and Pitt, 2002).

The most accurate indication of faecal bacterial contamination of surface waters and groundwater is the presence of faecal coliforms (WHO, 2006). Faecal coliform bacteria are a subset of the larger coliform bacteria group. They are rod-shaped, gramme negative, facultative anaerobes that can survive in the absence of oxygen, and they produce gas and acid at temperatures around 35 °C when they ferment lactose. Water-borne illnesses including diarrhoea, typhoid, and hepatitis are brought on by human waste, as are flu-like symptoms like nausea, vomiting, and fever. A community's lack of sanitation is shown by high coliform levels in water tests. Inadequate and unhygienic handling of solid wastes in the rural and urban areas leads to high concentrations of microbial organisms (Adekunle *et al.,* 2007).

2.2.2 Best management practices for urban runoff

Any action taken to safeguard water quality and lessen the amount of pollutants in storm water runoff is referred to as a best management practice (BMP). Legal entities are obligated to specify and put into practise a number of BMPs to lower the amount of pollutants that are discharged from their storm drain system. Both long-term (for building) and short-term (for permanent) BMPs are subject to the permit requirement. Temporary and permanent BMPs are the two main kinds of BMPs (Yang and Lusk, 2018). Temporary BMPs or construction BMPs are compliant with the BMPs required by the General Permit and are based on Best Conventional Technology/Best Available Technology (BCT/BAT). Following construction, permanent controls are intended to limit erosion and sediment while still meeting the permit's basic criteria. Permanent BMPs are made to either treat storm water runoff by eliminating contaminants or regulate pollution at the source (Chen *et al.,* 2019). Source control methods and treatment control measures are two categories for permanent BMPs. By preventing pollutants from becoming entrained in runoff, source control strategies seek to reduce pollution at the source. Before being discharged into transportation networks or receiving water, control procedures to treat storm water runoff and remove contaminants of concern (Saraswat *et al.,* 2016).

2.3 Heavy Metals

According to Engwa *et al*. (2019), the phrase "heavy metals" refers to a class of metallic elements that have high densities, large atomic masses, and harmful effects on living things even at low concentrations. They are frequently found either in their elemental forms or in chemically bonded forms as components of compounds like carbonates, oxides, and silicates. Weather, erosion, and human activity are mostly responsible for the discharge of heavy metals from these deposits. After being released, heavy metals enter the environment through a variety of natural and human processes, ending up in the soil, groundwater, and surface water bodies (Koller and Saleh, 2018). Although heavy metals are typically thought of as poisonous to living things, there are several that are needed by living things for usage in different biological processes. Zinc, copper, iron, cobalt, manganese, chromium, selenium, and magnesium are a few examples of these metals. Gold, silver, and platinum are among heavy metals that are categorised as precious metals and are prized for their great economic worth (Engwa *et al*., 2019). On the other hand, certain heavy metals aren't known to have any biological purpose at all. Among them are mercury, cadmium, lead, and arsenic, all of which are poisonous at extremely low amounts. Through processes such as oxidative stress, neurotoxicity, and damage to macromolecules, these metals have a detrimental impact on the health of living things (Asati *et al.,* 2016). Some of the most common heavy metals are discussed briefly below.

Cadmium

Along with lead and mercury, cadmium is one of the three metallic elements that are the most toxic to living things. Atomic weight of 112.4, atomic number 48, and density of 8.65 g/cm^3

are a some of its characteristics. Due to its resemblance to zinc and location on the periodic table, cadmium is frequently hazardous. Cadmium is primarily used in the creation of alloys, pigments, PVC stabilisers, electronics, and batteries (Ali *et al*., 2019).

Chromium

In group VIB of the periodic table, the transition metal chromium is found. Its characteristics include an atomic weight of 52, an atomic number of 24, and a density of 7.19 g/cm^3. Because it is only found in nature in conjunction with other elements, free chromium is not existent. Chromite, which is its primary mineral resource, is used to extract chromium (Wuana and Okieimen, 2011). According to Tchounwou *et al*. (2012), chromium is used in the production of pigments, electroplating, steel production, wood preservation, and leather tanning.

Arsenic

Arsenic naturally occurs as a brittle, crystalline, silvery-gray metal. Atomic number 33, atomic weight 74.9, and density 5.73 g/cm^3 are some of its characteristics. Arsenic doesn't taste or have an odour, and it may mix with many other elements to create a wide range of compounds. Electronic devices, wood preservatives, and agricultural herbicides are all made using arsenic (Wuana and Okieimen, 2011).

Mercury

Mercury is a colourless, odourless liquid that may be found in the environment in a number of different forms. When mercury reacts with other elements like chlorine, sulphur, and oxygen, inorganic oxides and salts are readily formed. When mercury and carbon interact, organic mercury compounds are produced. Mercury is used in the production of petrochemicals and agrochemicals, cleaning products for the home, thermometers, paints, electric lights, lubricating oils, and electronics. According to Chibuike and Obiora (2014), mercury is extremely harmful to living things.

Copper

One of the transition metals, copper is found in period 4 of the periodic table and group IB. Atomic number 29, atomic weight 63.5, and density 8.96 g/cm^3 are some of its characteristics. Among all the metals utilised on Earth, copper comes in third place. For the development and growth of plants, animals, and people, copper is a crucial micronutrient. Other use for copper include the manufacture of wire apparatus, roofing and plumbing components, and industrial machine parts. According to Wuana and Okieimen (2011), copper-based compounds are utilised to reduce algal blooms.

Lead

On the periodic table, lead belongs to period 6 and group IV. It appears to be blue or silvery-grey and is a metallic element. These are only a few of its attributes: 82, 207.19, and 11.34 g/cm3 (Wuana and Okieimen, 2011) are the atomic weight and number of this substance. Almost all environmental media include lead, which can take many different forms in the environment. In addition to making leaded fuels and industrial machine parts, it is used to make plumbing pipes. (Tchounwou *et al*., 2012) Other applications of lead include making batteries, soldering, ammunition, pigments, chemical installations, and nuclear shielding.

