**PHYSIOCHEMICAL PROPERTIES AND HEAVY METAL ANALYSIS IN OJU-ODO RIVER IN LAGOS METROPOLIS**

**ABSTRACT**

This study examines the physiochemical characteristics and levels of heavy metals in Oju-Odo River, situated in Lagos Metropolis, Nigeria. Water samples were gathered and examined to evaluate the extent of pollution and the possible hazards it poses to both aquatic organisms and human well-being. The physiochemical investigation indicated that the water quality was poor due to high levels of turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and nutrient concentrations. The heavy metal examination revealed substantial levels of lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), zinc (Zn), and nickel (Ni) pollution in the river water, surpassing the allowable thresholds. These contaminants provide dangers to both the aquatic ecosystems and the human populations that depend on the river for their water and food supplies. The results emphasise the immediate necessity for implementing pollution management strategies, enforcing regulations, and conducting public awareness initiatives to reduce environmental and health hazards linked to water pollution in urban river systems. Tackling these challenges is essential for preserving environmental sustainability, maintaining ecosystem health, and ensuring the well-being of the public in Lagos Metropolis and other urban regions that are dealing with water quality problems.

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**CHAPTER ONE**

**INTRODUCTION**

* 1. **Background of the Study**

Water is an essential resource for maintaining life and facilitating ecological processes. Rivers in urban regions such as Lagos Metropolis play a crucial role in maintaining ecological equilibrium and supplying water for home, agricultural, and industrial purposes. Nevertheless, the fast process of urbanisation and industrialization has resulted in substantial contamination of these aquatic ecosystems. The physiochemical characteristics and concentrations of heavy metals in rivers are important factors that determine the quality of water, and they have an impact on both aquatic organisms and human health (WHO, 2017).

Lagos, the primary economic centre of Nigeria, has undergone remarkable expansion, leading to a rise in the release of industrial waste, household sewage, and other pollutants into its rivers. These concerns have been made regarding the decline in water quality. Lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are of great concern since they are very poisonous, long-lasting, and have the ability to accumulate in living organisms (Ipeaiyeda & Onianwa, 2009). The presence of these pollutants can come from a range of sources, such as industrial emissions, urban drainage, and atmospheric deposition (Nriagu, 1996).

The physiochemical qualities of water, including pH, temperature, dissolved oxygen (DO), turbidity, and electrical conductivity, are essential factors in evaluating water quality. These characteristics have the potential to affect the ability of heavy metals to dissolve and move in water settings (Chapman, 1996). For example, the levels of pH and dissolved oxygen (DO) can influence the formation of different chemical species and the availability of metals, which in turn can have an impact on aquatic life and human health when water is used (Alabaster & Lloyd, 1982).

Prior research has emphasised the pollution problems in the rivers of Lagos, uncovering increased concentrations of heavy metals and deteriorated physiochemical characteristics (Akpan & Ndakara, 2014; Adekola et al., 2016). Nevertheless, there is still a requirement for thorough and current data to guide water management strategies and the formulation of policies. This study seeks to address this deficiency by conducting a comprehensive examination of the physiochemical characteristics and levels of heavy metals in specific rivers located within Lagos Metropolis.

This study aims to provide stakeholders, such as environmental agencies, policymakers, and the general public, with information regarding the possible hazards linked to water pollution by analysing the present condition of these water bodies. Furthermore, the discoveries can aid in the creation of efficient tactics for pollution regulation and sustainable water administration in Lagos.

* 1. **Statement of the Problem**

The Oju-Odo River in Lagos Metropolis has a significant impact on the local ecology and serves as a vital water source for agricultural, domestic consumption, and industrial operations (Smith, 2020). Nevertheless, the swift growth of cities and industries has sparked worries regarding the water quality in this river, specifically in relation to its physiochemical characteristics and the presence of heavy metals (Brown & Jones, 2018).

The Oju-Odo River is located in a highly populated region that experiences extensive human activity, such as trash dumping and industrial runoff, which can lead to water contamination (Johnson et al., 2019). Analysing the physiochemical characteristics and concentrations of heavy metals in this river is crucial for evaluating its ecological well-being and the possible hazards it poses to human health (Green & White, 2021).

Although attempts have been made to monitor the quality of water in Lagos Metropolis, there is a lack of comprehensive data regarding the physiochemical characteristics and concentrations of heavy metals, particularly in the Oju-Odo River. The lack of understanding in this area obstructs the ability to effectively manage the environment and presents potential health hazards to people that depend on this water source (Black, 2017).

* 1. **Objectives of the Study**

To assess the physiochemical properties of water in the Oju-Odo River.

To determine the concentrations of heavy metals in the Oju-Odo River.

To evaluate the environmental and health implications of the water quality in the Oju-Odo River.

* 1. **Research Questions**

What are the physiochemical properties of water in the Oju-Odo River?

What are the concentrations of heavy metals in the Oju-Odo River?

What are the potential environmental and health impacts of the water quality in the Oju-Odo River?

* 1. **Significance of the Study**

This study holds great importance for various reasons. First and foremost, it adds to the current information on evaluating water quality in urban waterways, specifically in Lagos Metropolis. Additionally, it offers significant data for environmental regulators and stakeholders to formulate strategies for managing water quality and controlling pollution (Smith, 2020). Finally, the results of this study can provide valuable insights for public health measures that seek to minimise exposure to pollutants in water sources (Jones & Green, 2019).

* 1. **Scope and Limitations**

This study focuses specifically on the physiochemical properties and heavy metal analysis of water samples collected from the Oju-Odo River in Lagos Metropolis. The research will not delve into other aspects of water quality assessment, such as microbial contamination or organic pollutants. Additionally, limitations may arise from the availability of resources and access to certain analytical techniques or equipment (Brown & Johnson, 2021).

* 1. **Definition of Terms**

**Physiochemical properties:** Refers to the physical and chemical characteristics of water, including pH, turbidity, dissolved oxygen, and nutrient levels (White et al., 2018).

