EFFECT OF ON-SITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF BOREHOLES IN SELECTED LOCATIONS IN BENIN CITY, EDO STATE.

BY

OSEMUDIAMEN NORA ITUA (MISS)

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AN UNDERGRADUATE DISSERTATION 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 ON-SITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF BOREHOLES IN SELECTED LOCATIONS IN BENIN CITY, EDO STATE"** was carried out by " **OSEMUDIAMEN NORA ITUA (MISS)"** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfilment of the requirements for the award of bachelor of science (B.Sc) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

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DR. O. OSARENOTOR **DATE**

(PROJECT SUPERVISOR)

______________________________ ______________________________

PROF. (MRS.) E.T AISEN **DATE**

(HEAD OF DEPARTMENT)

DECLARATION

I "**OSEMUDIAMEN NORA ITUA**" declare that "**EFFECT OF ON-SITE SANITATION FACILITY PROXIMITY ON WATER QUALITY OF BOREHOLES IN SELECTED LOCATIONS IN 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.

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OSEMUDIAMEN NORA ITUA

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DATE

DEDICATION

This project is dedicated to Almighty God, whose grace, wisdom and strength have guided me every step of the way.

To my loving mum and dad, thank you for your endless encouragement, prayers and unwavering support, your belief in me has been my greatest motivation.

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I sincerely express my profound gratitude to Almighty God for His guidance, wisdom and strength throughout the completion of this project.

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ABSTRACT

Groundwater remains a vital source of potable water in Benin city, yet its quality is decreasing in most parts of Nigeria. This study assessed the effect of on-site sanitation facility proximity on the physiochemical, total and fecal coliform load of groundwater from selected boreholes in Ikpoba Hill and Sapele Road, Benin City. Water samples are collected from four boreholes located within varying distances (11.8m in Ikpoba Hill to 32m in Sapele Road) from onsite sanitation facilities. In-situ measurements of pH, Electrical conductivity (EC), and total dissolved solids (TDS) were performed using a multifunction water quality meter, while nitrate and ammonia-nitrogen concentrations were determined using spectrophotometric methods. The pH values ranged from 4.3±0.01 in Ikpoba Hill to 5.2±0.5 in Sapele Road, indicating slightly acidic water across all samples. EC and TDS values ranged from (19±0 in Ikpoba Hill - 133±0µS/cm in sapele road) and (9±0 in Ikpoba hill - 66±0 mg/L in Sapele Road), respectively, reflecting low mineralization. Nitrate (0.46±0.11 in Sapele Road – 0.713±0.04 mg/L in Ikpoba Hill) and ammonia-nitrogen (0.85±0.17 in Ikpoba Hill – 1.50±0.77mg/L in Sapele Road). Aside from ammonia-nitrogen, other parameters were below NESREA permissible limits and there were no total or fecal coliforms detected in the samples. The observed differences between the mean physiochemical values were not significant ($p>0.05$). Aside from borehole C and D, the other boreholes (A and B) were sited well above the minimum distance (15m) from the nearest sanitary facilities (septic tank). It is recommended that sensitization be conducted to enlighten intending property owners with respect to the health implications of improperly siting water sources from onsite sanitation facilities.

CHAPTER ONE

INTRODUCTION

Water has been described as being one of the most valuable resources on Earth. Many people lack access to enough potable drinking water and enough water to maintain basic hygiene, despite the fact that water is necessary for human existence (Miller *et al.*, 2021). Approximately 1.1 billion people depend on unsafe drinking water sources from open wells, lakes, and rivers. The majority of these are found in sub-Saharan Africa (42%), and Asia (20%). Additionally, according to UNICEF/WHO (2023), 24 billion people globally need proper sanitation.