2.4 Heavy Metals in Aquatic Ecosystems

Water is essential for the health and productivity of all ecosystems on Earth. One of water's characteristics is its capacity to dissolve practically every natural substance, which enables the dissolution of both beneficial and detrimental substances, including heavy metals. Heavy metal poisoning of water bodies is a problem since it has a negative impact on aquatic life and people who are exposed to these waters (Ali *et al*., 2019). Heavy metals are extremely hazardous to aquatic creatures, even in minute amounts, and can change their morphology and histology. The dumping of untreated sewage and industrial effluents into water bodies, runoff from mining operations, and leaching from agricultural areas are some of the sources of heavy metals in water. Water contaminated with heavy metals also provides space for their bio-absorption and multiplication in the food chain (Ouma, 2017).

2.4.1 Factors affecting heavy metals in water

Upon the entrance of heavy metals into water bodies, a number of variables affect their concentration and speciation in the water, and eventually a significant amount of these metals collect in the water body's bottom sediments. High concentrations of heavy metals in sediments may have an impact on the quality of ground water (Ali *et al*., 2019). Sediments act as both sources and sinks of heavy metal pollution in water bodies. Physicochemical factors or conditions of the affected water bodies, such as temperature, organic matter concentration, salinity, particle size, redox state of sediments, and presence of microorganisms, further determine how heavy metals in sediments are affected by processes like adsorption and desorption (Nowrouzi *et al*., 2014). Organic matter concentration, particle size distribution, sediment composition, and pH levels are sediment variables that influence the dispersion of heavy metals. Low pH levels make metals and hydrogen ions more competitive for binding sites, which may lead to the release of heavy metal ions into surrounding water. It has been demonstrated that benthic species living in water are negatively impacted when large concentrations of heavy metals are present in sediments (Decena *et al*., 2018).

2.4.2 Effects on fish

Aquatic creatures are affected negatively by heavy metals in a wide range of ways. Aquatic species' development, metabolism, and reproduction are disturbed and altered as a result of exposure to heavy metals. According to Ali *et al*. (2019), heavy metals build up in the gills, gonads, and muscles of aquatic creatures. Fish are frequently employed as markers of the toxicity of heavy metals in water. This is due to the fact that they are among the species that are adversely impacted by heavy metals in water and one of the primary pathways for heavy metals to enter the body via water sources (Karadede-Akin and Unlu, 2007). Heavy metals have been shown to influence the morphology and histology of fish in several studies. Only a few effects include the formation of vacuoles, an increase in chlorine cell number and degeneration, epithelial sloughing and gap-widening, constriction of blood vessels and increased susceptibility to illness, hypoxia in tissues, and decreased levels of plasma protein and haemoglobin (Besirovic *et al*., 2010). Additional effects include lowered egg viability and hatchability, negative effects on growth and development, delayed embryonic development, suppression of reproduction and growth, lamella shrinkage, weight loss, and epithelial cell injury (Abdel-Baki *et al*., 2011).

Heavy metals are impacted by a wide range of conditions upon introduction into aquatic systems, which affects how they speciate in water. Some of these processes leave some of these heavy metals in the water column above them or cause them to accumulate in the sediments at the water body's bottom (Duruibe *et al*., 2007). It has been demonstrated that bottom sediments may act as both a source and a sink for a variety of pollutants, including heavy metals. High concentrations of these heavy metals in sediments have the potential to contaminate groundwater (Ali *et al*., 2019). Adsorption and desorption are the main mechanisms that influence the accumulation of heavy metals in sediments. Heavy metal concentrations and accumulation are influenced by the physicochemical properties of the water, including temperature, organic matter content, salinity, particle size, redox state of sediments, and the presence of microbes (Nowrouzi *et al*., 2014). The distribution of heavy metals is further influenced by sediment-specific factors, including organic matter concentration, particle size distribution, sediment composition, and pH levels. Low pH levels make metals and hydrogen ions more competitive for binding sites, which may lead to the discharge of heavy metal ions into the water below. It has been demonstrated that benthic species living in water are negatively impacted when large concentrations of heavy metals are present in sediments (Ali *et al*., 2019).

2.4.3 Impacts on human health

Ingestion of polluted water, aquatic plants, and animals, skin absorption while swimming and bathing, and inhalation of contaminated aerosols are the three main ways that humans are exposed to heavy metals from water bodies. The quantity and duration of exposure determine whether the effects of heavy metals on human health are acute or chronic (Ali *et al*., 2019). The next section discusses some of the harmful impacts of heavy metals on human health.

When exposed to arsenic acutely, the blood vessels and tissues of the gastrointestinal system are damaged, and the heart and brain may also suffer. Vomiting and nauseousness are two additional acute side effects (Huy *et al*., 2014). Skin pigmentation and keratosis, skin lesions, vascular and cardiovascular illness, lung damage, and malignancies of the skin, bladder, lungs, and kidneys are only a few of the chronic impacts of arsenic exposure (Engwa *et al*., 2019). Lead is well recognised for its damaging effects on human neurological and gastrointestinal systems. According to Ali *et al*. (2019), acute lead exposure may cause headaches, stomach discomfort, sleeplessness, lethargy, appetite loss, renal failure, and arthritis. Chronic exposure to lead can result in kidney and brain damage, birth deformities, allergic responses, coma, mental retardation, muscular weakness, and, in the worst circumstances, death (Nkwunonwo *et al*., 2020).

The human body is poisonous to mercury in all of its forms. Mercury can affect the brain's regular functioning, which can lead to tremors, memory loss, irritation, and changes in hearing and vision. According to Engwa *et al*. (2019), acute mercury exposure results in gastrointestinal problems, skin rashes, lung damage, migraines, and hair loss. Tremors, forgetfulness, sleeplessness, and negative effects on performance-related characteristics including motor coordination, speed, and memory have all been linked to prolonged exposure to mercury (Bernhoft, 2012). Acute cadmium exposure results in severe lung damage, respiratory tract irritation, and gastrointestinal disorders such vomiting and diarrhoea. Osteoporosis, also known as Itai-Itai disease, is caused by the accumulation of cadmium in bones and tissues as a result of chronic exposure to the metal (Nishijo *et al*., 2017). The formation of renal stones, changes in the body's calcium metabolism, toxicity to the kidneys, and carcinogenicity are some other negative consequences (Wuana and Okieimen, 2011). Exposure to chromium causes gastrointestinal tract damage, anaemia, allergic responses, and nasal discomfort in addition to other side effects. Additionally, it harms sperm cells and other reproductive systems. High chromium concentrations have been linked to catastrophic neurological, cardiovascular, gastrointestinal, and other side effects, including death in certain cases (Engwa *et al*., 2019).

