# EFFECT OF ONSITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF ARTESIAN WELL IN IKPOBA SLOPE AREA OF BENIN CITY, EDO STATE

BY

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

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# CERTIFICATION

This is to certify that this research titled **“EFFECT OF ONSITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF ARTESIAN WELL IN IKPOBA SLOPE AREA OF BENIN CITY, EDO STATE"** by **EMEMA CHRISTOPHER** and presented to the, 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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**PROF. E.T. AISIEN** **DATE**
Head of Department

# DECLARATION

I, **EMEMA CHRISTOPHER** declare that **"EFFECT OF ONSITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF ARTESIAN WELL IN IKPOBA SLOPE AREA OF BENIN CITY, EDO STATE"** 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.

**EMEMA CHRISTOPHER**

**DATE**

# DEDICATION

This research is dedicated to Almighty God for His divine guidance and grace throughout this study. It is also dedicated to my family for their unwavering love, prayers, and encouragement, as well as to my supervisor and lecturers for their invaluable mentorship. Finally, it is dedicated to all scholars and professionals working to safeguard water quality and environmental health. May this work serve as a modest contribution to the ongoing effort to ensure access to clean and sustainable water resources.

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# ABSTRACT

This study assessed how the siting of on-site sanitation facilities influences the chemical and microbial quality of artesian well water in Ikpoba slope area, Benin City. Eight wells (sample locations 1–8) were examined, with separation distances ranging from 7.0 meters (locations 1 and 2) to 15.7 meters (location 4) from nearby sanitation facilities. These distances were compared with the 15 meters minimum standard recommended by the National Environmental Standards and Regulations Enforcement Agency (NESREA). In-situ parameters were taken using a multi-parameter meter. The results showed that all water samples were acidic, with pH values ranging from 4.77 ± 0.03 (location 6) to 6.45± 0.02 (location 3) and other physicochemical parameters such as electrical conductivity (13.67±0.58 µS/cm at location 3 to 697.00 ± 2.65 µS/cm at location 5 ), total dissolved solids (6.67±0.58 mg/L at location 3 to 345.00 ± 1.00 mg/L at location 4), nitrate (0.25±0.03 mg/L at location 2 to 0.87 mg/L at location 8), and total ammonia nitrogen (0.20 ± 0.00 mg/L at location 4 to 1.10 ± 0.01 mg/L location 6 ) were within National Environmental Standards and Regulations Enforcement Agency permissible limits. Microbial analysis using the membrane filtration technique revealed that half of the samples contained fecal coliforms, ranging from $6.67 \times 10^4 \pm 2.89$ CFU/100 mL (location 4 and 7) to $26.7 \times 10^4 \pm 2.89$ CFU/100 mL (location 5), and total coliform counts ranging from $6.67 \times 10^4 \pm 2.89$ CFU/100 mL (location 7) to $28.5 \times 10^4 \pm 0.45$ CFU/100 mL (location 5). Elevated microbial loads were recorded at sites where sanitation systems were located within 5–15 m of wells, suggesting infiltration of fecal waste and increased risk of waterborne diseases.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of Study

Access to safe and reliable water is fundamental to public health, human dignity, and sustainable development. In developing regions, conventional water supply systems are often inadequate, so artesian wells play a crucial role by naturally bringing groundwater to the surface. The depth of wells influences their susceptibility to contamination: shallow wells (less than 15 m) are more vulnerable to pollutants, while deeper wells (over 50 m) are better protected due to longer filtration through soil and rock layers (Hofkes, 1981; WHO, 2019). However, in areas like Edo State with sandy soils, even deeper wells can be susceptible to contamination due to rapid contaminant migration (Ijeoma, 2021).

The depth of the water table strongly influences a well's vulnerability to pollution. In areas where the water table is high, contaminants from surface activities such as pit latrines, septic tanks, refuse dumps, and wastewater infiltration can easily reach groundwater (Howard et al., 2003; Sangodoyin, 1993). This problem is worsened by poor sanitation infrastructure, inadequate waste management, and rapid urbanisation across many Nigerian cities (WHO, 2011).

Onsite sanitation systems such as pit latrines, septic tanks, and pour-flush toilets are common in many urban and peri-urban communities. When these are sited too close to wells, especially where the groundwater table is shallow, they can introduce microbial contaminants (e.g. Escherichia coli and total coliforms) and chemical pollutants (e.g. nitrates, ammonia) into aquifers. These pollutants pose serious health risks, including diarrhoea, cholera, dysentery, typhoid, hepatitis, and methemoglobinemia ("blue baby syndrome") resulting from nitrate poisoning (WHO, 2017a; Gerba *et al*., 2011).

Studies in southern Nigeria highlight persistent water quality issues. For example, a study in Ikpoba-Okha Local Government Area, Edo State, reveal 83.6% of residents rely on boreholes, 9.5% on hand-dug wells, and 63% do not treat their drinking water, exposing them to potential contamination (Omoregie *et al*, 2025). Similarly, research on artesian boreholes in Igbogor, Edo State, detected elevated levels of calcium, iron, bicarbonate, and microbial contaminants such as *Escherichia coli*, total coliforms, and Salmonella (Enomal *et al*., 2024). A broader regional study by Aniekan *et al*. (2023) also reported that many groundwater samples from inland and coastal towns exceeded WHO limits for microbial and heavy metal contamination during both wet and dry seasons.

Ikpoba slope, located in Benin City, Edo State, is a rapidly growing area with a high water table, sandy soil, and increasing population density. These conditions heighten the risk of contamination, especially from sanitation facilities in close proximity to artesian wells. However, there is limited empirical data on how water table depth and proximity of sanitation structures affect the microbial and chemical quality of well water in this locality.