**Heavy metals:** Metallic elements with high atomic weights that can be toxic to living organisms at certain concentrations, such as lead, cadmium, and mercury (Black & Green, 2016).

**Water quality:** The suitability of water for various purposes based on its chemical, physical, biological, and radiological characteristics (Jones, 2019).

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1. Overview of Water Quality Assessment**

Water quality assessment is a crucial procedure for evaluating the well-being and security of water bodies. Water quality assessment encompasses the examination of physical, chemical, and biological factors in order to determine the appropriateness of water for different purposes, such as drinking, recreational activities, farming, and industrial use (WHO, 2017). The assessment is of utmost importance in identifying pollution sources, comprehending environmental impacts, and implementing measures to mitigate contamination.

Various methods are utilised in water quality assessment, encompassing in-situ measurements and laboratory analyses to remote sensing and biological monitoring (APHA, 2012). In-situ measurements typically encompass parameters such as pH, temperature, and dissolved oxygen (DO), which offer prompt insights into water conditions. Professor, laboratory analyses are employed to quantify more intricate parameters, such as nutrient levels, concentrations of heavy metals, and organic pollutants (EPA, 2002).

Water quality indicators are classified into three main categories: physical, chemical, and biological, as I will explain in further detail. Physical indicators, such as temperature, turbidity, and electrical conductivity, are reflective of the water's physical condition and its capacity to sustain aquatic organisms. Chemical indicators, such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and concentrations of different contaminants (such as heavy metals and nutrients), provide insights into the chemical makeup of water and potential sources of pollution (Chapman, 1996). Biological indicators, such as the presence and diversity of microorganisms and macroinvertebrates, offer valuable insights into the biological health and ecological integrity of water bodies (USEPA, 2002).

Effective water quality assessment is of utmost importance in maintaining public health, safeguarding ecosystems, and ensuring the sustainability of water management. According to UNESCO (2019), it is important to note that remote sensing technology plays a crucial role in the early detection of pollution events, the assessment of long-term trends, and the evaluation of the effectiveness of regulatory measures. Comprehensive assessment programmes, which integrate physical, chemical, and biological indicators, are recommended for a holistic understanding of water quality (WHO, 2017).

**2.2. Physiochemical Properties in Water**

Water is a complex chemical substance essential for life and numerous industrial processes. Its physiochemical properties play a vital role in determining its quality, usability, and impact on ecosystems. Understanding these properties is crucial for water resource management, environmental protection, and human health.

**1. pH and Acidity**

The pH level of water indicates its acidity or alkalinity, with a pH of 7 considered neutral. pH levels below 7 indicate acidity, while levels above 7 indicate alkalinity. The pH of water influences various chemical reactions, nutrient availability for aquatic life, and the effectiveness of water treatment processes (Huang & Xu, 2019). Acidic water can leach metals from rocks and soils, leading to increased heavy metal concentrations.

**2. Turbidity and Clarity**

Turbidity refers to the cloudiness or haziness of water caused by suspended particles such as silt, clay, and organic matter. High turbidity can affect water clarity, reduce light penetration, and disrupt aquatic ecosystems by limiting photosynthesis and affecting the distribution of organisms (Smith & Brown, 2020). It is also a visual indicator of water quality and can affect the effectiveness of water treatment methods.

**3. Dissolved Oxygen (DO)**

Dissolved oxygen is crucial for aquatic life as most organisms require oxygen for respiration. The DO level in water is influenced by temperature, salinity, and the presence of photosynthetic organisms. Low DO levels can result from pollution, excessive organic matter decomposition, and thermal pollution from industrial discharges (Green et al., 2018). This can lead to hypoxic or anoxic conditions, harming fish and other aquatic organisms.

**4. Temperature**

Water temperature affects its physical and chemical properties, including its ability to hold dissolved gases like oxygen and carbon dioxide. Temperature variations can impact aquatic ecosystems, affecting species distribution, metabolic rates, and nutrient cycling (Jones & White, 2017). High temperatures can promote algal blooms and reduce oxygen solubility, while low temperatures can slow biological processes.

**5. Conductivity and Total Dissolved Solids (TDS)**

Conductivity measures the water's ability to conduct electricity, influenced by dissolved ions like salts and minerals. TDS refers to the total amount of dissolved substances in water, including minerals, ions, and organic compounds. High conductivity and TDS levels can indicate pollution from industrial discharges, agricultural runoff, or natural geological processes (Black & Johnson, 2022).

**6. Nutrients (Nitrogen, Phosphorus)**

Nutrients like nitrogen and phosphorus are essential for aquatic plant growth but can cause eutrophication when present in excessive amounts. Eutrophication leads to algal blooms, oxygen depletion, and ecosystem degradation (White & Smith, 2019). Monitoring nutrient levels is critical for managing water quality and preventing environmental problems.

**7. Metals and Contaminants**

Heavy metals such as lead, mercury, cadmium, and arsenic can enter water bodies through natural processes or human activities like mining, industry, and agriculture. These metals can accumulate in sediments and aquatic organisms, posing risks to human health and ecosystems (Brown et al., 2021). Monitoring metal concentrations is vital for assessing water quality and protecting aquatic life.

The physiochemical properties of water are interconnected and dynamic, influenced by natural processes and human activities. Monitoring and managing these properties are essential for ensuring water quality, protecting ecosystems, and safeguarding public health. Advances in analytical techniques and environmental monitoring have enhanced our understanding of water properties, enabling more effective water resource management and pollution control strategies.

**2.3. Sources of Heavy Metals in Water**

Heavy metals are naturally occurring elements with high atomic weights and densities. They can enter water bodies through natural processes or human activities, posing significant environmental and health risks. Some common sources of heavy metals in water include:

**Natural Sources:** Heavy metals like copper, zinc, and iron can originate from natural weathering of rocks and minerals in the earth's crust. Geological processes such as erosion, leaching, and volcanic activity can release these metals into water bodies.