2.5 Empirical Review

Okafor and Opuene (2007) carried out a preliminary assessment of the concentrations of polycyclic aromatic hydrocarbons and heavy metals in sediments from Taylor Creek in Yenagoa, Bayelsa State. The heavy metals assessed during the study were cadmium, chromium, cobalt, iron, lead, nickel, manganese and zinc by was of atomic absorption spectrometry.

Milukaite *et al.* (2010) assessed the physicochemical and ecotoxicological properties of stormwater from urban areas in Lithuania. Stormwater runoff samples were taken from five different locations in Vilnius city during three rain episodes in May–June and from one location with heavy traffic during six rain episodes in May - October of 2007. These samples were then analysed for suspended solids, petroleum hydrocarbons (C_{14}–C_{28}) (PH), benzo(a)pyrene (B(a)P), heavy metals (Hg, Cu, Zn, Cd and Pb), and pH. Depending on the sampling place and level of rainfall, the concentration of the xenobiotics studied in the samples varied greatly. It was determined if storm water runoff samples were hazardous to rainbow trout. Depending on the runoff discharge point and chemical composition, changes in fish biological parameters (mean growth, white blood cell count), as well as the harmful effects of storm water runoff samples, were found to differ significantly. Storm water runoff, which had the greatest quantities of benzo(a)pyrene and petroleum hydrocarbons, caused the most notable reduction in the development of rainbow trout fry.

Khun *et al.* (2012) employed periphyton communities in the examination of the impacts of urban runoff from two catchment areas on receiving water bodies. At an upstream reference location, periphyton colonies were colonised on glass substrate for two weeks in riverine waters receiving urban runoff and in non-receiving waters. The efficiency of photosynthetic processes and resistance to copper, which was found to be a substantial runoff stressor, were compared between the receiving communities and the reference community. A laboratory ecotoxicological test was used to evaluate community tolerance while photosynthesis efficiency was quantified as a PSII quantum yield. The idea being explored is that runoff causes populations in receiving waterways to become more vulnerable to runoff stressors, hence degrading the runoff. The bioassessment revealed a copper threshold that was substantially greater than what was recommended by the general water quality criteria. The use of local community is significant because it enables ecological risk analysis of exposure to runoff stressors and provides management-relevant site-specific data.

Al-Mashaqbeh *et al.* (2014) evaluated the quality of runoff water from rural and urban areas around Amman-Zarqa basin. In order to examine the stormwater runoff pollutant concentrations on local urban and rural locations over the winter season that spanned from October 2012 to April 2013, six storm events were observed. The average stormwater runoff pollutant concentrations were considerably different between the urban and rural locations. The findings revealed that the urban site generated stormwater runoff with the greatest concentrations of dissolved heavy metals Zn, Cu, Pb, and Mn (0.106 mg/L, 0.033 mg/L, 0.02 mg/L, and 0.189 mg/L, respectively), organic pollutants COD and BOD_5 (1685 mg/L and 91 mg/L), and COD and BOD_5 combined (0.106 mg/L, 0.033 mg/L, 0.02 mg/L, and 0). This is partly because urban sites see more traffic than rural sites do. While the rural site produced the greatest levels of total suspended solids (6029 mg/L), total nitrogen and total phosphorus (31.2 mg/L and 34.3 mg/L), TCC, TFCC, and *E. coli* (4.06E+07, 8.00E+05, and 1.31E+05 MPN/100ml, respectively), stormwater runoff also transported the highest levels of these pollutants. This reflects the existence of anthropogenically caused pollution sources, such as the use of synthetic and organic fertilisers in rural areas. When compared to those reported in other studies, total phosphorus, total kjehldahl nitrogen, total suspended solids, chemical oxygen demand, Pb, and Zn from urban and rural locations are regarded as being at very high levels. In order to reduce the effects of stormwater runoff, best management practises and appropriate land management techniques were advised.

Olal (2015) carried out an impact assessment for urban runoff on the concentrations of heavy metals in Migori River, Migori, Kenya. Six established monitoring stations along the river were used to gather water samples over a six-month period (during both the wet and dry seasons). The results for water quality were summed together as mean and standard error. The findings showed that urban runoff continues to have a negative influence on the Migori River's water quality. The decline in water quality of the river increased downstream, in the direction of the settlement. The concentrations of lead and nickel are well over the WHO's recommended limits for surface waters. As a result, people, animals, and aquatic life all faced major threats from river water. It was recommended that the members of the public be made aware of the issues with pollution in the Migori River and the effects they have. A research listing the many chemicals utilised by the various firms in Migori town was also deemed to be necessary.

Westerhoff (2016) studied the best management practices for stormwater based on the impacts of urban stormwater on biological functions of aquatic organisms including survival and reproduction. Sand and iron filings mixed together served as the filtering substrate for the BMPs under study. Water was gathered during spring rain events, winter snowmelt events, and summer rain events. To reveal *Daphnia magna* and *Pimephales promelas*, collected water was employed. Survival and reproduction were the exposure objectives for *D. magna*. For the purpose of determining adult survival and neonate generation, *Daphnia* were exposed for 16-day intervals. Tests of larval c-start performance, development, and eating served as outcomes for *P. promelas* exposure. Before evaluating the endpoints, larval *P. promelas* were exposed to stormwater for 21 days. Water chemistry shows that each BMP improves water quality from the inflow to the outflow. For all three storm water sample occasions, there were just a few marginally different results for larval minnow or *Daphnia* performance between the Inflow and Outflow of the BMPs. The only area that significantly improved with time was larval performance; minnows exposed to water collected later in the year outperformed those exposed to winter snow melt in tests measuring predator escape. To enhance biological results, the architecture of the BMP filtration system may need to be changed, or additional filtration may be required.

Salata *et al.* (2018) assessed the ecological risk associated with the concentrations of heavy metals and polycyclic aromatic hydrocarbons present in sediments collected from various parts of Kielce City in Poland. Samples were collected using a stainless steel standard bottom grab sampler while for sites with difficult access, sampling was done using Eijkelkamp equipment. Physicochemical parameters of the samples including pH, conductivity, temperature and organic matter were determined. Inductively coupled plasma atomic absorption spectrometry (ICP-AES) was used in the determination of the concentrations of the following heavy metals: cadmium, copper, chromium, nickel, lead and zinc. The concentrations of high- and low-molecular weight PAHs was determined using gas chromatography-mass spectrometry. PAHs quantified included naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, pyrene, fluoranthene, benzo (a) anthracene, benzo (k) fluoranthene, benzo (g,h,i) perylene and chrysene. The heavy metal concentrations in the samples ranged from 267.12 mg/kg to 369.36 mg/kg. The concentrations of PAHs ranged from 27.433 mg/kg to 48.179 mg/kg. From the results of ecological risk assessment, the sediments were found to pose high ecological risk (above 1.0).