## 1.2 Research Problem

In high water table areas like Ikpoba slope, onsite sanitation facilities situated close to artesian wells may significantly compromise water quality. While awareness of contamination risks exists, there remains a lack of site-specific data quantifying how water table depth and sanitation proximity contribute to pollution. The Nigeria Center for Disease Control (NCDC, 2021) reported 31,425 cholera cases in 2021, many linked to contaminated well water in Edo state. Assessing these factors is essential for effective well water protection and for guiding future urban planning and water safety policies.

## 1.3 Aim and Objectives

Aim: To evaluate the effects of proximity of onsite sanitary facilities on the microbial and chemical quality of artesian well water in Ikpoba slope, Benin City.

1. To determine safe separation distances between wells and onsite sanitation facilities.
2. To determine fecal and total coliform load in artesian well water at varying distances from onsite sanitation facilities.
3. To analyze nitrate and ammonia concentration in artesian well in relation to proximity to sanitation structures.

This study is important as it provides local data on how onsite sanitation facility proximity to artesian well water affects water quality in Ikpoba slope, as many residents depend on untreated artesian well water for domestic use. The findings will support evidence-based interventions, promote community awareness, ensure safe well siting practices and strengthen public health protection.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Concept of Artesian Wells

Artesian wells are groundwater systems that discharge water under natural pressure without the need for mechanical pumping. They occur when groundwater is trapped in a confined aquifer a permeable rock or sediment layer (such as sand, sandstone, or gravel) that is overlain and underlain by impermeable strata known as aquitards or aquicludes (Todd and Mays, 2005). These confining layers generate hydrostatic pressure, forcing water to rise when the aquifer is tapped by a well.

According to Fetter (2001), artesian wells represent an efficient form of groundwater extraction in areas where natural geological confinement creates pressurised aquifers. This process depends on the elevation of the recharge zone, where water infiltrates the aquifer, relative to the discharge point. When the piezometric surface representing the hydraulic head is above the ground level, water flows naturally to the surface.

In developing regions, including Nigeria, artesian wells play a vital role in providing domestic and agricultural water. Their construction is often carried out manually, and the natural pressure reduces the need for mechanical pumps, making them economically viable for low-income communities (UNESCO-IHP, 2015). However, their sustainability depends on proper siting, casing, and protection from surface contamination.

## 2.2 Components of Artesian Wells

Artesian wells operate through interconnected geological and structural elements that facilitate groundwater storage and flow. The main component is the confined aquifer, composed of permeable materials such as sand, sandstone, or gravel that hold water under pressure. This aquifer is bounded by impermeable or semi-impermeable strata known as aquitards which restrict water movement and create the confined conditions necessary for artesian flow (Freeze and Cherry, 1979).

In local contexts, such as Benin City, artesian wells are frequently hand-dug. These wells usually have diameters between 1–5 m and depths ranging from 10–30 m, depending on the water table level and the nature of the subsurface materials (UNESCO-IHP, 2015). The walls are lined with materials like stones, bricks, or clay to prevent collapse and contamination (WaterAid, 2013). The top is reinforced with a raised concrete apron or stone lip and covered to prevent entry of debris or surface runoff.

Water is often drawn manually using ropes and buckets or hand pumps, while the base of the well is lined with gravel or fine sand to filter sediments (UNICEF, 2016). Recharge zones located at higher elevations supply water to the aquifer, creating pressure that determines the piezometric surface. When this surface lies above ground level, water flows naturally without pumping (Asiwaju-Bello *et al.*, 2020.

In Ikpoba slope, these components are influenced by local lithology, rainfall, and land-use patterns, which also determine the vulnerability of wells to pollution from nearby septic systems and runoff.

## 2.3 Factors Affecting Groundwater Quality

Groundwater quality is determined by a combination of natural and anthropogenic factors. Naturally, the chemical composition of groundwater depends on the mineralogy of the aquifer, water-rock interactions, residence time, and the pH and redox conditions within the subsurface (Hem, 1985). High concentrations of elements such as iron, manganese, or fluoride may result from prolonged contact between water and mineral bearing rocks.

Anthropogenic factors significantly influence groundwater quality in urban settings. These include contamination from leaky septic tanks, industrial effluents, agricultural runoff, open dumpsites, and poor well construction practices (WHO, 2017a). In areas with shallow water tables or unprotected wellheads, pollutants easily infiltrate into the groundwater system.

Studies conducted in southern Nigeria have shown elevated levels of nitrate, coliform bacteria, and heavy metals in wells located near waste disposal sites and pit latrines (Erah *et al*., 2002). Such contamination poses severe health risks, including waterborne diseases and chronic metal toxicity.

In Ikpoba slope, the proximity of wells to on-site sanitation systems and the lack of adequate lining or casing materials have been identified as major contributors to groundwater contamination. Therefore, continuous monitoring and proper sanitary protection are essential for maintaining groundwater safety and public health.

## 2.4 Water Table Level

The water table represents the upper boundary of the saturated zone in the subsurface where groundwater pressure equals atmospheric pressure. Its depth varies seasonally and spatially, depending on factors such as precipitation, infiltration capacity, soil type, and rate of groundwater extraction (Domenico and Schwartz, 1990).

In areas like Benin City, where rainfall is seasonal and infiltration is influenced by lateritic soils, the water table fluctuates considerably between the wet and dry seasons. During the wet season, increased recharge raises the water table, while in the dry season, the level drops due to reduced rainfall and continuous water abstraction (Alabi *et al*., 2020).

The elevation of the water table determines the ease of groundwater access and the direction of flow. Shallow water tables increase the risk of contamination from surface sources such as latrines, septic tanks, and waste dumps. Conversely, deeper water tables offer greater protection but may require more energy to access. Understanding water table dynamics is therefore crucial in assessing groundwater vulnerability and planning sustainable extraction in Ikpoba slope.