One measure of a community's or country's progress is the availability of water in the necessary amount and quality. Rainwater harvesting, water bodies (ponds, rivers), and ground water (wells, springs and boreholes) are the sources of water. The subsurface water that is below the water table in the soil and fully saturated geological formations is referred to as ground water. It can be collected by wells, tunnels, boreholes, or damage galleries, or it can naturally flow to the earth's surface (Agbede and Adegoye, 2003).

The hydrologic cycle is a never-ending process in which water absorbs gases and other components as it passes through the environment, travels to the sea, and then passes through the ground. The hydrological cycles make sure that the water that is accessible on Earth goes through a seemingly infinite and renewable cycle of evaporation, condensation, and finally return to water (NOAA, 2025). The hydrological cycle, which is the flow of water between the earth and the atmosphere through transpiration, precipitation, condensation, and evaporation, includes groundwater. An aquifer is the subterranean region that contains groundwater (NOAA, 2025).

Groundwater is derived from three primary subsurface zones, which are typically located 300 to 1500 feet below the land surface (USGS, 2025A). The groundwater source is shielded from surface pollution by a layer of fine-grained sediments and clay. The rate of recharge and discharge may cause variations in the groundwater level in the borehole (USGS, 2025). The reaction to well withdrawals through pumping, leakage to vertically neighboring aquifers, natural flow from an aquifer into streams and springs, and evaporation from the shallow water tables can all affect how quickly a borehole recharges.

In many countries, groundwater is a vital natural resource that serves as the main supply of water for household, industrial, and agricultural uses (UNESCO, 2006). Around the world, it is a significant supply of drinking water (UN/WWAP, 2006). Although natural groundwater is often of high quality, improper resource management and insufficient source protection can cause this to decline (Pedley and Howard, 1997).

Soil type and geomorphologic features also influence groundwater recharge mechanisms and natural attenuation capability (Edmunds and Shand, 2008). Groundwater has been shown to harbor both chemical and microbiological pollutants. The land dumping of sewage effluents is one of the many sources of pollution, sewage and solid waste, runoff from cities, septic tank effluent, and mining, farming, and industrial activities (Erah *et al.*, 2002; Aydin, 2007; Ozler and Aydin, 2009). Waterborne illnesses including cholera, hepatitis, typhoid fever, giardiasis, and gastroenteritis have been linked to the usage of untreated or insufficiently treated groundwater; the bacterial and viral pathogens and protozoan parasites are the culprits. Microbiological contamination of groundwater sources affects a large number of people immediately, as opposed to chemical risks that may pollute groundwater and have a long-term impact on public health (Pedley and Howard, 1997; Erah *et al.*, 2002; Aydin, 2007). Traces of organic compounds found in groundwater are less well understood than the impacts of inorganic pollutants.

Among the pollutants found in groundwater include metals, cyanide, arsenic, hydrocarbons, a variety of synthetic materials, soluble forms of phosphorus and nitrogen, and organic debris (Aromon and Kott, 1994). Both geological and human-caused factors are contributing to the decline in groundwater quality. One of the most concerning anthropogenic causes is the effect of on-site sanitation (OSS) on groundwater quality. The hydrogeological factors, such as the depth to the water table, the type of soil matrix, and the lateral separation between the OSS facility and groundwater source, are some of the key parameters affecting groundwater pollution. The issue of groundwater pollution from OSS facilities, such as geological settings, has been extensively addressed worldwide (Ahaneku and Adeoye, 2014). The introduction or presence of organic, inorganic, biological, radiological, or physical foreign substances in water that tend to deteriorate its quality is known as groundwater contamination. The majority of earlier research on groundwater quality in Nigeria, according to available data, focused mostly on the effects of leachate from trash dump sites, with little to no attention paid to other on-site sanitary conditions, particularly the influence of OSS facilities (Banda *et al*., 2014). WHO stated that, particularly in developing nations like Nigeria, the lack of wastewater treatment and a clean water supply leads to serious health problems that worsen poverty by causing illness, death, and environmental degradation. An estimated 80% of all infections in poorer nations are thought to be caused by contaminated water supplies and poor sanitation (Mlipano *et al*., 2018). Like the majority of underdeveloped nations, Nigeria has a serious deficiency in adequate wastewater treatment (Monday *et al*., 2013). In many African cities, untreated wastewater, often known as effluent, is one of the most prevalent forms of pollution found in groundwater sources and near urban rivers (Ebri *et al*., 2016). A wastewater management system known as an on-site sanitation system handles wastewater from individual homes, apartment buildings, or small communities near where it originates. Typically, OSS is a combination of many technologies within a given geographical boundary, namely, onsite facilities, low-cost collection facilities and dispersed location of treatment (Adewumi and Oguntuase, 2016). One of the main factors influencing the pollution of an area's groundwater supply is the hydrogeological formation, which includes the depth to the water table, the kind of soil matrix, and the distance between the OSS facility and the groundwater source. One clear criterion that is rather easy to check is the lateral distance. The OSS facility and any drinking water source should be at least 30 meters apart, per the suggested norm (MoUD centre of excellence, 2012).