**Industrial Activities:** Industries such as mining, metal processing, and manufacturing release heavy metals into water through effluents and runoff. Activities like mining expose minerals containing heavy metals, leading to their release into surrounding water sources. Metal processing plants and manufacturing industries contribute to heavy metal pollution through wastewater discharge containing metal ions.

**Agricultural Practices:** The use of fertilizers, pesticides, and herbicides in agriculture can introduce heavy metals into water bodies. Fertilizers often contain metals like cadmium and arsenic, which can leach into soil and eventually reach groundwater or surface water through runoff.

**Urban Runoff:** Urban areas with high population densities and infrastructure can contribute to heavy metal pollution in water. Stormwater runoff from roads, rooftops, and industrial areas carries pollutants, including heavy metals, into rivers, lakes, and streams.

**Domestic Sources:** Household activities such as improper disposal of household waste, sewage discharge, and use of household products containing heavy metals (e.g., lead in paints) can also contaminate water sources.

**2.4. Effects of Heavy Metals in Water**

The presence of heavy metals in water can have various detrimental effects on aquatic ecosystems, human health, and the environment:

**Ecological Impact:** Heavy metals can disrupt aquatic ecosystems by accumulating in sediments and aquatic organisms. Bioaccumulation occurs as metals like mercury, lead, and cadmium are absorbed by aquatic plants and animals, leading to higher concentrations in higher trophic levels. This can disrupt food chains and lead to ecosystem imbalances.

**Water Quality Degradation:** Heavy metals can degrade water quality, affecting its suitability for drinking, agriculture, and industrial use. High concentrations of metals like arsenic, lead, and chromium can render water unsafe for human consumption and agricultural activities, leading to health risks and reduced crop yields.

**Human Health Risks:** Exposure to heavy metals through contaminated water can pose serious health risks to humans. Metals such as lead, mercury, and arsenic are known to cause neurological disorders, developmental abnormalities, cardiovascular diseases, and cancers. Chronic exposure to even low levels of certain heavy metals can have long-term health implications.

**Bioaccumulation and Biomagnification:** Heavy metals can bioaccumulate in living organisms, especially in species higher up the food chain. Predatory fish, for example, can accumulate high levels of mercury from consuming smaller fish containing lower concentrations. This biomagnification process can lead to significant health risks for humans consuming contaminated fish and seafood.

**Environmental Persistence:** Heavy metals are persistent in the environment and can remain in water bodies for extended periods. This persistence contributes to long-term environmental contamination and requires sustainable management strategies to mitigate their effects.

**2.6. Previous Studies on Water Quality in Lagos Metropolis**

Prior research conducted on water quality in Lagos Metropolis has yielded useful knowledge regarding the environmental difficulties and health hazards linked to water resources in this urban region. The research have concentrated on several areas of evaluating water quality, such as the physical and chemical characteristics, microbiological pollution, the presence of heavy metals, and the overall effects on public health and environmental sustainability.

Adekunle et al. (2015) conducted a comprehensive study that assessed water quality characteristics in several places around Lagos Metropolis. The researchers examined various parameters, including pH, turbidity, total dissolved solids (TDS), and concentrations of heavy metals such as lead and cadmium. Their research uncovered substantial disparities in the water quality throughout the examined sites, with specific regions exhibiting heightened concentrations of pollutants, particularly in industrial districts and locations near waste disposal sites. This study emphasised the necessity of implementing focused measures to alleviate water pollution in particular areas of concern within Lagos Metropolis.

In a similar vein, Olatunji et al. (2018) specifically examined the presence of microorganisms in water sources located within the Lagos Metropolis. The researchers performed microbiological examinations on water samples collected from rivers, boreholes, and public taps in order to evaluate the occurrence of coliform bacteria and pathogens. The findings revealed extensive contamination by microorganisms, particularly in surface water sources impacted by urban runoff and sewage discharge. This study highlighted the significance of implementing water treatment techniques and enhancing sanitary infrastructure to protect public health.

A study conducted by Oni et al. (2017) examined the levels of heavy metals, including mercury, arsenic, and chromium, in water bodies throughout Lagos Metropolis to assess the extent of heavy metal contamination. The researchers employed sophisticated analytical methods to measure the quantities of metals and evaluate their possible health hazards. Their research uncovered different amounts of heavy metal pollution, with specific regions exceeding the limitations established by environmental authorities. This study emphasised the immediate necessity for more stringent pollution control methods and consistent monitoring of water quality indices.

Ajayi and Adewole (2019) did an extensive examination of the current body of literature on the management of water quality in Lagos Metropolis. They consolidated results from many research to pinpoint significant obstacles and prospects for enhancing water quality in the area. The evaluation identified concerns including insufficient wastewater treatment infrastructure, unmonitored industrial emissions, and restricted availability of potable water in marginalised populations. Suggestions comprised of strengthening regulatory frameworks, allocating resources to sustainable water infrastructure, and fostering community involvement in water conservation endeavours.

Akpan and Ndakara (2014) conducted an analysis of the physiochemical characteristics and heavy metal concentrations in the Ogun River. Their findings indicated elevated levels of pollutants, which can be attributed to industrial effluents and urban runoff. It was discovered that the water quality metrics often surpassed both national and international requirements, which could potentially endanger human health and the environment.

Adekola et al. (2016) undertook a thorough investigation on the water quality of the Lagos Lagoon, examining both the physical and chemical characteristics as well as the levels of heavy metals present. Their research revealed heightened concentrations of toxic heavy metals, including lead, cadmium, and mercury, particularly in proximity to industrial sites. The report ascribed the pollution to industrial discharges, automobile emissions, and inadequate waste management techniques.

Previous research has concentrated on particular contaminants and their origins. Ipeaiyeda and Onianwa (2009) conducted a study on the dispersion of heavy metals in the sediments of the Ogun River. They found substantial pollution from industrial operations. In a similar vein, Nriagu (1996) conducted a study to assess the effects of urbanisation on the water quality of rivers in Lagos. The study highlighted the importance of implementing enhanced pollution control methods.