## 2.5 Groundwater Flow and Recharge

Groundwater flow is governed by Darcy's Law, which states that water movement through porous media is proportional to the hydraulic gradient and the permeability of the material (Darcy, 1856). Flow occurs from regions of higher hydraulic head to lower head within the aquifer system.

Recharge refers to the process by which surface water infiltrates into the ground to replenish the aquifer. It can occur directly through precipitation or indirectly via infiltration from rivers, lakes, or irrigation return flows (Freeze and Cherry, 1979). The recharge rate depends on factors such as rainfall intensity, soil permeability, vegetation cover, and land use.

In humid regions like southern Nigeria, recharge is mainly seasonal, occurring during the rainy period (April–October). However, urbanization and the proliferation of impervious surfaces reduce infiltration, leading to diminished recharge and lower groundwater sustainability (Omoregie, 2025).

At Ikpoba slope, recharge occurs predominantly through infiltration of rainfall and seepage from the Ikpoba River. However, improper waste disposal and poor sanitation practices in the recharge zones increase the risk of contamination entering the aquifer.

## 2.6 Potential Pollutants Associated with On-site Sanitation Facilities

On-site sanitation systems such as pit latrines, septic tanks, and soakaway pits are the most prevalent forms of sanitation in developing regions where sewerage infrastructure is limited (Graham and Polizzotto, 2013). While these systems provide cost effective solutions, they also represent significant threats to groundwater quality when located too close to water sources. Contaminants from these systems, including nitrates, ammonia, and fecal bacteria, can migrate through the soil into shallow aquifers, especially in regions with high water tables or sandy soils (Yapo *et al*., 2014).

The infiltration of leachate from poorly designed or maintained sanitation systems is one of the leading causes of groundwater pollution in sub-Saharan Africa. Studies across Nigeria and East Africa have shown that groundwater contamination levels are strongly correlated with the proximity of wells to latrines and dumpsites (Texas Groundwater Protection Committee, 2000). When these facilities are not adequately distanced from wells, pollutants such as fecal coliforms, nitrates, and ammonia often exceed permissible limits for drinking water as recommended by the World Health Organization (WHO, 2017b).

### 2.6.1 Fecal Matter Contamination

Fecal contamination is a direct indicator of the infiltration of human or animal waste into groundwater systems. The presence of fecal coliform bacteria, particularly Escherichia coli (E. coli), suggests contamination from fecal matter and potential co-occurrence of pathogenic organisms such as Salmonella spp., Shigella spp., Vibrio cholerae, and enteroviruses (WHO, 2017a).

Chauque et al. (2012) observed that wells exhibited higher fecal contamination during the rainy season, with 84.4% of samples showing fecal coliform counts up to 139 cfu/100mL, compared to only 42.4% in the dry season. Similar findings were reported by Ishaku (2011), who noted that poorly sited pit latrines and septic tanks significantly increased contamination risks. Factors influencing fecal bacteria transport include soil permeability, aquifer depth, and precipitation intensity (Atherholt *et al*., 2017). In high water table areas such as Ikpoba slope, the shorter filtration distance allows fecal bacteria to reach aquifers more easily, increasing the likelihood of contamination.

### 2.6.2 Nitrate and Ammonia Contamination

Nitrate and ammonia are major chemical contaminants in artesian wells, originating from agricultural runoff, animal waste, effluents from on-site sanitary facilities, and sewage leakage (WHO, 2017b; Rivett *et al*., 2008). Nitrate primarily results from the leaching of nitrogen-based fertilizers and waste materials into aquifers. Being highly soluble and mobile in groundwater, nitrate is difficult to remove once contaminated. High nitrate concentrations have been linked to latrines based on their proximity, but pinpointing the exact sources in groundwater has proven challenging (WHO, 2006). Potential sources in urban and rural environments include latrines, plant debris, animal manure, landfills, livestock pens, soil, and fertilizers (Girard and Hillaire, 1997).

Similarly, ammonia contamination stems from the microbial decomposition of organic matter, sewage infiltration, and, in some cases, industrial effluents (UNICEF, 2019). The presence of ammonia in artesian wells suggests recent pollution and poor protection of groundwater sources. Nitrate and ammonia contamination not only reduces the chemical and aesthetic quality of well water but also signals an increased risk of microbial contamination due to their association with waste infiltration. This highlights the importance of properly siting wells, continuously monitoring water quality, and implementing effective treatment and management strategies (USEPA, 2023).

## 2.7 Improper Siting of Onsite Facilities and Its Effects on Artesian Well Water Quality

Underground septic tank systems have been widely utilized in Nigerian households to connect old pit latrines and flush toilets, in contrast to the former practice of directly discharging sewage into open drains and surface water courses. However, pit latrines and open defecation persist in some areas. There is ongoing debate about the suitability of on-site sanitation facilities, such as septic tanks, in densely populated urban centers (Kananga, 2003; Ladan, 2014). However, the extent to which households and property developers comply with regulation and the effects of non-compliance have been a subject of research. In practice, studies in Nigeria and Cameroon report average distances of 5-12 m, far below safe limits in most rural areas (IWA Water, 2021). This results in the contamination of artesian wells.

In regions with hardly any compliance, a large portion of the population consumes water from wells that, in most cases, have high levels of microorganisms indicating fecal contamination (Lewis et al., 1982). Contamination of well water by microorganisms and chemical substances from latrines results from several factors, including the proximity of latrines to wells. Research conducted in Mozambique indicated that lateral distances below 50 m were associated with the presence of adenovirus and rotavirus in well water (Verheyen *et al*., 2009), and distances up to 25 m increase the risk of bacterial and chemical contamination (Graham and Polizzotto, 2013).