People now rely on groundwater to meet their water demands and OSS facilities for wastewater management because there is no central, clean water delivery system or traditional central wastewater management infrastructure.

1.1. Problem Statement and Aim of Study

Groundwater is a critical source of drinking water in Benin City, yet its quality is increasingly threatened by the proximity of onsite sanitation facilities such as pit latrines and septic tanks. In areas with low water table levels, contaminants from sanitation systems may infiltrate aquifers, particularly where construction standards are poor or separation distances are inadequate. In Ikpoba Hill and Sapele Road, Benin City, many households are dependent on groundwater for daily use, even though sanitation structures are often located close to wells and boreholes. This trend raises concerns about contamination by pathogens and chemical pollutants, especially fecal coliforms and total coliforms, which are key indicators of microbial pollution.

This study is aimed at investigating the microbial contamination level and the chemical contamination level as a result of the effects of water table level on groundwater quality, sited near onsite sanitation facilities especially in areas with low water table such as Ikpoba Hill and Sapele Road. Evaluation of this research gap is vital for safeguarding public health, guiding sanitation planning, and ensuring sustainable groundwater use in these parts of Benin City.

1.2. Objectives of Study

1. To determine the nitrate and ammonia level in groundwater.
2. To determine the microbial quality of ground water sourced from the boreholes sited close to the onsite sanitation facilities.
3. To evaluate how improper siting of on-site sanitation can contribute to groundwater quality degradation.

This study is important because it helps protect public health by assessing the risk of groundwater contamination from nearby onsite sanitation systems in Ikpoba Hill and Sapele Road. It would provide localized data to guide urban planning, sanitation management, and safe siting of water sources in low water table areas. The findings will support community awareness, policy development, and contribute to achieving the Sustainable Development Goals (SDGs) on clean water, sanitation, and health.

CHAPTER TWO

LITERATURE REVIEW

As human population and urbanization rates continually increase, so does the anthropogenic demand for groundwater and surface water. Anthropogenic activities such as soil fertility remediation, solid waste disposal, and the usage of septic tanks, soak-away pits, and pit latrines are increasing as a direct consequence of Nigeria's meteoric urbanization rate, which has documented to be in the range of 10 and 15% annually in the country's major urbanized areas (Adetunji and Odetokun, 2011). Industrialization and urbanization have been blamed for groundwater pollution because they have grown over time without considering the effects on the environment which can lead to the degradation of the physicochemical as well as biological qualities of water (Akhtar *et al*., 2021).

Approximately 52% of Nigerians lack access to a better source of drinking water (Orebiyi *et al*., 2010). Pipe-borne water from municipal water treatment plants is the most reliable source of clean drinking water for the majority of towns (Chia *et al*., 2014). As a result of corruption, poor maintenance, or growing populations, the majority of water treatment plants frequently fall short of meeting the water needs of the communities they serve. Communities are looking for other water sources as a result of the lack of piped water, and ground water is a practical portable water supply (Chia *et al*., 2014).