Young *et al.* (2018) explored the adverse impacts of urban stormwater runoff on the development of the lateral line in embryos of salmon and zebrafish at the larval stage. The findings demonstrated that whereas toxicants in stormwater did not result to the death of zebrafish hair cells, these cells did sustain harm. In addition to having decreased development, zebrafish grown in stormwater also had fewer neuromasts in the lateral line and fewer hair cells per neuromast. In coho salmon raised in stormwater, there was a comparable decrease in the number of neuromasts. Zebrafish lateral line defects were corrected by bioretention treatment, which was designed to filter out harmful stormwater constituents, but coho salmon lateral line defects were not. This finding suggests that not all of the harmful constituents were removed by the filtration media and that salmonids are particularly sensitive to aquatic toxicants. These findings show that fish sensory systems are adversely affected by sub-lethal exposure to stormwater runoff, which may have an influence on organismal fitness.

Harding *et al.* (2020) investigated the injury caused by crude oil and stormwater to the heart of the Pacific herring (*Clupea pallasti*). For a thorough characterization of embryolarval cardiotoxicity along a dilution gradient ranging from 12 to 50% stormwater diluted in clean saltwater, the study used the major aspects of the oil toxicity AOP for herring embryos, which have been well-characterized, as benchmarks. Measures of cardiac chamber looping, ventricular area, atrial and ventricle contractility, as well as measures of circulatory function were among the damage markers. Phenanthrene and other PAH tissue concentrations were measured in herring embryos. During cardiogenesis, tricyclic PAHs were shown to be easily bioavailable, and stormwater-induced toxicity was found to be quite similar to classical crude oil toxicity in many ways. The likelihood of non-tricyclic PAH-mediated pathways of developmental toxicity in fish was determined to be high due to the chemical complexity of urban runoff. The results did, however, imply that from the perspective of controlling wild herring populations, decades of prior study on crude oil toxicity may be used to understand stormwater-driven hazards to individual survival (both near-term and delayed mortality).

In their study, French *et al.* (2022) assessed the toxicity of runoff from roadways to various species of fish including congeneric sockeye, Chinook, steelhead and juvenile coho salmonids. Untreated urban runoff was exposed to juvenile coho, sockeye, steelhead, and Chinook for 24 hours before being moved to clean water for 48 hours. Coho were extremely vulnerable to runoff toxicity, as expected from earlier investigations, with cumulative fatality rates ranging from 92% to 100% over the course of the three storms. On the other hand, young sockeye were unaffected (100 percent survival), while the cumulative death rates for steelhead (4%–42%) and Chinook (0%–13%) were also in the middle. Additionally, coho perished shortly after being exposed to stormwater (often within 4 hours), but Chinook and steelhead deaths took between 1 and 2 days. Steelhead and Chinook did not recover when transported to clean water, which is consistent with earlier findings for coho. Lastly, even after roadway runoff was diluted by 95% in pure water, considerable death still happened in coho.

Li *et al.* (2022) conducted an assessment of antioxidant enzyme status, oxidative stress biomarkers and DNA damage in *Labeo rohita* upon exposure to pyriproxyfen. A total of 60 healthy individuals who were equally sized, age, and active were divided into four glass aquaria (T0-T3), each holding 100 L of water. They were also devoid of any externally visible illnesses. PPF dissolved in water at 300, 600, and 900 g/L was given to the fish in groups T1, T2, and T3 for a period of 30 days. On days 10, 20, and 30 of the experiment, different tissues, such as blood and visceral organs, were extracted from each fish. The number of pear-shaped erythrocytes, spherocytes, red blood cells with a blebbed nucleus, micronuclei, and nuclear remnants among the red blood cells of PPF-exposed *Labeo rohita* fish was much higher than expected. Fish exposed to insecticides had significantly (P<0.05) more DNA damage in several organs, according to the results of the genotoxicity (comet test). According to research on the oxidative stress profile (including reactive oxygen species and thiobarbituric acid reactive substances) and antioxidant enzymes (including reduced glutathione superoxide dismutase, peroxidase, and catalase) in various tissues of *Labeo rohita* fish, treated fish had significantly (P<0:05) higher levels of oxidative stress biomarkers and lower concentrations of various antioxidant enzymes. Accordingly, the results of the experimental investigation showed that PPF might have harmful effects on a number of different tissues in *Labeo rohita* fish.

Soltaninia *et al.* (2022) determined how climatic conditions and land use affected pollution due to heavy metals in urban runoff from a semi-arid zone in Tehran, Iran. Six sites, including five with different land uses and one with mixed land uses, were used to collect samples of urban runoff. Copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), arsenic (As) and mercury (Hg) were among the heavy metals measured in five land uses using the event mean concentration (EMC). From 2019 to 2020, sampling was carried out at six occurrences with various antecedent dry days (ADDs). Comparing the industrial land use to other land-use categories in the watershed, the results showed greater heavy metal concentrations in runoff. These were the calculated EMC rates: EMC Pb > EMC Zn > EMC Cu > EMC As > EMC Hg > EMC Cd. This study also discovered that rainfall occurrences with 115 and 1 dry days, respectively, were related with the largest and least EMCs of heavy metals. According to an examination of the EMC data, mercury and arsenic were present at greater levels in runoff than other heavy metals. Industrial land uses should be moved from urban environments to non-urban locations in order to reduce the danger of heavy metal pollution of runoff.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Benin City, Edo state, in southern Nigeria. Its geographic location is latitudes 6° 11' and 6° 29'N, and longitudes 5° 33' and 5° 47'E. In Nigeria's humid tropical rainforest zone, Benin City is located at an average height of 77.8 metres above sea level. The Ikpoba River flows through the local governments of Egor and Ikpoba-Okha in the Benin-Owena basin. Fishing, garbage disposal, boating, and the discharge of wastewater - particularly from commercial sources - are a few of the activities that happen along or on the river.

3.2 Sample Collection and Preparation

Water samples were taken from selected locations along the stretch of the Ikpoba. Samples were taken using sampling bottles from the benthic and pelagic zones of the river. Sampling took place monthly from June to August 2023.