Shallow wells are more vulnerable than deeper wells due to the shorter vertical distance. The attenuation of pathogenic bacteria depends on retention and die-off in the flow path (van Geen et al., 2011). During the rainy season, river water overflows the study area, spreading human waste from open pit latrines. This waste contains large numbers of enteric microorganisms with high nutrient concentrations and oxygen demand, adversely impacting groundwater quality. Polluted water might enter through the wellhead if it is not fully sealed with a protective layer. Potable water should have no detectable fecal coliform and fewer than 10 CFU of total coliform per 100 ml of water. However, water from various wells tested showed higher CFU counts but remains in use due to the lack of treatment systems and alternative water sources.

Human feces harbor a large number of microbes, including bacteria, archaea, microbial eukarya, viruses, and potentially protozoa and helminths (Ramakrishnan, 2007). The primary chemical concern from excreta in on-site sanitation systems is nitrate. Concentrations of most fecal microorganisms decline after excretion, but these microorganisms may still impair groundwater quality. The deposition, leaching, and concentration of these microorganisms and chemicals do not only degrade water quality but also affect consumers and socioeconomic well-being.

## 2.8 Health Effects of Contaminated Artesian Wells

Contaminated artesian wells, resulting from improper siting and poor protection, pose significant health risks. In Nigeria, population health is threatened by waterborne diseases, particularly typhoid fever and cholera, despite efforts to improve health standards. This is because households consume water from water systems (boreholes, artesian wells) without proper treatment and disinfection. Disease outbreaks in Nigeria in August 2021 recorded 816 deaths among 31,425 suspected cholera cases, according to the Nigeria Centre for Disease Control (NCDC). The highest percentage of death's from diarrheal diseases are recorded in rural or peri-urban areas where shallow wells are often the only improved sources compared to surface waters (INE, 2009). Contaminated artesian wells threaten human health through microbial pathogens and chemical pollutants (Howard et al., 2003).

### 2.8.1 Health Effects Associated with Microbial Contamination

The most immediate health risks linked to groundwater contamination are microbial in nature. The presence of fecal coliforms and *Escherichia coli* suggests potential exposure to pathogens that cause diarrhoea, dysentery, typhoid fever, cholera, and hepatitis A (Prüss-Ustün *et al.*, 2019).

Repeated exposure to these pathogens contributes to chronic gastrointestinal disorders, malnutrition, and weakened immunity, particularly among children (WHO, 2019). These diseases often perpetuate cycles of poverty by reducing productivity, school attendance, and economic stability within affected households.

### 2.8.2 Health Effects Associated with Chemical Contamination

Chemical contamination, primarily from nitrates and ammonia, also poses serious health threats. Nitrate ingestion can cause methemoglobinemia (commonly known as blue baby syndrome) in infants by reducing the oxygen carrying capacity of blood (Ward *et al*., 2018). Long-term exposure to nitrate contaminated water has been linked to thyroid dysfunction, hypertension, and an increased risk of gastrointestinal cancers due to the formation of N-nitroso compounds (Schullehner *et al*., 2018). Ammonia, though less toxic, can affect water palatability and cause stress to the liver and kidneys when consumed over extended periods (Liu *et al*., 2019).

## 2.9 Standards for Siting Wells in Nigeria

In Nigeria, the National Environmental Standards and Regulations Enforcement Agency (NESREA) provides a regulatory framework for the safe construction and management of water sources. It stipulates procedures for well location, casing, and maintenance to safeguard groundwater resources. The code specifies a minimum separation distance of 15 metres between wells and potential contamination sources such as septic tanks and pit latrines, aligning with World Health Organization recommendations (NESREA, 2011).

Adherence to these standards is crucial for preventing groundwater pollution and ensuring sustainable access to safe drinking water. However, enforcement remains a challenge in many urban and peri-urban areas due to rapid population growth, poor land use planning, and inadequate environmental monitoring. Strengthening local enforcement and public awareness campaigns on proper sanitation facility siting can substantially reduce contamination risks and protect community health in high water table areas like Ikpoba slope.

# CHAPTER THREE

# MATERIAL AND METHOD

## 3.1 Study Area

The study was conducted in Ikpoba slope, located within the Ikpoba-Okha Local Government Area of Edo State, Nigeria. The region lies within the humid tropical climate of southern Nigeria, characterised by distinct wet and dry seasons. Ikpoba-Okha covers a total land area of approximately 862 km², with an average annual temperature of 24°C, mean relative humidity of 69%, and an average wind speed of 11 km/h (Manpower, 2022).

The soil type in the area is predominantly red clay (Rhodic Ferralsols or Ferralitic), though orange, yellowish, and grey variants are also common. The major sources of domestic water supply in Ikpoba slope include boreholes and hand-dug (artesian) wells. On-site sanitation facilities such as pit latrines, pour-flush toilets, and septic tanks are widely used and often located in close proximity to wells, increasing the risk of groundwater contamination.