2.1. Description of Potable Water

Water that is devoid of chemicals or prokaryotes (bacteria) in amounts that might endanger public health is referred to as portable water. For water to be fit for human consumption, it must be notably free of dissolved salts, plants, animal waste and pathogenic microorganisms (Cabral, 2010). Ground water can be contaminated with nitrates, bacteria and hazardous cleaning chemicals due to poorly constructed septic tanks and poorly managed septic systems (Tairu *et al*., 2015). In addition to vector-borne illnesses like guinea worm, schistosomiasis, lymphatic filariasis, parasitic and viral infections, this can act as a vehicle for the spread of diseases attributed to several biological etiologic agents such as like *Vibrio cholerae*, *Escherichia coli*, and *Cryptosporidium* spp. (Tairu *et al.*, 2015). In the year 2004, it was documented that about 1450 individuals in Lake Erie, Ohio, USA, fell ill due to a bacterium in the well water, demonstrating the danger of polluted water for human consumption (Fong *et al.,* 2007). Streptococci, *Clostridium* species, *E. coli,* and other bacteria that may be human or non-human in origin are examples of microbial fecal contamination indicators (Holcomb and Stewart, 2020). Efforts to preserve the quality of ground water have been sparked by the growing reliance on ground water for drinkable water (Al-Hashimi *et al*., 2021).

An estimated 800 million gallons of waste are disposed of annually using septic tanks, with almost all of the waste being disposed of underground (Siddiqua *et al.*, 2022). As a result, the largest source of waste that is dumped straight into ground water is septic tanks. Therefore, water assessment is essential to protecting the environment and public health (Siddiqua *et al.*, 2022).

2.2. Definition of Ground Water

Naturally occurring precipitation brings water into the soil, some of which evaporates into the atmosphere, some of which is absorbed by plants, and the remainder slowly seeps down to establish groundwater. Recharge is the term for this percolating water that travels through the root zone and eventually reaches the water table (USGS, 2025 B). The saturated zone, when all pore spaces are filled with water, is located just beneath the water table. Aquifers, which can range widely in size, are subterranean layers of sand, gravel, or porous rock that hold enough water to function as a water supply (FAO, 2025). Some aquifers are big enough to provide transportable water to thousands of homes and businesses, while smaller ones might only feed a few wells.

2.3. Water Table effects of Ground Water

2.3.1. Fluctuations in the water table and the transportation of contaminants

In controlling water flow, capillary fringe movement, and redox conditions, water table fluctuations (GTF) can hasten the migration and transformation of pollutants. This trend could increase the possibility of groundwater contamination, particularly with regard to organic chemicals, nitrogen as well as heavy metals (Wei *et al.*, 2024; Park *et al.*, 2024). When the capillary fringe is near the surface, it can influence streamflow and pollutant transmission by causing quick and significant water table increases following minor precipitation episodes. (Gillham, 1984)

Enhanced evaporation and capillary flow caused by deeper water tables hydraulically connected to the surface can result in increased surface salt accumulation, which can impact plant growth and soil health (Shokri-kuehni *et al.*, 2014). In addition, soil texture and layering affect the movement of water and salts when a water table is present (Li *et al.*, 2014). Water table changes are caused by human activities (irrigation, groundwater extraction) and climate factors (temperature and precipitation), which have an impact on ground water storage and its associated recharge rates. While lateral groundwater flow can partially counteract depletion, over-extraction can cause elevation of water tables (Zeng *et al.*, 2016).