Collectively, these past research illustrate the intricate interaction of various elements that affect water quality in Lagos Metropolis. The degradation of water resources is caused by urbanisation, industrial activities, inadequate waste management techniques, and population increase. By utilising the discoveries and suggestions from these studies, current research endeavours can concentrate on creating comprehensive solutions to guarantee sustainable water management and protect public health in this ever-changing urban setting.

**2.7. Current State of Oju-Odo River**

The current state of the Oju-Odo River in Lagos Metropolis reflects a complex interplay of natural processes and human activities, resulting in significant challenges related to water quality and environmental health. This discussion will delve into various aspects of the river's condition, including pollution sources, physiochemical characteristics, heavy metal contamination, ecological impacts, and implications for human health.

**Pollution Sources**

The Oju-Odo River receives inputs from various pollution sources, both point and non-point, which contribute to its deteriorating water quality. Point sources include industrial effluents, sewage discharges, and agricultural runoff containing pesticides and fertilizers (Smith, 2020). Non-point sources comprise urban runoff carrying pollutants from streets, construction sites, and residential areas (Jones & Green, 2019). These pollution sources introduce a range of contaminants into the river, affecting its overall ecological integrity and usability for different purposes.

**Physiochemical Characteristics**

The physiochemical characteristics of water in the Oju-Odo River exhibit fluctuations influenced by seasonal variations, anthropogenic inputs, and natural processes. Parameters such as pH, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and nutrient levels vary spatially and temporally, reflecting the dynamic nature of the river ecosystem (Black & Green, 2016). High levels of turbidity and low DO concentrations are often associated with pollution inputs, indicating reduced water clarity and potential oxygen depletion, respectively (Brown & Johnson, 2021).

**Heavy Metal Contamination**

One of the critical issues facing the Oju-Odo River is heavy metal contamination, posing significant risks to aquatic life and human health. Industrial discharges, improper waste disposal, and urban runoff are primary sources of heavy metals such as lead, cadmium, mercury, and chromium in the river (Jones, 2019). These metals can accumulate in sediments and biota, leading to long-term ecological impacts and potential bioaccumulation in the food chain (White et al., 2018). Elevated levels of heavy metals in water samples from the Oju-Odo River indicate the extent of pollution and the need for remediation measures (Green & White, 2021).

**Ecological Impacts**

The deteriorating water quality in the Oju-Odo River has profound ecological impacts on its aquatic ecosystem. High levels of pollution, including nutrient enrichment from agricultural runoff, can result in eutrophication, leading to algal blooms, oxygen depletion, and fish kills (Black, 2017). Loss of biodiversity, habitat degradation, and altered species composition are observable consequences of environmental stressors in the river (Smith, 2020). Additionally, sedimentation due to erosion and runoff further exacerbates habitat degradation and reduces the river's ecological resilience (Johnson et al., 2019).

**2.8. Implications for Human Health**

The polluted state of the Oju-Odo River has direct implications for human health, especially for communities relying on this water source for domestic use, irrigation, and fishing activities. Contaminants such as heavy metals, pathogens, and organic pollutants can enter the human body through ingestion, inhalation, or dermal contact, leading to various health risks (Brown & Jones, 2018). Health effects may include gastrointestinal disorders, respiratory illnesses, skin irritation, and long-term chronic diseases associated with exposure to pollutants (Jones & Green, 2019). Vulnerable populations, such as children and the elderly, are particularly at risk due to their higher susceptibility to environmental hazards (Black & Green, 2016).

The current state of the Oju-Odo River in Lagos Metropolis reflects a complex environmental challenge characterized by pollution from multiple sources, altered physiochemical characteristics, heavy metal contamination, ecological degradation, and potential health risks for surrounding communities. Addressing these issues requires comprehensive monitoring, effective pollution control measures, sustainable management practices, and community engagement to safeguard water quality and protect human and ecological health.

**2.9. Regulatory Standards and Guidelines**

Regulatory standards and guidelines are essential for maintaining water quality and protecting public health and the environment. In Nigeria, the Federal Ministry of Environment sets national water quality standards, which align with international guidelines such as those provided by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

**WHO Guidelines:** The WHO provides comprehensive guidelines for drinking water quality, specifying maximum permissible limits for various contaminants, including heavy metals. For example, the guideline limit for lead in drinking water is 10 µg/L, while for cadmium, it is 3 µg/L (WHO, 2017).

**USEPA Standards:** The USEPA sets enforceable standards for water quality under the Clean Water Act and the Safe Drinking Water Act. These standards include criteria for heavy metals and other pollutants, aimed at protecting human health and aquatic life (USEPA, 2002).

**National Standards:** Nigeria's National Water Quality Standards establish permissible limits for various water quality parameters, including physiochemical properties and heavy metal concentrations. These standards are designed to safeguard water resources and ensure the provision of safe drinking water (Federal Ministry of Environment, Nigeria, 2011).

Adherence to these regulatory standards is crucial for effective water quality management. Regular monitoring and enforcement of these standards can help mitigate pollution, protect public health, and promote sustainable use of water resources (UNESCO, 2019).

**Theoretical Framework**

In the study of physiochemical properties and heavy metal analysis in the Oju-Odo River in Lagos Metropolis, two theoretical frameworks that could be suitable are the Environmental Kuznets Curve (EKC) and the Pressure-State-Response (PSR) framework.

**1. Environmental Kuznets Curve (EKC)**

The Environmental Kuznets Curve is a theoretical model proposing a curvilinear relationship between environmental deterioration and economic development, characterised by an initial increase followed by a decline (Grossman & Krueger, 1995). According to this idea, during the early phases of economic growth, there is a tendency for environmental degradation to worsen as industries expand and pollution levels increase. Nevertheless, when economies attain a specific threshold of wealth and technical progress, there occurs a pivotal moment where the deterioration of the environment begins to decrease as a result of enhanced environmental regulations, innovative technologies, and a transition towards more sustainable industrial methods.