Sediment samples were collected by grab sampling. Samples were wrapped in foil and properly labelled. After transportation to the laboratory, sediment samples were oven-dried and sieved using a 2mm mesh sieve and stored for analysis.

Samples of fish were captured randomly using a fishing net. They were transported to the laboratory for proper identification and storage. The total number of fish obtained from the rivers was six (6) i.e. three from the pelagic zone and three from the benthic zone. The fish samples were transported to the laboratory where they were washed using distilled water and stored at -10°C in separate polythene bags washed with acid. After that, the fish were dissected and the muscles were extracted for analysis.

The sampling locations for this study are shown in figure 3.1 below.

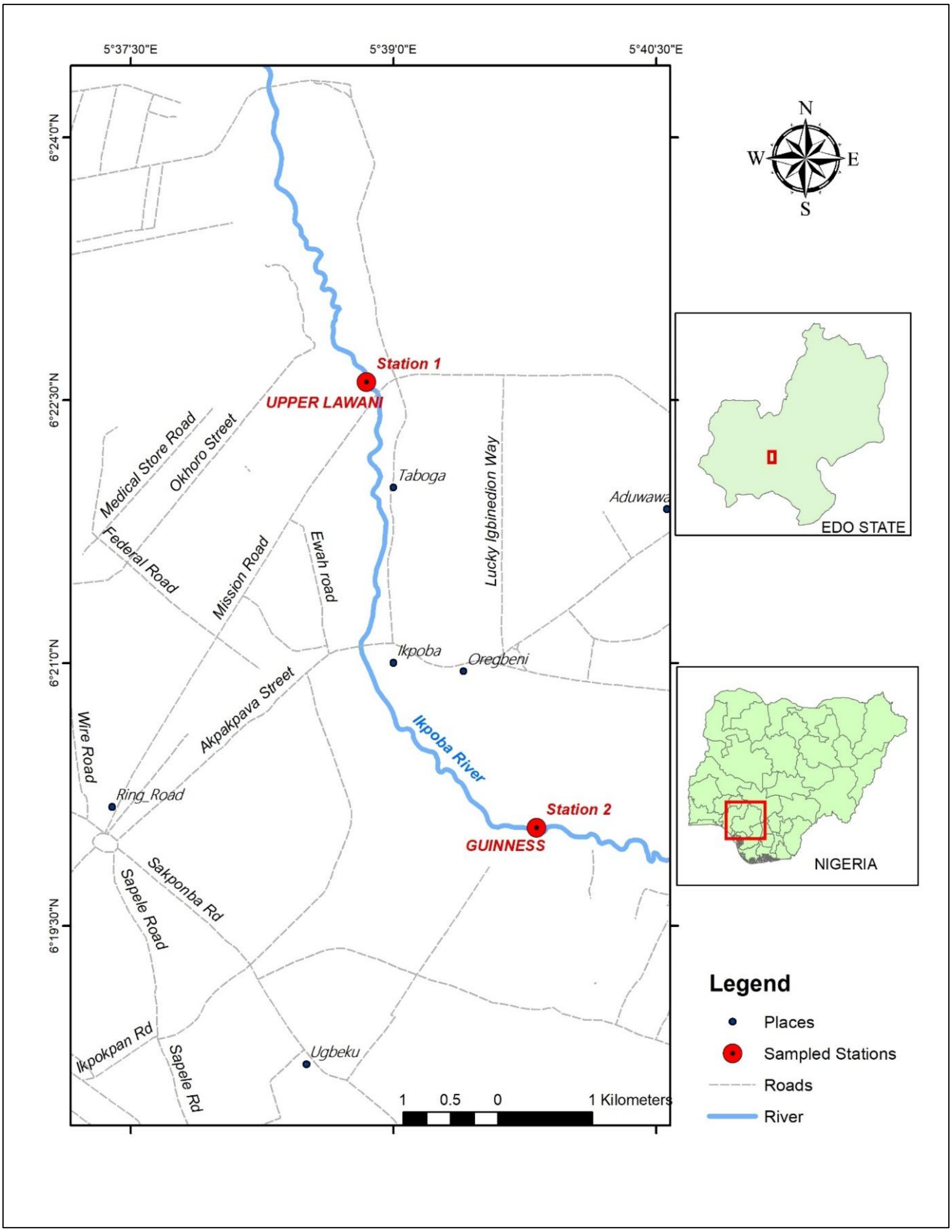

Figure 3.1: Map of the study area showing sampling locations

Plate 3.1: ***Clarias gariepinus*** **from study area**

Plate 3.2: Tilapia fish sample from study area

3.3 Analytical Procedures

3.3.1 Determination of Heavy Metals in Water Samples

Water sample were filtered through 0.45µm Millipore type filter. The concentration of lead in the samples was determined using the Atomic Absorption Spectrophotometer (AAS) Solar 969 Unicam Series model. Each metal has a hollow cathode lamp for its determination. The instrument was set up at wavelengths specific to lead. Distilled de-ionized water aspiration between each reading was conducted. Readings of the absorbance were obtained by observing the steady galvanometer reading in 1-2 mins. Analysis for each sample was carried out in triplicate to get representative results. The concentration of the metals was calculated using the standard calibration plot (Beauchemin and Berman, 1989).

3.3.2 Heavy Metals Determination in Sediment

1g of the prepared contaminated sediment sample was weighed using a top loading balance and placed in a 250ml beaker which had been previously washed with nitric acid and distilled water. The sample was reacted with 5ml of HNO_3, 15ml of concentrated H_2SO_4 and 0.3ml of $HClO_4$ using dropping pipette. The mixture was digested in a fume cupboard and heating continued until a dense white fume appeared. The mixture was then set aside to cool and diluted with distilled water. The mixture was filtered through Whattman filter paper into a 50ml volumetric flask and diluted to mark volume.

The samples were analysed using Atomic Absorption Spectrophotometer (AAS) Solar 969 Unicam Series model and the concentration of heavy metals were recorded in mg/kg.