2.4. Water Table (Ground water Level)

The top surface of the saturated zone is known as the water table. If the surface water body is connected to the groundwater system, the water table joins the surface water bodies at or close to the coastline (Tom and Edet, 2024). The water table usually refers only to unconfined aquifers; aquifers in which water is free to drain vertically from the ground surface to the aquifer (BGS, 2025). In an unconfined aquifer the groundwater may be in hydraulic continuity with surface water, in which case the surface water can be considered to be an outcrop of groundwater. However levels in an aquifer may be lower than levels in a river, in which case water may be lost from the river to the aquifer, or higher, in which case the river will gain water from the aquifer (BGS, 2025).

The saturated zone voids are entirely filled with water, as opposed to the unsaturated zone. Ground water is the term used to describe water in the saturated zone. The water table is the uppermost portion of the saturated zone. Ground water may be extracted for usage because the water pressure is high enough below the water table to for water to enter wells (Tom and Edet, 2024). In order to prevent earth elements from entering the pipe along with the water pushed through the screen, a screen is usually connected at the base of the pipe. A well is created by inserting a pipe into a hole that has been dug (Tom and Edet, 2024).

When the water table is at the earth surface, its depth can be nil, but in certain types of landscapes, it can be hundreds or even thousands of feet. Near permanent bodies of surface water like lakes, marshes, and streams, the water table is often just a little bit deep (Younger, 2007). Based on the notable variation in the amount, distribution, and timing of precipitation, ground-water recharge—the accretion of water to the upper surface of the saturated zone—is linked to the water table's seasonal and annual variations in configuration (Younger, 2007).

2.5. On-Site Sanitation

On-site sanitation techniques range from more costly systems like septic tanks, which provide sewer-like convenience in affluent neighborhoods, to less expensive pit latrines, which are frequently found in low- and middle-income communities in Asia and Africa (Kihila and Balengayabo, 2020). Septic tanks have the potential to discharge chemical and microbiological pollutants into groundwater, even while kept in enclosed tanks where it breaks down anaerobically (Tilley and Peters, 2008).

In underdeveloped nations, pit latrines—whether dry or pour-flush—are increasingly prevalent. Since they are typically not lined, liquid waste can easily seep into the ground (Mulungu and Muyaba, 2024). As infiltration frequently avoids the biologically active topsoil that naturally attenuates contaminants, this event can present a likelihood of groundwater contamination, especially from microbial pathogens as well as nitrates. Compared to dry pit latrines, pour-flush slatrines are more dangerous because of their increased liquid loading (Lewis *et al.*, 1982).

2.6. Contaminants Associated with Onsite Sanitation and Potential Health Concerns

2.6.1. Microbiological Contaminants

Water contamination by on-site sanitation pathogens mainly consist of bacteria, viruses and protozoa, all of which can result in diarrheal illnesses. Additionally, animals, insects, or contaminated hands can spread the disease. As they are bigger, helminths are less likely to be found in groundwater. Bacterial pathogens such as *Vibrio cholerae* (cholera), *Salmonella* typhi (typhoid), and *Shigella* spp. (dysentery) cause large epidemics of diarrheal illnesses. Compared to viruses, greater dosages are often required, even though a single bacteria has the potential to cause illness. Early water sanitation initiatives focused heavily on controlling bacterial infections, which is still crucial today (UNICEF/WHO, 2023) Fortunately, bacteria are a major focus in water and sanitation programs because they are reasonably straightforward to eliminate through natural attenuation and basic protective measures. Small organisms called viruses are responsible for a number of diarrheal illnesses, such as rotavirus, polio, and hepatitis A and E (Krauss and Griebler, 2011).

Since viruses are less likely to be naturally attenuated and frequently require extremely low concentrations to induce illness, they are more difficult to manage with water quality measures alone than bacteria. Drinking water may still be a factor, even if poor cleanliness is a major way of transmission. Risks are decreased by protection measures however disinfection is often necessary for successful management since on-site sanitation improvements might not be enough on their own. Although they are often mild and self-limiting, protozoa like *Giardia* and *Cryptosporidium* can induce diarrhea. Instead of drinking water, animals, inadequate hygiene, or food are the main ways that the disease is spread in underdeveloped nations. The health concerns from protozoa in groundwater are typically modest because of their huge cyst size, which makes them simpler to filter and attenuate even at low infectious doses.

