

**ASSESSMENT OF HEAVY METALS ASSOCIATED WITH ARTESIAN WELL
WATER IN IKPOBA SLOPE, BENIN CITY**

BY

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**AN UNDERGRADUATE THESIS SUBMITTED TO THE DEPARTMENT OF
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CERTIFICATION

This is to certify that this research titled “**ASSESSMENT OF HEAVY METALS ASSOCIATED WITH ARTESIAN WELL WATER IN IKPOBA SLOPE, BENIN CITY**” was carried out by **UWABOR ANDREW CHUKWUMA** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfillment 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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DECLARATION

I, **UWABOR ANDREW CHUKWUMA** declares that “**ASSESSMENT OF HEAVY METALS ASSOCIATED WITH ARTESIAN WELL WATER IN IKPOBA SLOPE, BENIN CITY**” 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.

UWABOR ANDREW CHUKWUMA
Student

DATE

DEDICATION

This project work is dedicated to God Almighty for His guidance and protection during this project.

I also want to dedicate this report to my beloved parents, Mr and Mrs Lucky Uwabor for their unwavering support, prayers, love and financial assistance throughout my academic journey.

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ABSTRACT

This study assessed the levels of heavy metal contamination in artesian well water in Ikpoba Slope, Benin City, Nigeria. A community dependent on shallow artesian well water for essential domestic needs. Water samples from eight artesian wells (well sample 1–8) were analyzed for heavy metals using Atomic Absorption Spectroscopy (AAS). Lead concentrations ranged from 0.008 ± 0.0001 mg/L in well 7 to 0.015 ± 0.002 mg/L in well 8, with well 2 (0.013 ± 0.001 mg/L), 5 (0.013 ± 0.0004 mg/L), and 8 (0.015 ± 0.002 mg/L) exceeding WHO (2011) and NSDWQ (2007) recommended permissible limit of 0.01 mg/L. While chromium ranged from 0.017 ± 0.001 mg/L in well 8 to 0.037 ± 0.002 mg/L in well 4, iron from 0.017 ± 0.0003 mg/L in well 1 to 0.264 ± 0.002 mg/L in well 3, copper from 0.019 ± 0.001 mg/L in well 3 to 0.038 ± 0.001 mg/L in well 7, and manganese from 0.012 ± 0.001 mg/L in well 8 to 0.018 ± 0.001 mg/L in well 7. They were all within WHO (2011) and NSDWQ (2007) recommended permissible limits. Cadmium was below the detection limit across all well samples. These findings offer critical data for public health interventions and sustainable water management in Ikpoba slope.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background of the Study

Artesian well water is an important source of drinking water for many people, especially in areas where tap water is not available. In Nigeria, many communities rely on artesian wells, which are wells that tap into confined aquifers where water is under pressure, causing it to rise naturally toward the surface without pumping. These wells are common in peri urban areas like ikpoba slope in Benin, Edo state, where people use them for drinking, cooking and other domestic activities. However, these wells are often shallow, making them easily contaminated by harmful substances like heavy metals. Heavy metals are dangerous because they can cause serious health problems, including gastrointestinal disorder, kidney damage, and even cancer if consumed over time (Obasi et al., 2020).

Ikpoba slope is a growing area with many activities like small scale industries, farming, and waste dumping, which can pollute groundwater with heavy metals. For example, chemicals from factories, fertilizers from farms, or waste from improper disposal can leak into the soil and reach the wells (Galadima et al, 2011). Rainfall during the raining season intensify this issue by washing heavy metals from the soil into the groundwater (Egbueri, 2020). Studies in other parts of Nigeria, like Niger Delta researched by Aladeboyeje et al., (2025), have shown that heavy metals in groundwater can exceed safe limit set by the World Health Organization (WHO), making the water unsafe for drinking.

1.2 Research Problem

The main problem is that we do not know how much heavy metal pollution is in the artesian well water in Ikpoba slope, Benin City. Many people in this area depend on these wells for drinking

water, but the water may be contaminated with heavy metals due to nearby activities. Drinking contaminated water can cause serious health issues, especially for children and older adults who use the water every day (Akudinobi et al., 2020). Without clear information about the heavy metals in these wells, it is hard to know how to protect the community or make the water safe for use.

1.3 Aim and Objectives

The aim of this study is to find out the levels of heavy metals in artesian well water in ikpoba slope, Benin City. The specific objectives are to

1. Measure the amount of heavy metals; Lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), copper (Cu) and manganese (Mn), in water samples from artesian wells in ikpoba slope, Benin City.
2. To compare the heavy metal levels in the well water with limits set by recommended guidelines and standards such as the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) to know if the water is safe.

1.4 Importance of the Study

This study is important because it will help us understand if the artesian well water in ikpoba slope is safe to drink. Many residents rely on these artesian wells, but heavy metal pollution can make the water unsafe. By finding out the quantity of heavy metal in the water, this study will provide information to help the government and community leaders to take action, such as treating the water or identifying and stopping the pollution sources in that area.