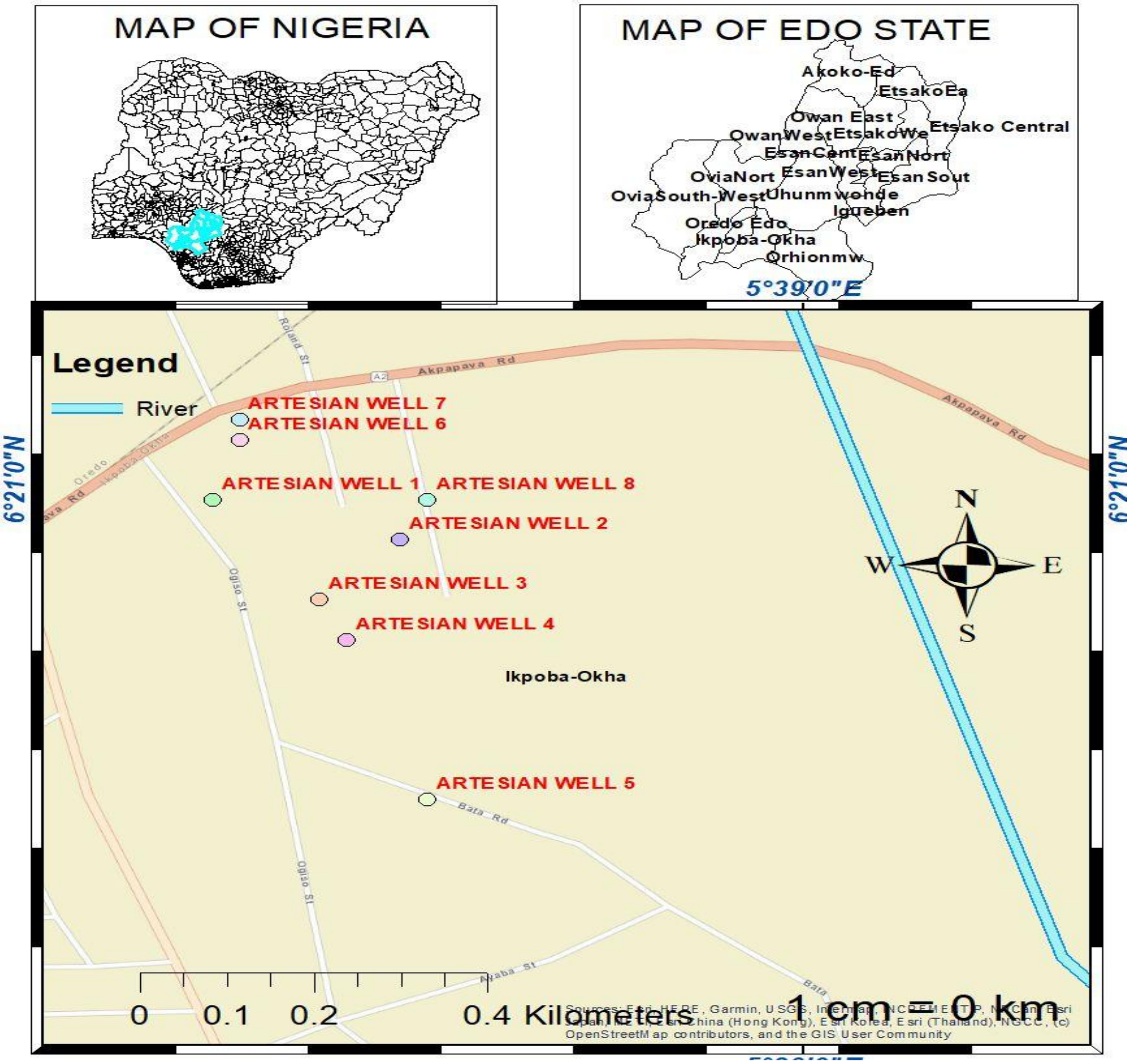

**Figure 1: A cartographic representation of Ikpoba slope showing the sampled artesian well sites.**

The study adopted a cross-sectional design with both observational and experimental components. This approach enabled the collection of data on the physicochemical and microbial quality of well water, as influenced by the proximity of sanitation facilities.

### 3.2 Field Data Collection

The distance between each well and the nearest sanitation facility (pit latrine or septic tank) was measured using a measuring tape, following WaterAid (2011) standards. These distances were compared with the WHO (2017a) recommended minimum separation of 30 metres.

Field parameters such as temperature, pH, electrical conductivity, and total dissolved solids (TDS) were measured in situ using a multiparameter probe immediately after sampling to ensure accuracy. Field observations, including soil type, surface runoff pathways, and waste disposal practices, were also documented.

### 3.3 Sample Collection

A total of eight (8) domestic wells were selected based on their proximity to onsite sanitary facilities such as pit latrines and septic tanks. All wells were hand-dug, cylindrical, and not exceeding 20 m in depth, with internal lining to prevent collapse. Water samples were collected from wells serving households that relied exclusively on them for domestic use.

Artesian well water samples were collected in sterile PET bottles. Before sampling, the bottles were rinsed with standardized sodium hypochlorite solution acclimated by filling and emptying them three times with well water. Samples were collected mid-depth to avoid surface debris and sediment. All samples were transported in iceboxes and analysed within 24 hours of collection in accordance with APHA (2017) guidelines.

#### 3.3.1 In situ parameters determination

The field in situ parameters determined included temperature, pH, nitrate, ammonia, electrical conductivity, and TDS. The analyses followed standard procedures outlined in APHA (2017). In-situ parameters such as temperature, pH, electrical conductivity, and total dissolved solids were determined using a Hanna HI9829 Multiparameter Probe.

### 3.3.2 Nitrate Determination

The nitrate concentration of the water samples were analyzed using Cadmium Reduction Method in accordance with APHA standard method 4500-$N_3^-$ E. The spectrophotometer (Hach DR 3900 UV-Vis) was set to wavelength of 543nm for nitrate determination. A 25mL aliquot of each sample was transferred into a conical flask, the contents of one Nitrever 5 reagent powder pillow were added. The flask was immediately sealed and shaken vigorously for approximately 3 minutes. After allowing the mixture to settle for 10 minutes, the solution was transferred into a clean cuvette and inserted into the spectrophotometer.