3.3.3 Determination of Heavy Metals in Fish

The concentration of lead in the fish samples was determined using the following procedure. A one-gram sample of the muscles of the fish was taken and placed in a clean screw-capped tube. Sample digestion was done by the addition of a concentrated mixture of H_2O_2 and

HNO_3 (1:3). The mixture was then heated at 150°C for 20 minutes after which it was allowed to cool to room temperature. This was followed by the addition of distilled water to fill up to the 50ml mark and then the mixture was filtered using Whatman filter paper. Atomic Absorption Spectrometry (AAS) was then used to analyse the samples for lead content. For each sample, triplicate digestion and analysis was carried out and the mean results were recorded in mg/kg.

3.4 Statistical and Data Analyses

The data collected was analysed using Microsoft Excel Sheets and IBM SPSS Statistics. Tests used included descriptive statistics and t-tests.

CHAPTER FOUR

RESULTS

4.1 Concentrations of heavy metals in water

The heavy metal concentrations measured for water samples in this study are shown in table 4.1 and figure 4.1.

Pb and Cd were not detected in the samples assessed. However, for all three months, the concentrations of Ni, Cr and Co were higher in the downstream samples than in those from upstream locations. Also, the concentrations of Ni was highest in June while that of Co was least. In July, Cr had the highest concentration and Co had the least concentration. The same trend was observed in August.

Table 4.1 Mean concentrations of heavy metals in water

Metal (mg/l)	June		July		August	
	Upstream	Down stream	Upstream	Down stream	Upstream	Down stream
Ni	0.04 ±0.002	0.05 ± 0.002	0.03 ± 0.004	0.05 ± 0.002	0.03± 0.005	0.04 ± 0.002
Pb	ND	ND	ND	ND	ND	ND
Cr	0.03 ± 0.003	0.05 ± 0.003	0.04± 0.001	0.04± 0.003	0.04 ±0.004	0.05± 0.003
Cd	ND	ND	ND	ND	ND	ND
Co	0.02 ± 0.003	0.02 ± 0.006	0.02 ± 0.003	0.03 ± 0.002	0.03 ±0.004	0.04 ± 0.002

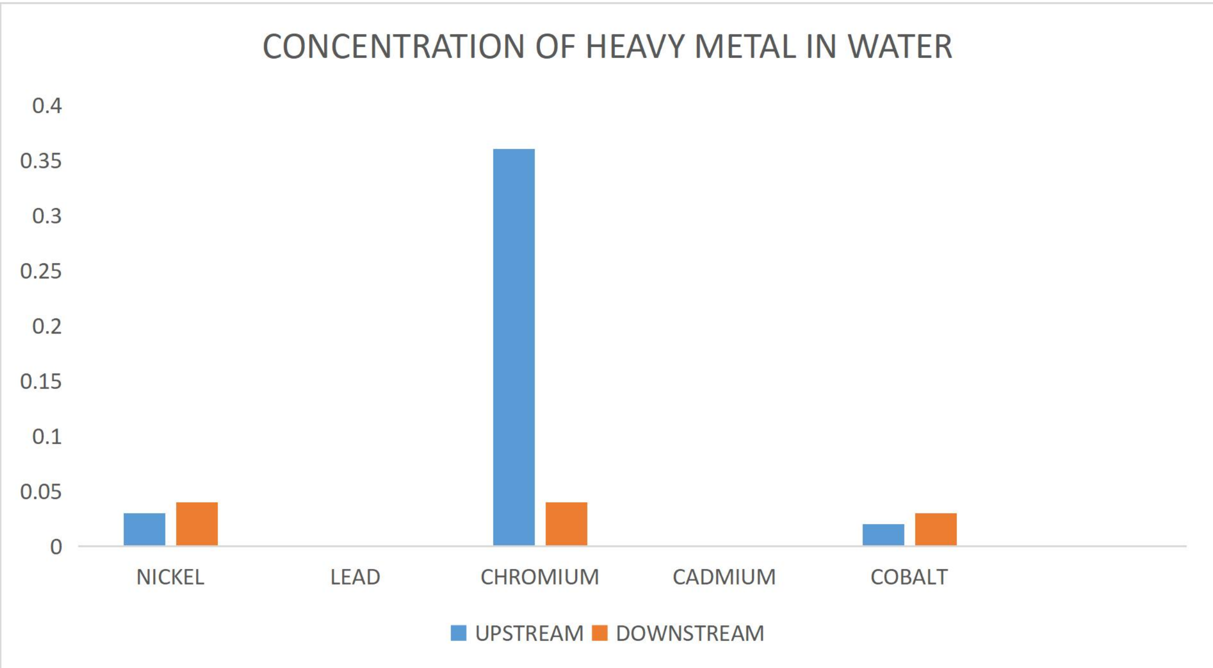

Figure 4.1: Concentrations of heavy metals in water

4.2 Concentrations of heavy metals in sediment

The concentrations of heavy metals detected in the sediment samples is shown in table 4.2 and figure 4.2.

The results show that Ni concentrations across the three months ranged from 2.7 ± 0.3mg/l to 7.9 ± 0.3mg/l. The minimum Pb concentration was 0.3 ± 0.01mg/l and the maximum was 0.5 ± 0.11mg/l. Cr concentrations ranged from 1.8 ±0.07mg/l to 2.6 ± 0.52mg/l. The concentrations of cadmium were in the range of 0.1 ± 0.01mg/l to 0.22 ± 0.01mg/l. Co concentrations ranged from 1.1 ±0.06mg/l to 2.1 ± 0.1mg/l.

Table 4.2: Heavy metal concentrations in sediments

Metal (mg/l)	June		July		August	
	Upstream	Down stream	Upstream	Down stream	Upstream	Down stream
Ni	6.1 ±0.18	7.9 ± 0.3	5.8 ± 1.03	4.9 ± 0.39	2.7 ± 0.3	3.9 ± 0.29
Pb	0.4 ±0.03	0.5 ± 0.01	0.49 ± 0.03	0.5 ± 0.11	0.3 ± 0.02	0.3 ± 0.01
Cr	2.6 ± 0.52	2.2 ± 0.04	1.9 ± 0.25	2.4 ± 0.33	1.8 ±0.07	2.1 ± 0.04
Cd	0.2 ± 0.01	0.2 ± 0.004	0.2 ± 0.06	0.22 ± 0.01	0.1 ± 0.01	0.2 ± 0.01
Co	1.7 ± 0.24	2.1 ± 0.1	1.6 ± 0.11	1.6 ± 0.1	1.1 ±0.06	1.5 ± 0.04