1.5 Scope of the Study

This study will focus on several key aspects to comprehensively investigate the levels of heavy metal contamination in artesian well water in Ikpoba slope, Benin City. The study will begin with

a detailed review of existing literature on artesian wells, heavy metal contamination, properties and characteristics of heavy metals and their associated health and environmental impacts. The study will examine six specific heavy metals which include Lead (Pb), Cadmium (Cd), Chromium (Cr), Iron (Fe), Copper (Cu), and Manganese (Mn), which were selected due to their prevalent and potential risks in shallow groundwater systems. This study will outline the methodology used in collecting and analyzing water samples from artesian wells across Ikpoba slope and detail the laboratory techniques used to measure heavy metal concentrations. Additionally, the study will compare the measured heavy metals levels with recommended guidelines and standards to assess the safety of these artesian well water for domestic use.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Artesian wells and Heavy Metal Contamination

An artesian well is a well that taps into a confined aquifer where water is under pressure from surrounding impermeable layers, such as clay or rock, causing the water to rise naturally toward the surface without the need for mechanical pumping. This natural pressure makes artesian wells a good option in regions where modern drilling technology or tap water systems are often unavailable or too costly. However, their shallow depth and proximity to the surface make them highly vulnerable to contamination, unlike deeper boreholes that access more protected aquifers. The vulnerability of artesian wells to contamination is a significant concern, particularly for heavy metal pollution. Egbueri (2020), highlights that shallow wells are more likely to be polluted by pollutants such as heavy metals because their proximity to the surface allows contaminants from human activities to seep into the aquifer. Heavy metals, such as iron, cadmium, copper, lead, manganese, and chromium, can enter groundwater through various pathways, including agricultural runoff and leachates from improper waste disposal. In Ikpoba Slope, rapid urbanization and associated human activities increase the risk of contamination. For example, factories may dispose of waste containing lead or chromium, which can leach into the soil and eventually reach the aquifer. Similarly, agricultural practices, such as the use of fertilizers and pesticides, introduce metals like cadmium and copper into the soil, which can migrate to shallow aquifers during rainfall.

Poor waste management practices further intensify the contamination risks faced by artesian wells. Open dumpsites and informal waste disposal are common due to the lack of proper waste management infrastructure. These sites often contain materials like batteries, electronic waste, and

household refuse, which release heavy metals into the environment. According to Obasi et al., (2020), leachates from such dumpsites can infiltrate the soil and contaminate groundwater. Additionally, seasonal rainfall, which is heavy in Benin City, can worsen the problem by washing pollutants from the surface into the groundwater, further compromising the safety of artesian wells.

2.2 Properties and Characteristics of Heavy metals in artesian well water

Heavy metals are elements with high atomic weights and densities, which distinguish them from other environmental contaminants. The persistence of these heavy metals in the environment is a key factor that makes them a significant threat to groundwater quality. Unlike organic pollutants, which can be broken down by natural processes, heavy metals remain in the environment for long periods, accumulating in aquifers and increasing the risk of exposure through drinking water (Ibe et al., 2021).

2.2.1 Iron

Iron naturally exists in the earth's crust and is dissolved from geological formations like rocks and soil by rainwater and snowmelt as they seep into the ground. Artesian wells which taps into a deep, pressurized aquifers, can draw this naturally iron rich groundwater to the surface. Corrosion of iron and steel pipes can also add to the iron content. Iron in artesian well water, is typically found in its dissolved soluble state (ferrous iron), as the water is sealed from oxygen deep underground. When this water is exposed to the air, the iron oxidizes, transforming into an insoluble, visible particle (ferric iron). In water, high levels of iron can cause a metallic taste, making water unpleasant to drink (Usese et al., 2015) and can cause staining of clothes and household fixtures. Iron In water does not usually present a health risk. The body needs iron to transport oxygen in the blood. Most iron comes from food, as the body cannot easily absorb iron from water. Iron may present some concern if bacteria have entered into a well, as some harmful organisms require iron

to grow. The presence of iron in water makes it difficult to get rid of harmful bacteria in water. There are three common forms of iron found in well water, each with distinct properties

Ferrous Iron (clean water iron): This is the soluble form of iron that is dissolved in water. The water appears clear when it is first drawn from the well. Upon exposure to oxygen, it oxidizes and leaves behind a reddish- brown sediment

Ferric Iron (red water iron): This is the insoluble, oxidized form of iron. It appears as visible red, yellow, or rusty brown particles suspended in the water.

Iron bacteria: These are harmless microorganisms that feed on iron. They create a slimy, foul smelling biofilm that can appear as red, brown, or yellow sludge in plumbing or toilet tanks.

2.2.2 Cadmium

Cadmium is a highly toxic heavy metal that poses significant health risks even at low concentrations. The presence of cadmium cannot be detected by sight, taste or smell, making regular water testing the only way to confirm its presence. It typically exists as the divalent ion, Cd^{2+} . Unlike other metals, its behavior in groundwater makes it less likely to be filtered out naturally, especially in acidic conditions. Cadmium is one of the most mobile heavy metals in water, instead of reliably binding to soil particles, it can remain dissolved in the water, allowing it to migrate through the aquifer.

Cadmium readily forms dissolved complexes with both inorganic and organic ligands, including chloride and sulfates. This complex formation further prevents it from being removed by natural sorption and precipitation processes. It is released into the environment through natural materials in rocks such as acidic ores like sphalerite (ZnS) and pyrite (FeS_2), and phosphate rocks. The natural weathering of these materials can release cadmium into shallow artesian wells. Human

activities such as agriculture, industrial activities and waste disposal also release cadmium into the environment.

2.2.3 Copper (Cu)

Copper (Cu) is an essential trace element for human health, playing a role in enzyme function, but it becomes toxic at high concentrations. High copper levels in artesian well water are typically not a natural geological condition but rather a result of corrosion from acidic water interacting with copper plumbing as well as from pesticides used in agriculture. The primary characteristic properties of copper in this water are its aesthetic effects. At high levels, copper can cause a bitter metallic taste in water, the taste threshold can vary between individuals but is generally noticeable at concentrations 1-2 mg/L. High copper levels also result in blue green stains on plumbing fixtures.