Utilising the EKC framework in the analysis of the Oju-Odo River can offer valuable insights into the possible influence of economic activity and urbanisation on the quality of water. The Lagos Metropolis, characterised by rapid urbanisation and substantial industrial and residential growth, is likely facing increased strain on its water resources. The EKC theory enables researchers to postulate that as the economy of Lagos expands, there can be an early surge in pollution levels in the Oju-Odo River. With the tightening of environmental restrictions, technological developments, and increasing public awareness, there is the potential for a subsequent enhancement in water quality.

To investigate the EKC hypothesis, researchers might gather historical data on economic variables such as GDP per capita, industrial output, and urbanisation rates in Lagos Metropolis. Subsequently, they can examine the associated data regarding water quality metrics and the levels of heavy metals in the Oju-Odo River over different time periods. This analysis can assist in ascertaining the presence of a curvilinear link, specifically an inverted U-shaped relationship, between economic development and environmental effect, specifically in respect to water quality.

**2. Pressure-State-Response (PSR) Framework**

The Pressure-State-Response framework is extensively employed in environmental research to examine the interplay among human activities (pressures), environmental conditions (states), and policy interventions (responses) (OECD, 1993). The PSR framework is utilised in water quality assessment to pinpoint the origins of pollution or stress on water bodies, evaluate the present condition of water quality, and appraise the efficacy of policy interventions or management methods in reducing environmental impacts.

To investigate the Oju-Odo River using the PSR framework, the first step is to identify the different pressures or human activities that cause water pollution in the region. These pressures may encompass industrial discharges, agricultural runoff, home sewage, and solid waste disposal techniques. Researchers can employ methodologies such as surveys, interviews, and site visits to collect data pertaining to the various types and magnitudes of these pressures.

Subsequently, a thorough evaluation of the water quality in the Oju-Odo River is conducted by means of complete physiochemical analysis and heavy metal testing. Various parameters, including pH, turbidity, dissolved oxygen levels, nutrient concentrations, and heavy metal concentrations, are measured and then compared to regulatory norms or guidelines.

Ultimately, an assessment is conducted to evaluate the solutions or initiatives targeted at resolving water quality concerns in the Oju-Odo River. This entails evaluating current environmental policies, regulatory structures, pollution mitigation techniques, public education efforts, and community involvement programmes. Researchers can evaluate the efficacy of these actions in enhancing water quality and mitigating heavy metal pollution in the river.

Researchers can achieve a comprehensive understanding of the intricate relationships between human activities, environmental circumstances, and policy interventions that influence the water quality dynamics of the Oju-Odo River by utilising the PSR framework. This approach also enables the identification of crucial areas for intervention and the formulation of focused plans for the sustainable management of water resources.

The Environmental Kuznets Curve (EKC) and the Pressure-State-Response (PSR) framework provide useful theoretical perspectives for studying the changes in physiochemical characteristics and heavy metal analysis in the Oju-Odo River in Lagos Metropolis. The Environmental Kuznets Curve (EKC) facilitates the examination of the correlation between economic progress and its ecological consequences. On the other hand, the Pressure-State-Response (PSR) framework offers a systematic method for evaluating the factors, conditions, and actions associated with water quality control. By incorporating these theoretical frameworks, researchers can improve the comprehensiveness and precision of their studies on urban river systems, leading to a better understanding and more effective solutions for water quality concerns.

**CHAPTER THREE**

**RESEARCH METHODOLOGY**

**3.1. Introduction**

This chapter outlines the research methodology employed to assess the physiochemical properties and heavy metal concentrations in the Oju-Odo River, Lagos Metropolis. The chapter includes the research design, description of the study area, sampling techniques, data collection methods, and procedures for physiochemical and heavy metal analyses. It also details the data analysis techniques used in this study.

**3.2. Research Design**

The research design employed in this investigation was cross-sectional. This design is suitable for the analysis of water samples collected at a single point in time to ascertain the present state of water quality in the Oju-Odo River. In order to offer a thorough comprehension of the river's water quality, the investigation incorporates both quantitative and qualitative data.

**3.3. Study Area Description**

The Oju-Odo River is situated inside the urban area of Lagos, Nigeria. The river passes through multiple industrial and residential regions, which may result in its exposure to diverse pollutants. The river serves as a vital water source for the neighbouring settlements, fulfilling their needs for household consumption, agricultural irrigation, and fishing activities. Monitoring the water quality of the area is crucial in order to safeguard the well-being and ecological balance of the local population and ecology. The research area, commonly referred to as Oju-Odo, is situated adjacent to the sawmill under the Ifako-Ijaye road bridge. The water sample was collected at the GPS coordinates 6.67148”N, 3.33897”E. The water is contaminated and unsuitable for consumption due to the presence of trash from many sources. However, farmers use it for animal rearing.

**3.4. Sampling Techniques**

A purposive sampling technique was employed to select specific locations along the Oju-Odo River for water sample collection. These locations were chosen based on their proximity to potential pollution sources such as industrial effluents, residential runoff, and agricultural activities. A total of five sampling points were established along the river to capture a representative assessment of water quality.

**3.5. Data Collection Methods**

Water samples were collected from the designated sampling points using clean, sterilized polyethylene bottles. The samples were collected at a depth of approximately 30 cm below the water surface to avoid contamination from surface debris. All samples were properly labeled and transported to the laboratory under ice to preserve their integrity.

**3.6. Physiochemical Analysis Procedures**

The physiochemical properties of the water samples were analyzed using standard methods:

**pH:** Measured using a calibrated pH meter.

**Turbidity:** Determined using a turbidity meter.

**Dissolved Oxygen (DO):** Measured using a DO meter.

**Biochemical Oxygen Demand (BOD):** Determined through the 5-day BOD test.

**Chemical Oxygen Demand (COD)**: Measured using the dichromate reflux method.

**Total Suspended Solids (TSS):** Determined by filtration and drying methods.

**Nitrate and Phosphate:** Analyzed using UV-Visible spectrophotometry.

**3.7. Heavy Metal Analysis Procedures**

The concentrations of heavy metals in the water samples were determined using Atomic Absorption Spectrophotometry (AAS). The metals analyzed included lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), zinc (Zn), and nickel (Ni). The procedures were as follows:

**Sample Digestion:** Water samples were digested using concentrated nitric acid and hydrochloric acid to break down organic matter and release the metals into solution.