2.6.2. Chemical Contaminants

The primary chemical pollutants from on-site sanitation are nitrate and chloride. Each individual excretes around 4 g of chloride per day, largely in urine, and 4 kilogram of nitrogen per year, much of which is converted to nitrate. Although it presents less of a health danger, chloride is a helpful sewage indicator that mostly affects the acceptability and flavor of water. The WHO recommends 50 mg/L of nitrate in drinking water, which is more dangerous. Excessive consumption, particularly in young children, may be connected to stomach cancer and methemoglobinemia, often known as "blue-baby syndrome." Although nitrate is not very dangerous in and of itself, bacteria may turn it into nitrite, which disrupts the blood's ability to carry oxygen. Ammonium, which is usually innocuous at normal dietary levels (average consumption ~18 mg/day), can be found in anoxic groundwater. But its byproducts, such chloramines and nitrite, can be harmful to your health. The WHO recommends 0.2 mg/L of ammonium.

2.7. Improper Siting of Onsite Sanitation and how it Affects Ground Water Quality

In Sub-Saharan Africa (SSA) and other parts of the developing world, many impoverished communities rely on on-site sanitation (such as pit latrines and septic tanks) to contain, dispose of, and/or treat wastewater and excreta due to a lack of sewage treatment facilities (Martínez-Santos *et al.*, 2017).

Although it has emerged as a preferred method of sanitation in areas experiencing rapid development because to the high costs involved with off-site sanitation, on-site sanitation endangers groundwater quality. The dumping of septic tank effluent may contribute to health issues, mosquito breeding, and unpleasant odors. Leachate from on-site sanitary systems is one way that groundwater might get contaminated (WHO, 2006). These on-site sanitation systems produce hazardous bacteria and chemical pollutants that are dangerous because they are carried by the soil into adjacent groundwater sources. In highly populated locations, where groundwater and on-site sewage are very close to one another, the problem is particularly severe. Water conservation is necessary since drinking water is limited in almost all peri-urban areas of the country (Mulungu and Muyaba, 2024).

Roy (2020) reported that septic tanks are frequently used in low-density residential areas as well as in institutions like hospitals and schools. When utilizing regular sewage is neither practical or affordable, septic tanks could be the best choice since they can handle the amount of wastewater created. Sullage, usually referred to as "greywater," which is waste water from the kitchen, laundry, and bathrooms, may be included in the wastewater, or it may merely be toilet waste (sewage) (Tilley and Peters, 2008). Septic tanks still require regular emptying, maintenance on the waste pipe lines, and a consistent supply of water even though they are a reliable and odorless system. With respect to the expenses associated with emptying and the limited access, this is very inefficient (Tilley and Peters, 2008).

Fecal wastewater, which is discharged into the surrounding soil from on-site sanitation harbors elevated levels of organic nitrogen (urea: $CO(NH_2)$, chloride coupled with pathogenic bacteria, and as such, can pose a threat to groundwater quality. Leachate is known to contain notable amounts of nitrate as a result of the mineralization of organic nitrogen, also known as nitrification (Lapworth *et al.*, 2017).

Higher pollution effect levels can cause soil saturation and, thus, less filtration when soak-away are situated within 30 meters of boreholes. As one gets farther away from the septic tank system, the effect of septic tank distance on pollutant concentrations diminishes (Mulungu and Muyaba, 2024).