2.2.4 Lead (Pb)

Lead is one of the most toxic heavy metals with no safe level of exposure, particularly for children. Lead cannot be seen, tasted and has no smell in water. The only way to confirm its presence is through proper water testing. Water temperature, acidity (low pH) and mineral content can all influence the rate at which lead leaches into the water. Lead contamination in artesian well water most often occurs not from the natural groundwater itself, but from the well's construction.

2.2.5 Manganese (Mn)

Manganese is a naturally occurring metal found in rocks and soils, but it can be released into groundwater through industrial and mining activities. Manganese affects the taste and color of water, making it less suitable for domestic use. Artesian wells are vulnerable to contamination in areas where natural soil composition may contribute to manganese levels. The most common sign of high manganese levels is staining on plumbing fixtures, laundry and dishes. Unlike the reddish

brown stains caused by iron, manganese leaves a brownish black or dark gray stain. The presence of manganese can impart an unpleasant metallic or bitter flavor to the water. While less common, some unpleasant odors, including a rotten egg smell (often accompanying hydrogen sulphide), can occur alongside manganese. Lastly, as the manganese oxidizes, the water may turn black or dark brown. Black particles and slimy black deposits can also accumulate in sinks and toilet tanks.

2.2.6 Chromium (Cr)

Chromium is commonly released from industrial processes like electroplating, leather tanning, and textile manufacturing. In artesian well water, chromium is not detectable by taste or odor, regardless of its form. It primarily exists in two forms: Trivalent chromium (Cr(III)) and hexavalent chromium (Cr(VI)), with hexavalent chromium (Cr(VI)) being the most toxic and a known carcinogen (Wise et al., 2018). The properties and characteristics of chromium in the water depend heavily on which of these forms is present, as they differ significantly in toxicity, solubility, and mobility. Chromium is a naturally occurring metallic element found in rocks and soils. In artesian wells, the chromium can come from the erosion and weathering of chromium rich minerals in the rock formations. The ratio of Cr(III) to Cr(VI) is determined by the water's geochemistry, including its oxidation and reduction potential (redox), pH, and the presence of other compounds.

Trivalent Chromium (Cr(III)): in less oxygenated (reducing) groundwater, Cr(III) is the dominant and most stable form. Under neutral pH, it is generally insoluble and immobile, tending to bind to mineral surfaces or precipitate out of the water.

Hexavalent Chromium (Cr(VI)): In oxygenated (oxic) or alkaline well water, Cr(VI) is more prevalent. It is highly soluble and mobile, meaning it can easily dissolve and travel through the groundwater.

2.3 Health and Environmental Impacts of Heavy Metals

Heavy metals in drinking water can cause a wide range of health problems, from acute symptoms that appear quickly to chronic conditions that develop over time due to prolonged exposure. Heavy metals naturally occur in the environment and are vital for survival, but they may become hazardous when they accumulate in organisms (Hazrat et al., 2019).

Each metal in this study; iron, cadmium, copper, lead, manganese, and chromium has unique health impacts, making their presence in artesian well water a pressing concern for the Ikpoba Slope community.

Iron, while naturally occurring and less toxic than other heavy metals, can still cause health and aesthetic problems when present in high levels in drinking water. Excessive iron consumption can lead to stomach pain, vomiting, and damage to the digestive system, particularly if consumed over time (Talwer et al., 2017).

Cadmium is one of the most toxic heavy metals, with severe health consequences even at low concentrations. It accumulates in the kidneys, leading to kidney damage (NSDWQ), bone disease, and an increased risk of cancer (WHO). Cadmium's ability to build up in the body over time makes it particularly dangerous for rural communities, where long-term exposure through contaminated well water is likely. For example, residents who consume cadmium-contaminated water daily may face serious health risks without immediate symptoms, making regular monitoring critical. Children and pregnant women are especially vulnerable, as cadmium can affect fetal development and cause developmental issues (Vahter et al., 2007).

Copper, while essential in small amounts for human health, becomes harmful at high concentrations. Excessive copper in drinking water can cause nausea, vomiting, gastrointestinal disorder (NSDWQ) and, in severe cases, liver damage, particularly in children or individuals with

pre-existing liver conditions. High copper levels not only pose health risks but also affect the taste and usability of water, adding to the challenges of accessing safe drinking water.

Lead is toxic to the human body when exposed to amounts greater than the optimum. It can cause cancer, interference with vitamin D, affect mental development in infants, and toxic to the central and peripheral nervous system (NSDWQ). Children are at higher risk of lead poisoning.(Loh et al., 2016).

Manganese, another naturally occurring metal, can also be harmful when present in high concentrations in drinking water. It affects the nervous system, causing tremors, memory problems, and developmental delays, especially in children. Although manganese is required for a variety of physiological activities, excessive consumption results in substantial toxicity (Loranger and Zayed, 1995, O'Neal and Zheng, 2015).

Chromium, particularly in its hexavalent form (Cr (VI)), is a known carcinogen and one of the most dangerous heavy metals in groundwater (Wise et al., 2018). It can cause skin irritation, lung cancer, and kidney damage when consumed in contaminated water (WHO). The toxicity of hexavalent chromium makes it a priority for monitoring, as even small amounts can have devastating health effects over time.