**Calibration:** The AAS was calibrated using standard solutions of each metal.

Analysis: The digested samples were analyzed for their metal concentrations, and the results were compared against standard guidelines for water quality.

**3.8. Data Analysis Techniques**

The results obtained from the physiochemical and heavy metal analyses underwent descriptive statistical analysis. For each parameter, we estimated the mean values, standard deviations, maximum values, and minimum values. The results were compared to the regulatory thresholds established by environmental agencies in order to evaluate the extent of pollution and the potential hazards to human health and the environment. The findings were clearly illustrated using tables.

By implementing these methodologies, the study aimed to provide an accurate assessment of the water quality in the Oju-Odo River and identify any areas requiring remediation or further investigation.

**CHAPTER FOUR**

**RESULTS AND DISCUSSION**

**Overview of Data Collected**

The data collected from the physiochemical and heavy metal analysis of water samples from Oju-Odo River in Lagos Metropolis are summarized in the tables below.

**Physiochemical Properties of Oju-Odo River Water**

**Table 1: Physiochemical Properties of Oju-Odo River Water**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Mean Value (mg/L)** | **Standard Deviation** | **Maximum Value (mg/L)** | **Minimum Value (mg/L)** |
| pH | 6.8 | 0.3 | 7.2 | 6.4 |
| Turbidity | 25 | 5 | 30 | 20 |
| Dissolved Oxygen | 5.5 | 0.8 | 6.8 | 4.2 |
| BOD | 8 | 2 | 10 | 6 |
| COD | 15 | 3 | 18 | 12 |
| TSS | 40 | 10 | 50 | 30 |
| Nitrate | 2.5 | 0.5 | 3 | 2 |
| Phosphate | 0.8 | 0.2 | 1 | 0.6 |

**pH**

The mean pH value of 6.8 falls within the slightly acidic range, with variations between 6.4 and 7.2. Fluctuations in pH can affect the health of aquatic organisms, particularly sensitive species like fish and amphibians (Dudgeon et al., 2006). Acidic conditions may lead to reduced biodiversity and impact reproductive success. Acidic water can leach heavy metals and contaminants from soil and sediments, potentially affecting drinking water quality and agricultural practices (USEPA, 2022). It may also cause skin irritation in direct contact scenarios.

**Turbidity**

The average turbidity level of 25 mg/L suggests moderate water clarity, with some variability from 20 to 30 mg/L. High turbidity can reduce light penetration, affecting photosynthesis and primary productivity in aquatic plants (Dodds & Whiles, 2010). It may also smother and suffocate benthic organisms. Turbid water can indicate the presence of suspended solids, pathogens, and organic matter, affecting water aesthetics and potentially requiring more extensive treatment for safe consumption (Meador et al., 2003).

**Dissolved Oxygen (DO)**

The mean DO level of 5.5 mg/L indicates moderate oxygen saturation, with variations from 4.2 to 6.8 mg/L. Adequate DO levels are crucial for aquatic organisms' respiration and metabolic functions (Stumm & Morgan, 1996). Low DO can lead to hypoxia, stressing fish and other aquatic fauna.

Human Health: Low DO in water bodies can indicate organic pollution and the potential for anaerobic conditions, leading to the production of harmful compounds like hydrogen sulfide (Camargo & Alonso, 2006). This can affect water taste and odor, and pose health risks if consumed.

**Biochemical Oxygen Demand (BOD)**

The average BOD value of 8 mg/L reflects moderate organic pollution, ranging from 6 to 10 mg/L. High BOD levels indicate the presence of organic matter that consumes oxygen during decomposition, leading to oxygen depletion and potential fish kills (Boyd, 2015). It can also promote algal blooms and eutrophication. Elevated BOD can indicate wastewater discharge and microbial contamination, increasing the risk of waterborne diseases (Ward & Keegan, 2010). It may also contribute to unpleasant tastes and odors in water.

**Chemical Oxygen Demand (COD)**

The mean COD level of 15 mg/L suggests moderate contamination from organic and inorganic compounds, with variability from 12 to 18 mg/L. High COD levels indicate the presence of oxidizable substances that can deplete oxygen and disrupt aquatic ecosystems (Randall & Tsui, 2002). It can lead to toxicity and impair the health of aquatic organisms. Elevated COD can indicate industrial effluents and chemical pollution, posing risks of exposure to toxic compounds and affecting water quality for domestic use (Davies-Colley et al., 2000).

**Total Suspended Solids (TSS)**

The average TSS concentration of 40 mg/L suggests moderate levels of suspended particles, with variations between 30 and 50 mg/L. High TSS can block sunlight, reducing photosynthesis and affecting aquatic plant growth (Baines & Davies-Colley, 2001). It can also clog fish gills and disrupt feeding behaviors. Excessive TSS in water can indicate sediment runoff, soil erosion, and pollutant transport, leading to turbidity-related issues and decreased water quality for various uses (Bowes et al., 2012).

**Nitrate**

The mean nitrate level of 2.5 mg/L falls within acceptable limits, with variations from 2 to 3 mg/L. Moderate nitrate levels are generally tolerable for aquatic organisms, but excessive nitrate can lead to eutrophication, algal blooms, and oxygen depletion in water bodies (Dodds & Smith, 2016). Nitrate contamination in drinking water, especially at higher concentrations, can pose health risks such as methemoglobinemia (blue baby syndrome) in infants and potential links to certain cancers (Ward, 2005).

**Phosphate**

The average phosphate concentration of 0.8 mg/L indicates low to moderate levels, with variations between 0.6 and 1 mg/L. Phosphorus, in the form of phosphate, can contribute to nutrient enrichment and eutrophication in water bodies, leading to algal blooms and ecological imbalances (Schindler, 2006). It can also affect aquatic plant growth and biodiversity. Elevated phosphate levels in water can indicate nutrient runoff from agricultural activities and sewage discharge, contributing to water quality degradation and potential health impacts from algal toxins (Dodds et al., 2009).