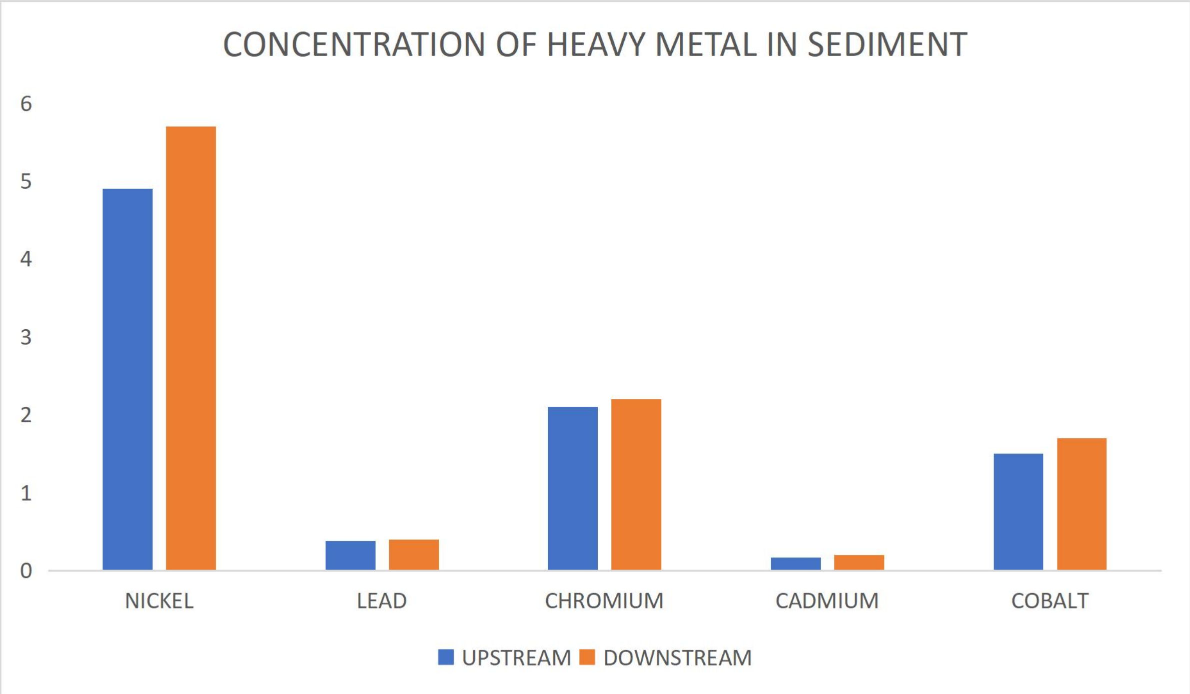

Figure 4.2: Concentrations of heavy metals in sediments

4.3 Monthly distribution of metals in water and sediment

The monthly trends for heavy metal concentrations in the water and sediment samples is shown in figures 4.3 and 4.4, respectively.

The trends reveal that for water, Ni had the highest concentration in June for both upstream and downstream samples. However, in July, Cr had the highest concentration upstream while nickel was highest downstream. In August, Cr concentrations were highest for both upstream and downstream samples.