The environmental impacts of heavy metals are equally concerning, as they can disrupt aquatic ecosystems and affect biodiversity. Heavy metals that accumulate in shallow groundwater can flow into connected water bodies, such as rivers and streams harming fish, plants, and other organisms (Ali et al., 2013). Manganese is found in various oxidation states in nature. During combustion of methylcyclopentadienyl manganese tricarbonyl (MMT), an additive in gasoline, manganese oxides are emitted into the air which could later enter into water bodies. High manganese levels can also alter the taste and color of water, reducing its suitability for domestic

use and adding to the burden on communities already struggling with limited water access. Copper is recognized as a vital micronutrient for living organisms. It has a role in normal physiological functions of plants, such as formation of chlorophyll, photosynthesis, and carbohydrate and protein metabolism. Copper deficiency alters important metabolic processes, and elevated exposure causes toxicity. (Schwartz et al., 2003). High levels of copper and cadmium can be toxic to aquatic life, leading to reduced biodiversity and disrupted food chains. Cadmium does not have any attributes that are helpful for plant growth and metabolic processes (Hayat et al., 2018).

2.4 Regulatory Standards for Heavy Metals in Water Quality

Regulatory standards for drinking water are established by international and national bodies to guide governments, communities, and water suppliers in maintaining water quality. The World Health Organization (WHO) provides global guidelines through its Guidelines for Drinking-Water Quality, which set maximum allowable concentrations for contaminants, including heavy metals, based on scientific evidence of their health impacts. In Nigeria, the Nigerian Standards for Drinking Water Quality (NSDWQ) established by the Standard Organization of Nigeria (SON) adopts almost similar limits, to ensure the safe quality of drinking water in the country. In Nigeria, where shallow wells and various other water sources are vulnerable to contamination, adherence to these standards is essential to protect residents from the risks of consuming polluted water.

The WHO and NSDWQ have set specific permissible limits for the heavy metals relevant to this study, reflecting their varying levels of toxicity and impact on human health. For iron, the limit is 0.3 mg/L, based on aesthetic quality rather than health concerns, as high iron levels cause a metallic taste, discoloration, and staining of clothes. While iron is less toxic than other metals, exceeding this limit can make water unpalatable and reduce its usability for domestic purposes. Cadmium has a much stricter limit of 0.003 mg/L due to its high toxicity, as it accumulates in the kidneys

and can cause long-term health issues (WHO). Copper is permitted up to 2.0 mg/L because it is essential in small amounts but the NSDWQ has a stricter limit of 1.0 because high levels can affect taste. Lead, one of the most dangerous heavy metals, has a limit of 0.01 mg/L, as even low levels can impair neurological development in children (WHO). Manganese is allowed up to 0.4 mg/L, as excessive levels can lead to health issues and affect water taste. Finally, chromium, particularly in its hexavalent form, has a limit of 0.05 mg/L due to its carcinogenic properties (WHO). These limits are designed to ensure that drinking water does not pose immediate or long-term health risks.

Table 2.5.1: WHO and NSDWQ permissible limits for heavy metals in drinking water

Heavy Metal	WHO permissible limit (mg/L)	NSDWQ (Nigeria) permissible limit (mg/L)
Lead (Pb)	0.01	0.01
Copper (Cu)	2.0	1.0
Chromium (Cr)	0.05	0.05
Cadmium (Cd)	0.003	0.003
Manganese (Mn)	0.4	0.2
Iron (Fe)	0.3 (SMCL*)	0.3 (SMCL*)

SMCL* stands for Secondary Maximum Contaminant Level, meaning the limit is based on aesthetic factors like taste or color rather than health effects.

Water that exceeds these permissible limits is considered unsafe for drinking and may require treatment, such as filtration or chemical removal (Traore et al., 2023), or alternative water sources, such as deeper boreholes or piped water systems. Studies in Nigeria have shown that many groundwater sources, including well water, frequently exceed these regulatory limits, highlighting the need for regular monitoring and assessment. For instance, Aladeboyeje and Olaseeni (2025) conducted a study in Niger Delta and found that groundwater samples near industrial areas had

elevated levels of iron, lead, and chromium, often surpassing WHO and NSDWQ standards. In some cases, lead concentrations exceeded 0.01 mg/L, posing significant health risks to residents. The exceedance of regulatory limits in these studies underscores the urgent need to identify contamination levels in those areas.

2.5 Previous Studies of Heavy metals in Ikpoba Slope

Wangboje and Ekundayo (2013) investigated the concentrations of heavy metals (Cd, Mn, Cu, Fe, Pb, and Cr) in the surface water of the Ikpoba Reservoir. Water samples were randomly collected from four stations within the Reservoir and tested using Atomic adsorption spectroscopy (AAS). Their findings revealed mean concentrations of Cd (0.02 mg/L), Mn (0.026 mg/L), Cu (0.24 mg/L), Fe (5.60 mg/L), Pb (0.07 mg/L), and Cr (0.033 mg/L), with Cd, Fe and Pb, exceeding the World Health Organization (WHO) maximum permissible levels for drinking water. The direct implication of this finding, is that water from the reservoir is unsafe for human consumption due to heavy metal contamination. It has therefore become imperative for regulatory authorities to closely monitor the Ikpoba water sources.

The level of monitoring is expected to generate relevant data that would be needed to implement better management strategies which would alleviate the present negative implications and safeguard public health and resources for the ikpoba community. Given the close proximity of the artesian wells to the reservoir, the artesian well water is likely to face comparable contamination risks.

While the study by Wanboje and Ekundayo focused on surface water, shallow artesian wells in Ikpoba Slope are vulnerable, and also likely to face similar heavy metal pollution due to seepage, runoff, and leaching from contaminated surface water and soil.