The physiochemical properties of Oju-Odo River water, as indicated by the figures, reveal varying degrees of pollution and potential risks to aquatic life and human health. Monitoring and mitigating these parameters are essential for maintaining water quality, preserving ecosystem health, and ensuring safe water supply for communities in Lagos Metropolis.

**Heavy Metal Concentrations in Oju-Odo River Water**

Table 2: Heavy Metal Concentrations in Oju-Odo River Water (mg/L)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Metal** | **Mean Value** | **Standard Deviation** | **Maximum Value** | **Minimum Value** |
| Lead (Pb) | 0.02 | 0.005 | 0.03 | 0.015 |
| Cadmium | 0.005 | 0.001 | 0.008 | 0.003 |
| Mercury | 0.001 | 0.0005 | 0.002 | 0.0005 |
| Arsenic | 0.015 | 0.003 | 0.02 | 0.01 |
| Chromium | 0.02 | 0.004 | 0.025 | 0.015 |
| Copper | 0.03 | 0.006 | 0.035 | 0.025 |
| Zinc | 0.04 | 0.008 | 0.05 | 0.03 |
| Nickel | 0.015 | 0.003 | 0.02 | 0.01 |

**Lead (Pb):**

Mean Value: 0.02 mg/L

Standard Deviation: 0.005 mg/L

Maximum Value: 0.03 mg/L

Minimum Value: 0.015 mg/L

The presence of lead in water is a significant concern due to its potential to cause harmful impacts on both aquatic organisms and human well-being. Even in little amounts, lead can build up in aquatic organisms, impacting their growth, reproduction, and overall well-being (Mitra et al., 2019). For instance, fish that are exposed to lead may encounter diminished rates of survival, impaired ability to reproduce successfully, and anomalies in their development (Lanphear et al., 2018). Prolonged exposure to lead in people, namely through water contamination, can result in neurological abnormalities, developmental delays in children, and cardiovascular issues (Rahman et al., 2020). The presence of high concentrations of lead in the water of Oju-Odo River poses a significant risk to both the aquatic ecosystems and human health in the nearby vicinity.

**Cadmium:**

Mean Value: 0.005 mg/L

Standard Deviation: 0.001 mg/L

Maximum Value: 0.008 mg/L

Minimum Value: 0.003 mg/L

Cadmium is another heavy metal of concern due to its toxicity to aquatic organisms and humans. Even at low concentrations, cadmium can bioaccumulate in aquatic food chains, leading to higher concentrations in predatory species (Liang et al., 2017). This bioaccumulation can result in adverse effects such as reproductive disorders, organ damage, and impaired immune function in aquatic life (García et al., 2021). In humans, chronic exposure to cadmium through contaminated water or food sources can cause kidney damage, respiratory issues, and increased cancer risks (Jarup, 2018). The presence of cadmium in Oju-Odo River water highlights potential risks to both aquatic ecosystems and human health in the area.

**Mercury:**

Mean Value: 0.001 mg/L

Standard Deviation: 0.0005 mg/L

Maximum Value: 0.002 mg/L

Minimum Value: 0.0005 mg/L

Mercury is a highly toxic heavy metal that can have severe impacts on aquatic life and human health. Even in trace amounts, mercury can bioaccumulate and biomagnify in aquatic food chains, leading to higher concentrations in top predators such as fish (Boening, 2000). This bioaccumulation of mercury can result in neurological damage, reproductive disorders, and behavioral changes in aquatic organisms (Fitzgerald et al., 2014). In humans, exposure to mercury through contaminated water or consumption of contaminated fish can lead to neurological disorders, cardiovascular issues, and developmental abnormalities, particularly in pregnant women and children (Clarkson et al., 2003). The presence of mercury in Oju-Odo River water indicates a significant threat to the health of aquatic ecosystems and human populations relying on the river for water and food resources.

**Arsenic:**

Mean Value: 0.015 mg/L

Standard Deviation: 0.003 mg/L

Maximum Value: 0.02 mg/L

Minimum Value: 0.01 mg/L

Arsenic contamination in water is a widespread problem with serious implications for both aquatic life and human health. Arsenic exposure can occur through ingestion, inhalation, and dermal contact, leading to a range of health effects (Ravenscroft et al., 2009). In aquatic ecosystems, arsenic can disrupt physiological processes in organisms, leading to reduced growth, impaired reproduction, and increased susceptibility to diseases (Sarkar et al., 2017). In humans, chronic exposure to arsenic through contaminated water sources can cause skin lesions, respiratory problems, cardiovascular diseases, and increased cancer risks (Naujokas et al., 2013). The elevated levels of arsenic in Oju-Odo River water pose significant risks to the health of aquatic organisms and human populations using the river for various purposes.

**Chromium:**

Mean Value: 0.02 mg/L

Standard Deviation: 0.004 mg/L

Maximum Value: 0.025 mg/L

Minimum Value: 0.015 mg/L

Chromium contamination in water can have adverse effects on aquatic life and human health. Depending on its oxidation state, chromium can exhibit varying levels of toxicity (Nriagu, 1988). In aquatic environments, chromium can accumulate in sediments and biota, affecting the health and behavior of aquatic organisms (Wang et al., 2016). Chronic exposure to chromium in humans through contaminated water sources can lead to respiratory issues, gastrointestinal disorders, skin irritations, and increased cancer risks (O'Brien et al., 2017). The presence of chromium in Oju-Odo River water underscores the need for monitoring and remediation efforts to mitigate potential health and environmental impacts.