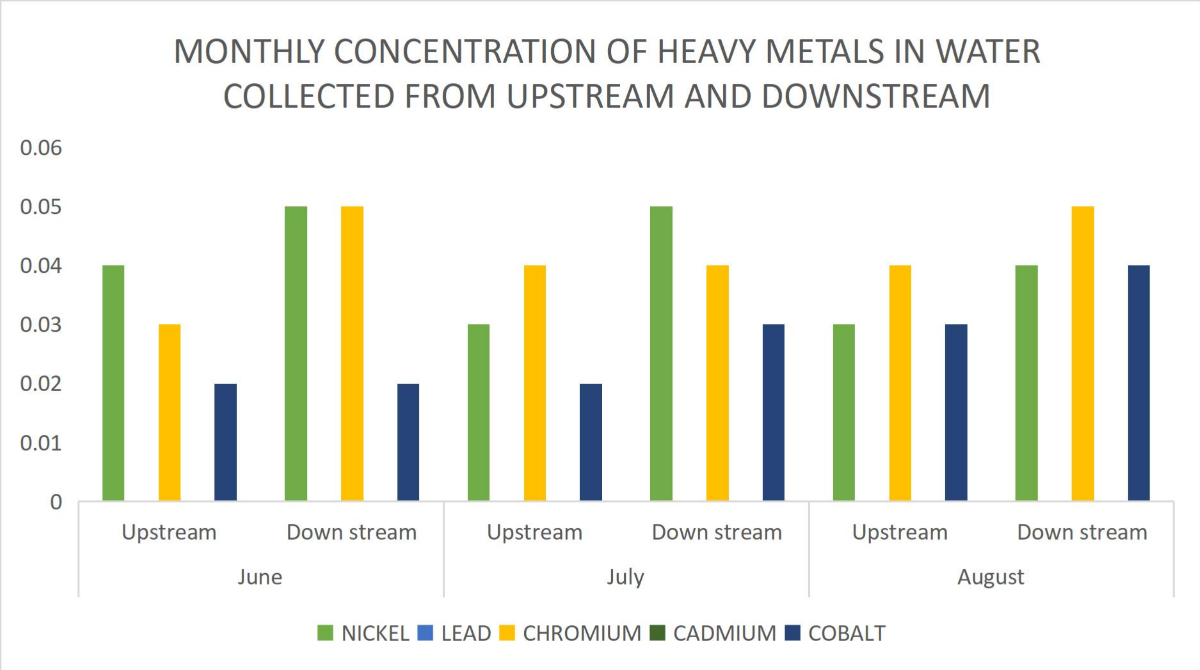

Figure 4.3: Monthly heavy metal concentrations in water

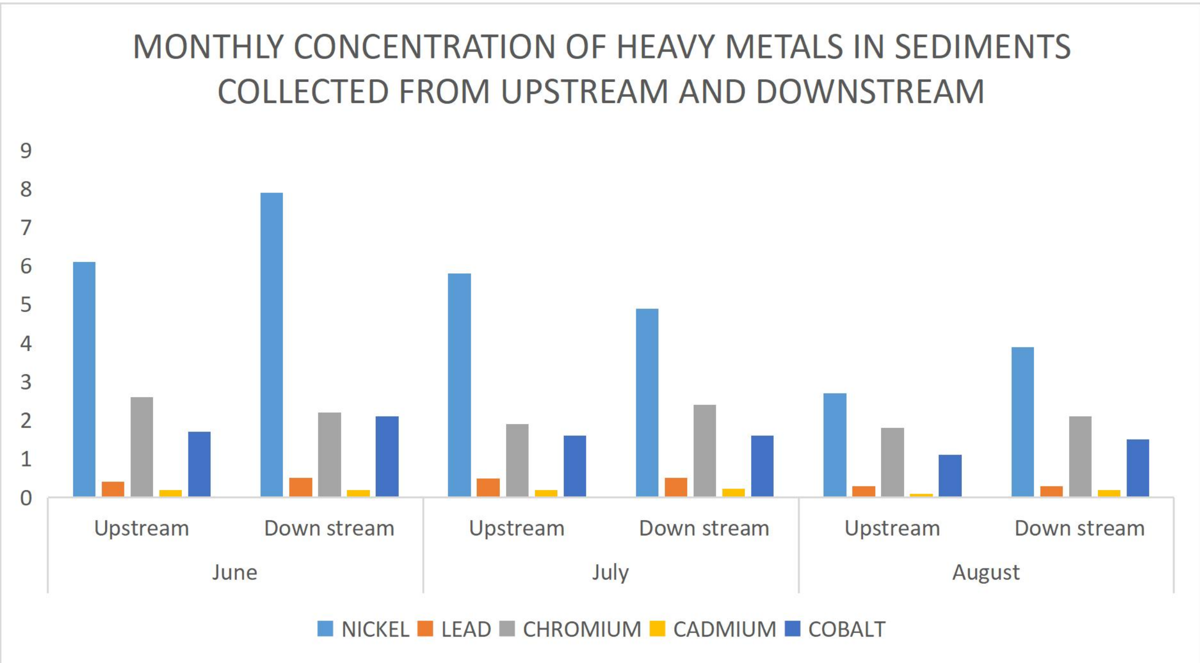

Figure 4.4: Monthly heavy metal concentrations in sediments

4.4 Concentrations of heavy metals in fish muscle

The mean concentrations of heavy metals present in muscles of fish samples.

Ni concentrations ranged from 0.488±0.151mg/l to 0.813±0.098mg/l. Pb concentrations were in the range of 0.04±0.012mg/l to 0.054±0.011mg/l. Cr concentrations ranged from 0.224±0.034mg/l to 0.522±0.206mg/l. Cd concentrations ranged from 0.022±0.007mg/l to 0.037±0.009mg/l. Co concentrations ranged from 0.061±0.009mg/l to 0.073±0.008mg/l.

Table 4.4 Mean concentrations of heavy metals in the muscles of fish samples

Sample	mg/l				
	Ni	Pb	Cr	Cd	Co
			Pelagic		
FISH 1	0.567±0.124	0.043±0.011	0.522±0.206	0.022±0.007	0.061±0.009
FISH 2	0.516±0.123	0.049±0.013	0.351±0.150	0.033±0.015	0.073±0.008
FISH 3	0.488±0.151	0.04±0.012	0.224±0.034	0.026±0.015	0.072±0.015
			Benthic		
FISH 4	0.813±0.098	0.054±0.011	0.398±0.189	0.029±0.018	0.069±0.013
FISH 5	0.668±0.099	0.047±0.008	0.281±0.167	0.027±0.011	0.070±0.006
FISH 6	0.646±0.172	0.048±0.004	0.324±0.123	0.037±0.009	0.062±0.003

CHAPTER FIVE

DISCUSSION

5.1 Discussion

Heavy metal contamination of water bodies is a pressing problem in contemporary times due to the wide range of applications to which these elements are put. Heavy metals decrease water quality and affect aquatic organisms adversely through various mechanisms (Ali *et al.,* 2019). This study was carried out to determine heavy metal concentrations in water, sediment and biota of Ikpoba River, Benin City, Nigeria.

The results of heavy metal analyses of water show that Pb and Cd were not detected in any of the water samples. Co concentration, on the other hand, fell within the permissible limits for CO in water. The concentrations of Ni and Cr in the water samples exceeded the limits recommended for these heavy metals in water by the WHO (2017). Being that samples were collected during the rainy season, the high concentrations of these metals is attributed to the influx of stormwater runoff into the river (Ilir, 2019). High concentrations of heavy metals in river water have been recorded in previous studies. The values obtained in this study were generally less than those obtained in a study by Muhammad *et al.* (2021). Another study by Adebayo (2017) recorded heavy metal concentrations in water up to 0.1mg/l.

The monthly trends for heavy metals in the water showed that nickel had higher concentrations than all of the other heavy metals in water. In the case of sediments, the concentrations of nickel also exceeded all others

The concentrations of heavy metals in the sediment samples were found to be much lower than those reported in previous studies. This indicated that there was low sedimentation of heavy metals in the river. This could be attributed to the high flow rate of water in the river which prevents sedimentation (Backhaus *et al.,* 2019).

The comparison of the heavy metal concentrations in the muscles of benthic and pelagic fish showed that the benthic fish had higher metal concentrations in the muscles than pelagic fish. This can be attributed to the fact that the benthic fish had higher interactions with sediments than pelagic fish and since sediments contained more metals, they benthic fish could take up more heavy metals that those at the water surface. The concentrations of heavy metals in the fish muscles were lower than the permissible limits for these metals in food substances. In comparison with previous studies, the concentrations obtained for heavy metals in fish samples from this study were lower. A study by Muhammad *et al.* (2021) recorded heavy metal levels in fish in the range of 0.336 - 1.957mg/kg. Another study recorded concentrations between 0.04 - 0.45mg/kg and 0.04 - 0.62mg/kg for cadmium in catfish and tilapia fish, respectively (Ekeanyanwu *et al.,* 2010). However, similarities exist between the values obtained in this present study and those in the study by Zhang *et al.* (2007) where heavy metal concentrations ranged between 0.004 - 0.035 in fish samples.

5.2 Conclusion

This study assessed heavy metal concentrations in water, sediment and pelagic and benthic fish collected from Ikpoba River, Benin City, Nigeria. The results obtained showed that heavy metal concentrations in water were above the permissible limits for water quality. However, the concentrations of heavy metals in sediments were less than those in other studies. Benthic fish were found to have higher concentrations of heavy metals in their muscles compared to those of pelagic fish. The concentrations of heavy metals in fish muscles were within regulatory limits and posed no threats to consumers.

Routine surveillance of the water body is recommended.

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