2.6 Gaps in Existing Literature

Research on heavy metal contamination in shallow well water has provided valuable insights into the impacts and management of polluted water sources in Nigeria. Studies such as Buba and Maina, (2020) in Abuja and Kayode in Ogun state (2019), investigated elevated levels of heavy metals like iron, cadmium and chromium respectively in shallow well water. These studies have been critical in raising awareness about the risks of heavy metal pollution in shallow well water,. However, a common limitation in the existing literature is the narrow focus on a few heavy metals, typically those with the most severe health impacts, such as chromium and cadmium. Buba and Maina (2020) primarily investigated cadmium, iron and chromium in well water in Jiwa village, Abuja. Kayode et al, (2019) examined chromium and copper in well water in Ogun State but did not include iron or lead, potentially missing other contaminants affecting water quality. This selective approach, while useful for understanding specific contaminants, fails to capture the full spectrum of heavy metal pollution, as multiple metals can coexist in groundwater and collectively pose risks to human health and the environment.

Heavy metals such as iron, cadmium, copper, lead, manganese, and chromium each have unique properties and health implications, and their combined presence can exacerbate contamination risks. When these metals are present together in artesian well water, their combined impact may be more severe than that of any single metal. By focusing on only one or two metals, previous studies may underestimate the overall contamination risk, leaving communities like Ikpoba Slope who depend on well water for their daily domestic use, vulnerable to unrecognized threats.

The comprehensive approach of this study also contributes to public health and environmental management by providing data that can inform policy and interventions. In Nigeria, where many communities lack access to centralized water supply systems, artesian wells are a critical resource

due to their ability to provide water without pumping, yet they are rarely monitored for a wide range of contaminants. By assessing six heavy metals, this study will offer a more holistic view of contamination risks, helping local authorities prioritize mitigation measures, such as water treatment systems or restrictions on pollution sources. For example, identifying high iron or manganese levels could prompt the installation of filtration systems to improve water quality.

By including iron, cadmium, copper, lead, manganese, and chromium, this study ensures a more thorough assessment, capturing both health-based and aesthetic impacts of heavy metals.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Sample Collection

The study was longitudinal and involved eight cylindrical shallow domestic artesian wells, each less than 20 meters deep located at Ikpoba slope, Benin City. The samples were randomly collected from eight wells. The water was not tested directly in the wells. Instead, 2L samples were taken in PET bottles from each well. Before collection, bottles were treated with standardized sodium hypochlorite solution then rinsed three times with well water to ensure the bottles are conditioned to the well water properties, removing any residual sodium hypochlorite solution or contaminants from the bottle. So that the collected sample accurately represents the well water composition. Samples were taken to the lab and processed within 24 hours of collection.