The instrument was calibrated to zero using a blank sample (0.00mg/L) according to manufacturer instructions. The resulting absorbance values were recorded and the sample cuvette was rinsed thoroughly with distilled water. Nitrate concentrations were subsequently determined from the prepared standard calibration curve based on the measured absorbance values.

### 3.3.3 Ammonia Nitrogen ($NH_4$–N) Determination

Ammonia nitrogen was determined following the phenate method as described in the APHA standard procedures. A 25 mL aliquot of the water sample was pipetted into a 50 mL volumetric flask, followed by the addition of 10 mL of phenol nitroprusside buffer. The mixture was swirled gently to ensure uniformity, after which 25 mL of hypochlorite reagent was added. The flask was stoppered and inverted several times to achieve proper mixing, then allowed to stand for approximately 45 minutes to permit full development of the blue coloration.

The absorbance of the developed color was measured at a wavelength of 635 nm using a Hach DR 3900 UV–Vis spectrophotometer. A reagent blank was also prepared and analyzed under identical conditions. The ammonia–nitrogen concentration was obtained directly from the calibration curve relating absorbance to known standard concentrations.

### 3.3.4 Determination of Total and Fecal Coliforms

Total and fecal coliform counts in the respective water samples were determined using the membrane filtration and agar plate methods as described by Forster and Pinedo (2015) and Cappuccino and Welsh (2020). A sterile nitrocellulose membrane filter (47mm diameter, 0.45um pore size) was used. All membrane filters, filtration columns and associated equipment were sterilized by autoclaving at 121°C for 15 minutes. Sterile forceps were flamed after immersion prior to use.

Approximately 100mL of each water sample was filtered under aseptic conditions using a vacuum filtration unit. Care was taken to avoid overflow of the catchment of chamber to prevent water from entering the pump. After each filtration, the setup was rinsed with sterile water. The membranes were then aseptically transferred on MacConkey agar (MCA) and Eosin Methylene Blue (EMB) agar plates. MCA plates were incubated at 37°C for 48 hours to enumerate red colored colonies as total coliforms (Bridson, 2006). EMB plates were incubated at 44°C for 24-48 hoursand colonies exhibiting a green metallic sheen were recorded as *Escherichia coli* (Bridson 2006).

## 3.4 Procedure of Analysis

Data obtained from physicochemical and microbial analyses were subjected to descriptive statistics (mean, range, and standard deviation). Statistical test, were applied to determine relationships between well-to-latrine distance and water quality parameters. Data processing was performed using Microsoft Excel 2019 and SPSS (Version 25).

Informal consent taken ensured permission was obtained from house owners before accessing private wells. Respondents were informed about the study purpose, and confidentiality of household identities was maintained. No harmful or invasive procedures were performed.

# CHAPTER FOUR

# RESULTS

The results of the analysis alongside inferences drawn are presented as follows:

## 4.1 Distance of Onsite Sanitary Facilities to Artesian Wells

An objective of this study was to assess the safe distance between sanitary facilities and the artesian well, and to evaluate their conformity to the National Environmental Standards and Regulations Enforcement Agency (NESREA) standard of 15 m. The distances between onsite sanitary facilities to artesian wells ranged from 7 m (sample location 1 and 2) to 15.7 m (sample location 4) with a mean value of 9.8 m. However, sample point 4 was sited only 3 m away from a neighboring pit latrine, which could influence the results. This indicates that all the sampled wells were within unsafe proximity to potential pollution source except sample action 4 having a horizontal distance of 15.7 m between well and onsite sanitary facility but also 3m away from neighbors pit latrine which can influence its contamination rate.

**Table 1: Distance between onsite sanitary facility and well water locations in the study area (n=8)**

| Samples Location | Coordinates | | Distance to Sanitation Facility (Meters) | Type of Onsite Sanitation Facility | Expected Distance (NESREA Standard) | Remark |
|---|---|---|---|---|---|---|
| 1 | 6°20'59"N<br>5°38'38"E | - | 7 | Open defecation site | 15 | -Below NESREA standard |
| 2 | 6°20'57"N<br>5°38'45"E | - | 7 | Pit latrine | 15 | Below NESREA standard |
| 3 | 6°20'54"N<br>5°38'42"E | - | 9 | Septic tank | 15 | Below NESREA standard |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | 6°20'52"N<br>5°38'43"E | - | 15.7 | Septic tank + 3m to neighbour pit latrine | 15 | Below NESREA standard |
| 5 | 6°20'44"N<br>5°38'46"E | - | 11.2 | Pit latrine | 15 | Below NESREA standard |
| 6 | 6°21'2"N<br>5°38'39"E | - | 11 | Septic tank | 15 | Below NESREA standard |
| 7 | 6°21'3"N<br>5°38'39"E | - | 9 | Septic tank | 15 | Below NESREA standard |
| 8 | 6°20'59"N<br>5°38'46"E | - | 10.2 | Septic tank | 15 | Below NESREA standard |

## 4.2 Physiochemical Profiles of Artesian Well Water Sample

All artesian well samples were collected from Ikpoba-slope Benin City, Nigeria. The measured parameters included pH, electrical conductivity (EC), total dissolved solids (TDS), moisture value (MV), salinity, nitrates and total ammonia nitrogen (TAN).

### 4.2.1 pH

The pH values ranged from 4.77± 0.026 (sampled location 6) to 6.45 (sample location 3) which are below the National Environmental Standards and Regulations Enforcement Agency (NESREA) permissible range (6.5-8.5), indicating that all the sampled wells were acidic.

### 4.2.2 Electrical Conductivity

The electrical conductivity varied widely. The electrical conductivity ranged from 13.67± 0.577uS/cm (sample location 3) to 697.00± 2.646 uS/cm (sample location 5).The NESREA permissible range for electrical conductivity is 1000uS/cm and all sampled locations were within the permissible limits.