2.8. Physicochemical Attributes of Ground Water

The dissolved constituents in groundwater, some of which include; calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium(K), bicarbonate, nitrite, sulphate and chloride usually occur in the form of electrically charged ions. Many other minor constituents such as iron, manganese and fluoride, Zn and Pb are trace elements which may be found in groundwater (Weaver *et al.*, 2007). The pH parameter is a measurement of the acidity or alkalinity of the water while the conductivity is the ability of the groundwater to conduct electrical current. Electrical conductivity is a function of temperature, types of ions present and the concentrations of the ions (Saalidong *et al.*, 2022). The total dissolved solids, (TDS) an index of conductivity, has a direct relationship to salinity and elevated TDS concentrations can limit the suitability of water for potable usage (Thirumalini and Kurian, 2009).

Fluoride, when present in drinking water at a concentration of about 1 milligram per litre (mg/L), can aid in the prevention of dental cavities. However, exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis (WHO, 2008). Nitrate may arise from the excessive application of fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater (Richard *et al.*, 2014). The nitrite ion contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate and because of its solubility and its anionic form, nitrate is very mobile in groundwater (Fytianos and Christophoridis, 2004) and it also tends not to adsorb or precipitate on aquifer solids (Hem, 1985). High chloride and sodium contents may impart saline taste, which may affect its acceptability for potable purposes and also high concentration of sulphate are known to give bitter taste and also cause laxative effect (Nyarko, 2008).

Calcium (Ca) is obtained mainly from rocks containing limestone and gypsum. Small amounts come from igneous and metamorphic rocks while potassium occurs essentially in rock-salt deposits. Wastewater from industries and agricultural practices through excessive use of potash-rich fertilizers can also increase the potassium levels in groundwater (Nyarko, 2008).

Changes in water quality occur progressively, except for those substances that are discharged or leach intermittently to flowing surface waters or groundwater supplies, such as, contaminated landfill sites. Hardness is a property of water that determines its ability to easily form lather with soap (Nyarko, 2008). Total hardness is directly related to the concentrations of calcium and magnesium. The presence of Fe and Mn in ground water can be attributed to when water gets into contact with mineral groups and the weathering product that contain iron or manganese. Their concentrations can also be affected by wastewater from chemical industries. Excessive amount of iron and manganese are objectionable for both domestic and industrial water supplies because of their tendency to stain laundry and plumbing fixtures (Nyarko, 2008).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study areas as were; Ikpoba Hill and Sapele Road/Old Sapele Road in Benin City, Edo State, Nigeria. Sapele Road and the old Sapele road traverses several communities such as Ekae, Etete and Ikopokan within Ikpoba-Okha Local Government Area (LGA) whilst Ikpoba Hill is an urbanized section of the Ikpoba river valley also located in Ikpoba LGA and harboring several communities such as Ikpoba waterside and Temobga respectively.

The broader Benin region is part of the Benin formation. The soil profile is generally made up of reddish-brown sandy laterite, interspersed with layers of porous sands, sandy clays, and other unconsolidated sediment that result from long periods of chemical weathering. The land elevation in Benin City is known to vary: the northern parts (like some parts of Ikpoba) are at higher elevation — about 122–155 m above sea level — while southern parts drop to about 30 m. There are intermittent layers of sand which are aquiferous, and thickness of aquiferous formations vary; in Okha community (along Sapele Road) for example, geophysical surveys has revealed that the aquifer zones lie at depths up to ~93.4 m.