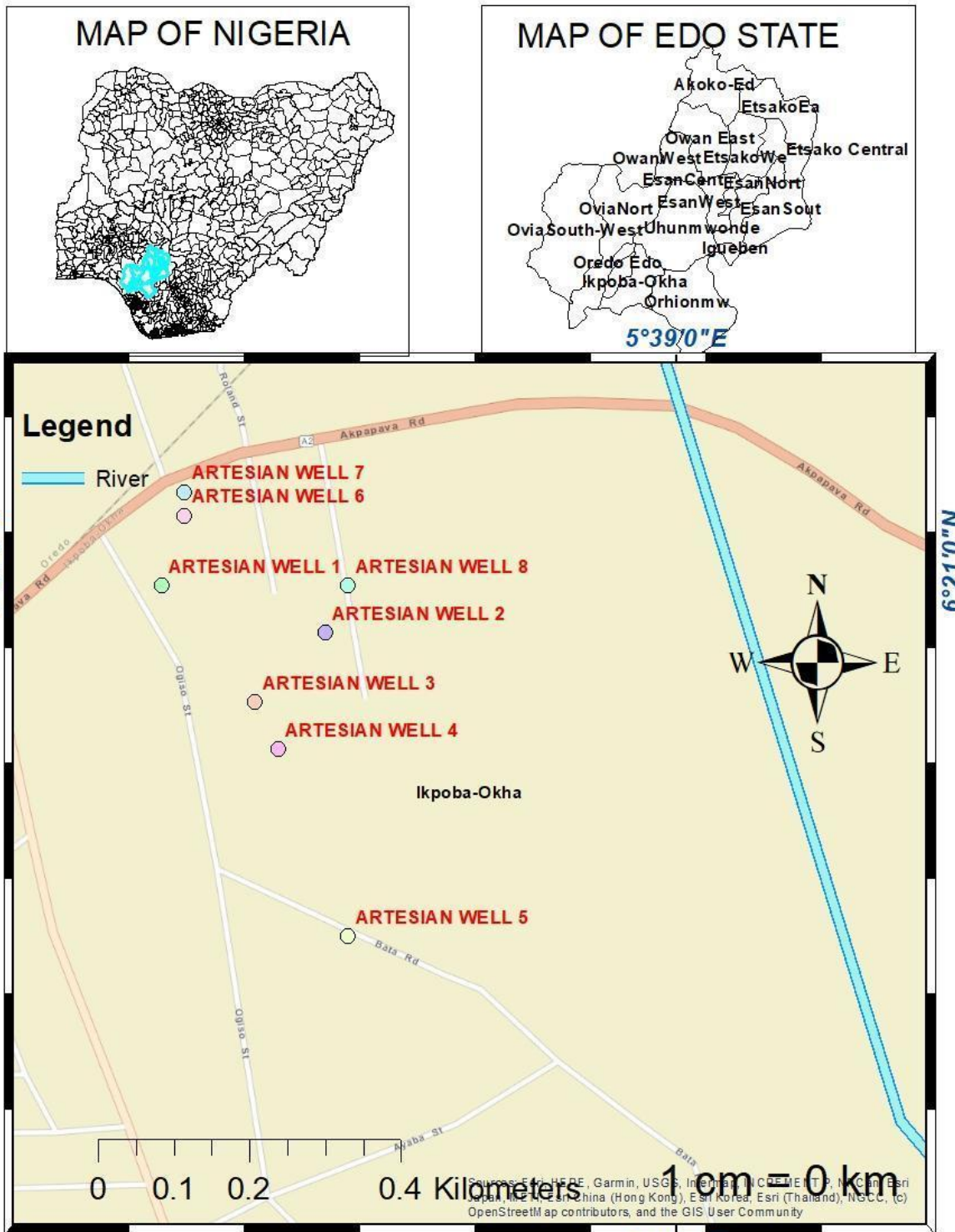


Fig 3.1.1: Map of Sample Collection Area

3.2 Heavy Metals Determination of Samples

The Association of Analytical Chemists (AOAC) methodologies were used to determine the concentration of heavy metals in water samples collected from Artesian wells located at Ikpoba slope, Benin city.



Fig 3.2.1: Artesian Well Water Samples

3.3 Working Principle of Atomic Absorption Spectroscopy

Atomic Absorption Spectroscopy (AAS) is an analytical technique used to measure a wide range of elements in materials such as metals, water, pottery, whole blood, serum, plants, glass etc. The sample is accurately weighed and then dissolved, often using strong acids. The resulting solution is sprayed into the flame of the instrument and atomized. Light of a suitable wavelength of a particular element is shone through the flame, and some of this light is absorbed by the atoms of the sample. The amount of light absorbed is proportional to the concentration of the element in the

solution, and hence in the original object. Measurements are made separately for each element of interest in turn to achieve a complete analysis of an object, and thus the technique is relatively slow to use. However it is very sensitive and it can measure trace elements down to the part per million levels as well being able to measure elements present in minor and major amounts.

3.4 Digestion of the Samples

After cleaning and drying the equipment, 10% aqua-regia (HCl, HNO₃ ratio: 3:1) was used to rinse it. In a clean, 250 ml conical flask, 5 ml of pure nitric acid (HNO₃), and 100 ml of the preserved sample were added. The mixture was cooked on a hot plate inside the fume cupboard until it was almost dry. A further addition of 10 ml of distilled deionized water and 1 ml of hydrogen peroxide was added. The digesting vessel was covered with a crucible and heated for a further 5 minutes. After cooling, the digest was filtered through Whatman No. 42 filter paper into a 50 mL volumetric flask, with the volume being made up of distilled deionized water. It was then labeled and analyzed for the parameter(s) of interest. All samples and blank were treated in the same way.

Blank was prepared and processed identically to the samples to account for any background contamination or interferences from reagents, equipment, or the environment.

3.5 Determination of Heavy Metals Concentrations

After digestion, the samples were tested for lead (Pb) at 283.3 nm, cadmium (Cd) at 228.8 nm, chromium (Cr) at 357.9nm, iron (Fe) at 248.3, copper (Cu) at 324.8 nm, and manganese (Mn) at 279.5 nm using the Perking 3300 AAS. The analytical conditions for the standard and blank assays for each metal were the same.

The AAS readout, sample volume acquired for analysis, and extract volume were all used to calculate the metal content in each sample.

$$\text{Metal (mg/L)} = \frac{(\text{The result} - \text{Blank}) \times \text{Vol. of extract}}{\text{Vol. of Sample taken}}$$

Result: The measured concentration of heavy metal in the extract, as determined by AAS.

Blank: The measurement from a blank sample (containing no analyte or a negligible amount) used to correct for background noise or contamination in the analytical process.

Volume of extract: The total volume (in liters or mL) of the solution prepared for analysis after extracting or digesting the sample.

Volume of sample taken: The volume (in liters or mL) of the original sample used for the analysis.

CHAPTER FOUR

RESULTS

4.1 Heavy Metals Concentrations

This section presents the results of the heavy metals analysis conducted on eight artesian wells in Ikpoba slope, Benin City. Samples were tested for the concentrations of heavy metals; Lead (Pb), Cadmium (Cd), Chromium (Cr), Iron (Fe), Copper (Cu), and Manganese (Mg).

4.1.1 Lead (Pb)

The lead concentrations in the well water samples ranged from 0.008 ± 0.0001 mg/L in well 7 to 0.015 ± 0.002 mg/L in well 8, well 8 (0.015 ± 0.002 mg/L) recorded the highest lead concentration, while well 7 (0.008 ± 0.0001 mg/L) had the lowest concentration. well 2 (0.013 ± 0.001 mg/L), 5 (0.013 ± 0.0004 mg/L) , and 8 (0.015 ± 0.002 mg/L) exceeded the WHO and NSDWQ permissible limit of 0.01 mg/L for lead in drinking water. While well 1 (0.008 ± 0.001 mg/L), 3 (0.008 ± 0.001 mg/L), 4 (0.009 ± 0.0002 mg/L), 6 (0.009 ± 0.0002 mg/L), and 7 (0.008 ± 0.0001 mg/L) were within the permissible limit.