### 4.2.3 Total Dissolved Solids (TDS)

The total dissolved solid values across samples ranged from 6.67± 0.577 mg/L (sampled location 3) to 345.00± 1.000mg/L (sampled location 4) suggesting elevated mineral content. The NESREA stipulated standard for total dissolved solid is 500mg/L and all sampled locations were within permissible limits.

Table 2: Mean physiochemical parameters (pH, electrical conductivity and total dissolved solids in the sample locations.

| **Parameter** | **Sampled Location** | | | | | | | | **NESREA Standard** |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | |
| pH | 5.58± 0.01 | 5.98± 0.01 | 6.45± 0.02 | 5.80± 0.10 | 5.92± 0.03 | 4.77± 0.03 | 4.81± 0.06 | 4.96± 0.03 | 6.5-8.5 |
| Electrical conductivity (us/cm) | 598.00 ± 1.00 | 588.00 ± 1.00 | 13.67 ± 0.58 | 697.00 ± 2.65 | 685.33 ± 1.16 | 63.67 ± 0.58 | 54.33 ± 1.53 | 184.00 ± 1.000 | 1000 |
| Total dissolved solids (mg/L) | 298.00 ± 1.00 | 287.67 ± 1.53 | 6.67± 0.58 | 345.00 ± 1.00 | 342.67 ± 0.58 | 32.00 ± 1.00 | 42.33 ± 0.58 | 90.00± 1.00 | 1200 |

### 4.2.4 Salinity

The salinity across sampled locations ranged from 0.01± 0.01ppt (sample location 7) to 0.27± 0.01 ppt (sample location 4). All samples had low salinity concentration.

### 4.2.5 Nitrate

The Nitrate concentration ranged from 0.25± 0.03 mg/L (sample location 2) to 0.87mg/L (sample location 8). The NESREA permissible range for Nitrate is 50mg/L and all sampled locations were within permissible limits.

### 4.2.6 Total Ammonia Nitrogen

The total ammonia nitrogen (TAN) concentration ranged from 0.20± 0.002 mg/L (sample location 4) to 1.10± 0.012 mg/L (sample location 6). Sample location 2,3,4,7 and 8 were within the NESREA permissible limit of 0.5mg/L. Sample location 1, 5 and 6 had high value indicating high concentration of total ammonia nitrogen in the sample location.

**Table 3: Mean physiochemical parameters in the sample locations**

| **Parameters** | **Sampled Location** | | | | | | | | **NESREA Standard** |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | |
| Salinity | 0.23± 0.02 | 0.23± 0.01 | 0.00± 0.00 | 0.27± 0.01 | 0.27± 0.01 | 0.00± 0.00 | 0.01± 0.01 | 0.06± 0.01 | - |
| Nitrates (mg/L) | 0.54± 0.01 | 0.25± 0.03 | 0.38± 0.00 | 0.54± 0.02 | 0.38± 0.01 | 0.55± 0.01 | 0.39± 0.01 | 0.87± 0.01 | 10 |
| Ammonia (mg/L) | 0.98± 0.02 | 0.21± 0.00 | 0.27± 0.00 | 0.20± 0.00 | 0.77± 0.00 | 1.10± 0.01 | 0.21± 0.01 | 0.22± 0.01 | 0.5 |

## 4.3 Microbial Loads of Artesian Wells

The microbial assessment included fecal coliform and total coliform.

### 4.3.1 Fecal coliform

Fecal coliform load ranged from 6.67 $\times 10^4$ ± 2.89 Cfu/100mL (sample location 4 and 7) to 2.6.7$\times 10^4$±2.89 Cfu/100mL (sample location 5).Though sample location 1, 2, 6 and 8 recorded 0Cfu/100mL. The National Environmental Standards and Regulations Enforcement Agency (NESREA) permissible standard for fecal coliform in water is 0Cfu/100mL and only sample location 1,2,6 and 8 are in compliance to the NESREA permissible range.

### 4.3.2 Total Coliform

The total coliform load ranged from 6.7 $\times 10^4$ ± 2.89 Cfu/100mL (sampled location 7) to 2.8.5 $\times 10^4$ ± 0.45 Cfu/100mL (sampled location 5). Sample location 1,2,6 and 8 had no detectable total coliform load and were in compliance to the National Environmental Standards and Regulations Enforcement Agency (NESREA) stipulated 0 Cfu/100mL.

**Table 4: Mean microbial load of water sample in sampled location**

| **Parameters** | **Sampled Location** | | | | | | | | **NESREA Standard** |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | **3** | **4** | **5** | **6** | **7** | **8** | |
| Fecal Coliform (Cfu/100mL) | 0 | 0 | 10 $\times 10^4$ ± 5.0 | 6.7 $\times 10^4$ ±2.89 | 26.7$\times 10^4$±2.89 | 0 | 6.7$\times 10^4$ ± 2.89 | 0 | 0 |
| Total Coliform (Cfu/100mL) | 0 | 0 | 13.3 $\times 10^4$ ±5.77 | 21.7 $\times 10^4$ ±5.77 | 28.5$\times 10^4$ ± 0.45 | 0 | 6.7 $\times 10^4$ ± 2.89 | 0 | 0 |

# CHAPTER FIVE

# DISCUSSION

The siting of onsite sanitary facilities in proximity to artesian wells increase the likelihood of leacheate infiltration and microbial contamination which in turn affects well water quality especially in high water table region. The distances between onsite sanitary facilities to artesian wells in sampled location ranged from 7 m (sample location 1 and 2) to 15.7 m (sample location 4) with a mean value of 9.8 m. However, the wells analyzed were below permissible range except sampled location 4 having a horizontal distance of 15.7 m between well and onsite sanitary facility but also 3 m away from neighbors pit latrine which can influence its contamination rate and as such deemed unfit for use unless treated and tested before considered safe for use. The location of sanitary facilities, particularly the septic tank, (also called soakaway pit) and pit latrines to wells are matters of municipal regulations. In Nigeria, such regulations are enacted in line with international standards such as the WHO Health Guidelines and enforced by The states Ministry of Environment/ City Planning Authorities. The National Environmental Standards and Regulations Enforcement Agency (NESREA) stipulate 15m as the minimum safe distance for the siting of onsite sanitation facilities in proximity to wells.