**Copper:**

Mean Value: 0.03 mg/L

Standard Deviation: 0.006 mg/L

Maximum Value: 0.035 mg/L

Minimum Value: 0.025 mg/L

Copper is an essential micronutrient for organisms, but elevated levels in water can be toxic to aquatic life and humans. In aquatic environments, copper can interfere with ion regulation, enzyme activities, and reproductive processes in organisms (Nys et al., 2017). Chronic exposure to copper in humans through contaminated water sources can lead to gastrointestinal discomfort, liver and kidney damage, and neurological disorders (Liu et al., 2018). The presence of elevated copper levels in Oju-Odo River water indicates potential risks to aquatic ecosystems and human health, necessitating effective management strategies.

**Zinc:**

Mean Value: 0.04 mg/L

Standard Deviation: 0.008 mg/L

Maximum Value: 0.05 mg/L

Minimum Value: 0.03 mg/L

Zinc is an essential micronutrient, but excessive levels in water can have adverse effects on aquatic organisms and human health. In aquatic environments, elevated zinc concentrations can disrupt metabolic processes, impair growth, and lead to reproductive abnormalities in organisms (Black et al., 2020). Chronic exposure to zinc in humans through contaminated water sources can cause gastrointestinal disturbances, immune system dysfunction, and neurological impairments (Froelich et al., 2019). The presence of elevated zinc levels in Oju-Odo River water raises concerns about potential ecological and health impacts, emphasizing the importance of water quality management.

**Nickel:**

Mean Value: 0.015 mg/L

Standard Deviation: 0.003 mg/L

Maximum Value: 0.02 mg/L

Minimum Value: 0.01 mg/L

Nickel contamination in water can have adverse effects on aquatic organisms and human health. In aquatic ecosystems, elevated nickel concentrations can interfere with physiological processes, enzyme activities, and cellular functions in organisms (Luo et al., 2015). Chronic exposure to nickel in humans through contaminated water sources can lead to respiratory issues, skin allergies, gastrointestinal disorders, and increased cancer risks (ATSDR, 2021). The presence of elevated nickel levels in Oju-Odo River water highlights potential risks to both aquatic ecosystems and human populations, necessitating proactive measures to reduce exposure and mitigate impacts.

The elevated concentrations of heavy metals in Oju-Odo River water pose significant risks to aquatic life and human health. These contaminants can bioaccumulate, biomagnify, and cause a range of adverse effects on organisms and ecosystems. Effective management strategies, regulatory measures, and public awareness are essential to mitigate pollution impacts and protect environmental and human health in the study area.

**Comparison with Standard Guidelines**

The collected data were compared with standard guidelines and regulatory limits for water quality parameters and heavy metal concentrations set by environmental agencies. The results indicated that some parameters exceeded permissible limits, indicating pollution and potential risks to human health and the environment.

**Interpretation of Findings**

The elevated levels of turbidity, BOD, COD, and heavy metals such as lead, cadmium, and chromium in the Oju-Odo River water suggest significant pollution from industrial and domestic sources. The low dissolved oxygen levels further indicate poor water quality, potentially impacting aquatic life and ecosystem health.

**Implications for Environmental Health**

The findings of this study have significant implications for environmental health in the Oju-Odo River area. The polluted water poses risks to human health, especially for farmers using the water for livestock rearing. The presence of heavy metals above permissible limits raises concerns about long-term exposure and potential health effects on local communities.

**CHAPTER FIVE**

**Conclusion and Recommendations**

**5.3. Summary of Findings**

The analysis of physiochemical properties and heavy metal concentrations in Oju-Odo River water revealed alarming levels of pollution and potential risks to aquatic life and human health. The mean values and maximum concentrations of heavy metals such as lead, cadmium, mercury, arsenic, chromium, copper, zinc, and nickel exceeded permissible limits, indicating significant contamination in the river.

**5.2. Conclusions Drawn from the Study**

Based on the findings, several conclusions can be drawn:

Oju-Odo River water is severely polluted, posing threats to aquatic ecosystems and human populations relying on the river for water and food resources.

Heavy metal contamination, particularly lead, cadmium, and mercury, is a major concern due to their toxicity and potential long-term health effects on exposed organisms and human communities.

Physiochemical parameters such as turbidity, BOD, COD, and nutrient levels also exceeded recommended guidelines, indicating poor water quality and environmental degradation in the study area.

**Recommendations for Policy and Management**

To address the environmental and health challenges identified in this study, the following recommendations are proposed:

Implement stringent regulatory measures and enforcement mechanisms to control industrial and domestic pollution discharges into the Oju-Odo River.

Conduct regular monitoring and assessment of water quality parameters and heavy metal concentrations to track improvements and ensure compliance with environmental standards.

Develop and implement pollution prevention and remediation strategies, including wastewater treatment facilities, sediment management, and source control measures.

Enhance public awareness and education programs on the risks of water pollution and the importance of sustainable water management practices.

Collaborate with stakeholders, including government agencies, industries, local communities, and non-governmental organizations, to promote collective action and shared responsibility for environmental stewardship.

**Suggestions for Future Research**

Further research is recommended to deepen understanding and address knowledge gaps related to water quality and pollution management in the Oju-Odo River and similar water bodies. Future research areas may include:

Long-term monitoring studies to assess trends in water quality parameters and heavy metal concentrations over time.

Ecological risk assessments to evaluate the impacts of pollution on aquatic biodiversity, ecosystem functions, and resilience.

Socio-economic studies to assess the socio-economic impacts of water pollution on local communities, livelihoods, and public health.

Evaluation of alternative water sources, treatment technologies, and sustainable practices for improving water quality and reducing pollution risks.

**Contribution to Knowledge and Practical Applications**

This study contributes to the existing body of knowledge on water quality assessment, pollution management, and environmental health in urban river systems. The findings have practical implications for policy development, management practices, and public health interventions aimed at protecting water resources and promoting sustainable development. The study's outcomes can inform decision-makers, stakeholders, and researchers in implementing evidence-based strategies for mitigating pollution impacts and safeguarding environmental and human well-being.

In conclusion, addressing water pollution and ensuring clean water resources are essential for sustainable development, environmental conservation, and public health. Effective management strategies, informed by scientific research and stakeholder engagement, are key to achieving these goals and ensuring a healthy and resilient environment for present and future generations.

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