Table 4.1.1 Mean \pm SD lead (Pb) levels in Artesian wells (mg/L)

Wells	Lead Concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	0.008 ± 0.001	0.01	0.01	Safe
2	0.013 ± 0.001	0.01	0.01	Unsafe
3	0.008 ± 0.001	0.01	0.01	Safe
4	0.009 ± 0.0002	0.01	0.01	Safe
5	0.013 ± 0.0004	0.01	0.01	Unsafe
6	0.009 ± 0.0002	0.01	0.01	Safe
7	0.008 ± 0.0001	0.01	0.01	Safe

8	0.015 ± 0.002	0.01	0.01	Unsafe
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4.1.2 Chromium (Cr)

Chromium concentrations ranged from 0.017 ± 0.001mg/L in well 8 to 0.037 ± 0.002 mg/L in well 4. All samples were well below the WHO and NSDWQ permissible limit of 0.05 mg/L for chromium, indicating safe status with drinking water standards.

Table 4.1.2: Mean ± SD Chromium (Cd) levels in Artesian wells (mg/L)

Wells	Chromium Concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	0.034 ± 0.001	0.05	0.05	Safe
2	0.036 ± 0.001	0.05	0.05	Safe
3	0.026 ± 0.002	0.05	0.05	Safe
4	0.037 ± 0.002	0.05	0.05	Safe
5	0.027 ± 0.003	0.05	0.05	Safe
6	0.033 ± 0.001	0.05	0.05	Safe
7	0.025 ± 0.002	0.05	0.05	Safe
8	0.017 ± 0.001	0.05	0.05	Safe

4.1.3. Iron (Fe)

Iron concentrations showed considerable variation, ranging from 0.017 ± 0.0003 mg/L in well 1 to 0.264 ± 0.002 mg/L in well 3. All samples were below the WHO and NSDWQ permissible limit of 0.3 mg/L for iron, which is set based on aesthetic considerations such as taste and water discoloration. These results suggest that iron levels in the water samples are unlikely to pose aesthetic or health concerns.

Table 4.1.3: Mean \pm SD Iron (Fe) levels in Artesian wells (mg/L)

Wells	Iron Concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	0.017 \pm 0.0003	0.3	0.3	Safe
2	0.195 \pm 0.006	0.3	0.3	Safe
3	0.264 \pm 0.002	0.3	0.3	Safe
4	0.148 \pm 0.001	0.3	0.3	Safe
5	0.136 \pm 0.003	0.3	0.3	Safe
6	0.157 \pm 0.002	0.3	0.3	Safe
7	0.095 \pm 0.001	0.3	0.3	Safe
8	0.187 \pm 0.002	0.3	0.3	Safe

4.1.4 Copper (Cu)

Copper concentrations varied from 0.019 \pm 0.001 mg/L in well 3 to 0.038 \pm 0.001 in well 7 mg/L. All samples were significantly below the WHO permissible limit of 2.0 mg/L and the NSDWQ permissible limit of 1.0 mg/L for copper.

Table 4.1.4: Mean \pm SD Copper (Cu) levels in Artesian wells (mg/L)

Wells	Copper Concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	0.025 \pm 0.002	2.0	1.0	Safe
2	0.022 \pm 0.001	2.0	1.0	Safe
3	0.019 \pm 0.001	2.0	1.0	Safe
4	0.027 \pm 0.001	2.0	1.0	Safe
5	0.022 \pm 0.001	2.0	1.0	Safe
6	0.037 \pm 0.001	2.0	1.0	Safe

7	0.038 ± 0.001	2.0	1.0	Safe
8	0.026 ± 0.001	2.0	1.0	Safe

4.1.5 Manganese (Mn)

Manganese concentrations ranged from 0.012 ± 0.001mg/L in well 8 to 0.018 ± 0.001 in well 7 mg/L. All samples were well below the WHO permissible limit of 0.4 mg/L and the NSDWQ permissible limit of 0.2 mg/L for manganese. These results confirm safe status with drinking water standards.

Table 4.1.5: Mean ± SD Manganese (Mn) levels in Artesian wells (mg/L)

Wells	Manganese Concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	0.013 ± 0.001	0.4	0.2	Safe
2	0.015 ± 0.001	0.4	0.2	Safe
3	0.016 ± 0.001	0.4	0.2	Safe
4	0.014 ± 0.001	0.4	0.2	Safe
5	0.014 ± 0.001	0.4	0.2	Safe
6	0.014 ± 0.0002	0.4	0.2	Safe
7	0.018 ± 0.001	0.4	0.2	Safe
8	0.012 ± 0.001	0.4	0.2	Safe

4.1.6 Cadmium (Cd)

Cadmium concentrations were consistently below the detection limit across all eight wells, indicating no measurable presence of cadmium in the water samples.

Table 4.1.6: Cadmium (Cd) levels in Artesian wells (mg/L)

Wells	Cadmium concentration	WHO Permissible Limits	NSDWQ Permissible Limits	Status
1	BDL	0.003	0.003	Safe
2	BDL	0.003	0.003	Safe
3	BDL	0.003	0.003	Safe
4	BDL	0.003	0.003	Safe
5	BDL	0.003	0.003	Safe
6	BDL	0.003	0.003	Safe
7	BDL	0.003	0.003	Safe
8	BDL	0.003	0.003	Safe

CHAPTER FIVE

DISCUSSION

5.1 Discussion

The findings of this study, provides critical insights into heavy metal contamination in artesian well water in Ikpoba Slope, Benin City, assessing implications for public health and water quality management. The analysis of eight water samples from well samples 1–8 revealed varying concentrations of lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), copper (Cu), and manganese (Mn). These concentrations were compared with World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) permissible limits to evaluate the safety of the water for domestic use.