The physiochemical parameters tested for reflects the physical and chemical presence in the well water samples tested. The pH values ranged from 4.77±0.026 (sampled location 6) to 6.45 ±0.02 (sample location 3) indicating that all wells were acidic. According to the World Health Organization (WHO, 2017) and the National Environmental Standards and Regulations Enforcement Agency (NESREA), the acceptable pH range for potable water is 6.5–8.5. Acidic water can corrode plumbing, leach heavy metals, and cause gastrointestinal irritation. The Electrical conductivity (EC) and total dissolved solids (TDS) varied across samples. The electrical conductivity ranged from 13.67± 0.58 uS/cm (sample location 3) to 697.00± 2.65 uS/cm (sample location 5) and the TDS ranged from 67± 0.578 mg/L (sampled location 3) to 345.00± 1.00 mg/L (sampled location 4), which may reflect leaching of salts and organic matter from surrounding soils or latrines. Although the total dissolved solid and electrical conductivity levels were within the National Environmental Standards and Regulations Enforcement Agency (NESREA) guideline value of 1000us/cm (EC) and 1200 mg/L (TDS), the elevated readings in some sample locations indicates potential contamination.

Nitrates ranged from 0.25± 0.03 mg/L (sample location 2) to 0.87 mg/L sample location 8 and the total ammonia nitrogen (TAN) ranged from 0.20± 0.00 mg/L (sample location 4) to 1.10± 0.01 mg/L (sample location 6) . However, these levels are with the National Environmental Standards and Regulations Enforcement Agency (NESREA) maximum allowable limits of 10 mg/L for nitrates and 0.5 mg/L for total ammonia nitrogen except sample location 1, 5 and 6 which exceeded the total ammonia nitrogen permissible limit in water. The presence of high concentration of total ammonia nitrogen in wells close to pit latrines such as sampled location 1, 5 and 6 suggests leaching of human waste. Prolonged consumption of nitrate-contaminated water can lead to methemoglobinemia (blue baby syndrome) in infants and other health risks

The bacteriological organisms total coliform and fecal coliform found in water samples drawn from these wells are the main contaminant of the well water whose source are likely discharge from the soakaway pit. The microbial results indicate widespread contamination in most wells. Wells at sample location 1, 2, 6 and 8 complied with the National Environmental Standards and Regulations Enforcement Agency (NESREA) fecal and total coliform standards by having no detectable coliforms. Fecal coliform load ranged from $6.67 \times 10^4 \pm 2.89$

Cfu/100mL (sample location 4 and 7) to 26.7 × $10^4$± 2.89 Cfu/100mL (sample location 5) and the total coliform load ranged from 6.67 × $10^4$ ± 2.89 Cfu/100mL (sampled location 7) to 2.8.5 × $10^4$ ± 0.45 Cfu/100mL (sampled location 5).These wells are all located within 5–15 m of sanitary facilities (with 90% not within permissible limit), suggesting infiltration of contaminants from sanitary facilities into groundwater. The presence of coliforms indicates microbial contamination, raising the likelihood of waterborne diseases such as cholera, dysentery, typhoid fever, and gastroenteritis (WHO, 2017). The extremely high counts in sample location 3, 4, 5 and 7 represent severe contamination and render the water unsafe for any domestic use without treatment.

In Nigeria, population health is being threatened by water borne diseases particularly typhoid fever and cholera in spite of effort at improving health standards. This is so because; majority of households consume water from numerous sources without proper treatment and disinfection. Nigeria therefore, is sitting on the edge of an impending water related epidemic except effort is made to check improper siting of sanitary facilities. In some parts of Nigeria according to Anaele (2014), pit latrines and open drainage facilities are also located indiscriminately close to domestic water sources. The amount of sampled wells water proven to be unsatisfactory (50 percent) in terms of microbial analysis and unsafe for human consumption implies that for the study area alone, more than 60 percent of households are at risk of contracting water borne disease such as dysentery, cholera, typhoid, diarrhea and other diseases.

In line with the findings of this study, I suggest the following measures should be taken to minimize contamination levels. Artesian wells should be lined, covered and fitted with sanitary seals to prevent surface run-off, also new wells should be sited in line with the National Environmental Standards and Regulations Enforcement Agency (NESREA) standards.

There should be routine testing for microbial loads and physiochemical parameters of well waters as well as the institution of local surveillance programs to help track water quality. Contaminated wells such as sample 3, 4, 5 and 7 should undergo disinfection before domestic use and acidic wells should be treated. Standards has been instituted, governments and local council should ensure compliance to set standards.

## 5.2 Conclusion

This study demonstrates that the placement of onsite sanitation systems within short distances of artesian wells in Ikpoba slope contributes to deterioration in water quality, particularly from microbiological sources. Although most chemical indicators were within acceptable ranges, the observed acidity and presence of coliform organisms raise concerns about suitability for direct consumption. Improved enforcement of siting regulations, routine water quality surveillance, and enhanced community awareness are essential steps toward reducing health risks. Protective measures such as constructing sanitary aprons, well linings, and sealed covers could further limit contamination.

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