Lead concentrations ranged from 0.008 ± 0.0001 in well sample 7 mg/L to 0.015 ± 0.002 mg/L in well sample 8. Sample points 2 (0.013 ± 0.001 mg/L), 5 (0.013 ± 0.0004 mg/L), and 8 (0.015 ± 0.002 mg/L) exceeded the WHO and NSDWQ permissible limit of 0.01 mg/L, indicating unsafe status. The elevated lead levels in these wells are likely due to the shallow nature of the artesian wells, which allows surface pollutants, to infiltrate into it. Sample points 1 (0.008 ± 0.001 mg/L), 3 (0.008 ± 0.001 mg/L), 4 (0.009 ± 0.0002 mg/L), 6 (0.009 ± 0.0002 mg/L), and 7 (0.008 ± 0.0001 mg/L) were within safe limit, suggesting these locations are farther from pollution sources or less affected by surface infiltration, highlighting spatial variation in contamination risk.

Chromium concentrations ranged from 0.017 ± 0.001 mg/L in well 8 to 0.037 ± 0.002 mg/L in well 4, all were below the WHO and NSDWQ limit of 0.05 mg/L for chromium. Iron concentrations varied from 0.017 ± 0.0003 mg/L in well 1 to 0.264 ± 0.002 mg/L in well 3, remaining below the WHO and NSDWQ limit of 0.3 mg/L, indicating no significant issues with taste or discoloration. Copper concentrations, ranging from 0.019 ± 0.001 mg/L in well 3 to 0.038

± 0.001 mg/L in well 7, were well below the WHO (2.0 mg/L) and NSDWQ (1.0 mg/L) limits. Manganese concentrations, ranging from 0.012 ± 0.001 mg/L in well 8 to 0.018 ± 0.001 mg/L in well 7, also complied with WHO (0.4 mg/L) and NSDWQ (0.2 mg/L) limits. The presence of these metals, even at low levels, may accumulate over time if not monitored.

Cadmium concentrations were below the detection limit across all samples, fully complying with the WHO and NSDWQ limit of 0.003 mg/L. This absence indicates minimal influence from cadmium-related sources, in the Ikpoba Slope area. However, ongoing monitoring is necessary, as agricultural activities could introduce cadmium over time, particularly with increased fertilizer use.

The health implications of elevated lead levels are significant, as even low-level exposure can cause chronic issues, including kidney damage, neurological impairments, and developmental delays in children (Obasi and Akudinobi, 2020). The unsafe concentrations of three wells (sample points 2, 5, and 8) underscores the urgency of addressing lead contamination to protect residents relying on these water sources. The safe concentrations of all samples for cadmium, chromium, iron, copper, and manganese is reassuring, but seasonal variations or increased industrial and agricultural activities could elevate these levels, necessitating vigilance (Aladeboyeje and Olaseeni, 2025). Environmentally, heavy metals in artesian wells could migrate to connected water bodies like the Ikpoba River, impacting aquatic life and downstream uses such as irrigation or fishing.

5.2 Recommendation

Regular water quality monitoring is essential. Quarterly testing using atomic absorption spectroscopy, as employed in this study, should be implemented to track heavy metals concentrations, particularly during the rainy season when pollutant mobility increases due to

rainfall (Egbueri, 2020). Local authorities should enforce stricter regulations on waste disposal near these artesian wells, establishing designated collection sites and recycling programs for hazardous materials. Additionally farmers should be educated on using low metal fertilizers and pesticides to reduce copper and cadmium runoff.

The vulnerability of shallow wells, with depths less than 20 meters, highlights the need for alternative water sources (Egbueri, 2020). Investing in deeper boreholes, or developing tap water systems could provide long term safe water supply for Ikpoba slope residents. Community awareness campaigns should encourage boiling or treating well water to reduce health risks. Finally further research is needed to pinpoint specific contamination sources through geospatial mapping of pollution sites, such as dumpsites and industrial areas. This will guide targeted interventions, such as soil remediation or relocating dumpsites, to prevent pollutant from leaching into aquifers. Sustainable water management for Ikpoba slope residents can be achieved if this measures are implemented.

5.3 Conclusion

The presence of elevated lead concentrations in several artesian wells in Ikpoba slope, Benin city, exceeding WHO and NSDWQ limits of 0.01mg/L, possesses significant health risks, including neurological damage and kidney issues, While cadmium, chromium, iron, copper, and manganese concentrations were within safe permissible limits. The risk of future contamination remains due to shallow well vulnerability. Effective strategies, such as regular monitoring and water treatment, are critical to mitigate heavy metal pollution and ensure safe drinking water, for the Ikpoba slope community.

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APPENDIX

Elements	Wavelength (nm)	Flame -Gases	Detection Limit (mg/L, approx.)
Lead (Pb)	283.3	Air - Acetylene	0.01-0.1
Copper (Cu)	324.8	Air - Acetylene	0.001-0.01
Cadmium (Cd)	228.8	Air - Acetylene	0.0005-0.002
Iron (fe)	348.3	Air - Acetylene	0.005-0.02
Manganese (Mn)	279.5	Air - Acetylene	0.002 - 0.01
Chromium (Mn)	357.9	Air - Acetylene	0.005 - 0.02

Table showing Wavelength, Flame gases, and Detection Limits of Heavy Metals

Parameter	unit		
cadmium (Cd)	mg/L	0.003	Toxic to the kidney
Chromium (Cr)	mg/L	0.05	Cancer
Copper (Cu)	mg/L	1	Gastrointestinal disorder
Iron (Fe)	mg/L	0.3	none
Manganese (Mn)	mg/L	0.2	Neurological disorder
Lead (Pb)	mg/L	0.01	Cancer, interference with vitamin D, affect mental development in infants, toxic to the central and peripheral nervous systems

Table showing NSDWQ drinking water requirements of inorganic constituents