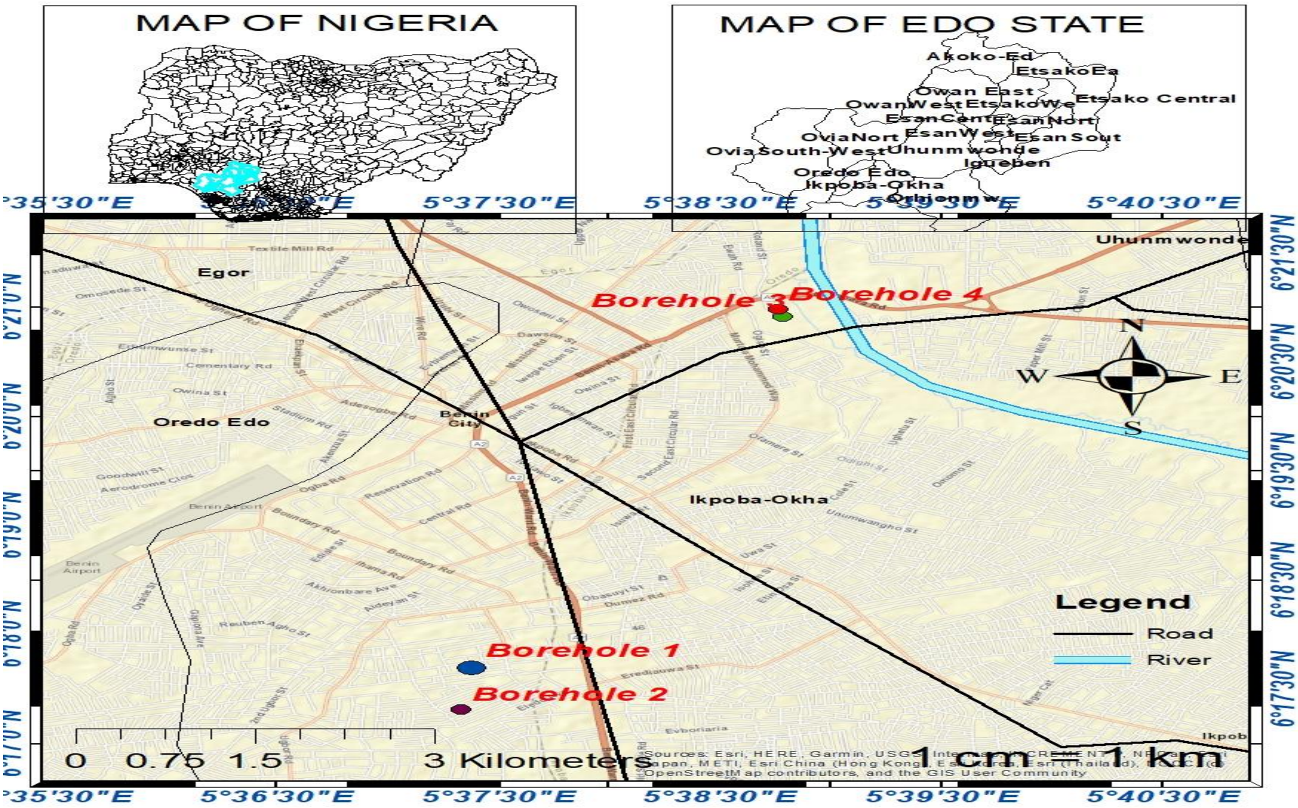

Figure. 1: Map of the study locations

3.2. MEASUREMENT OF THE DISTANCE

The distance was measured from the boreholes to the septic tanks using a tape rule. The water samples were transported to the laboratory for physicochemical and bacteriological evaluation with a few hours of collection.

3.2.1 COLLECTION OF WATER SAMPLES

Fresh ground water samples were collected from borehole pumping machines located close to septic tanks in 4 (2 each) residential premises in both Ikpoba Hill and Sapele Road respectively. The water samples were collected with the aid of properly labeled clean plastic containers.

3.3. *In situ* determination of temperature, pH, Electrical Conductivity (EC) and Total dissolved solids (TDS)

Field *in situ* measurement of temperature, pH, EC and TDS were done using the calibrated probe of the multimeter; Searchtech multifunction water quality meter C-600.

3.3.1. Nitrate determination

The nitrate content of the respective water samples was determined using the Cadmium reduction method (APHA 4500 NO_3^-- E). After switching on the Spectrophotometer, the program number 543 nm for nitrate determination was entered. The content of one Nitraver 5 reagent powder pillows was added to 25ml of water sample in conical flask. The flask was closed and the content was shaken vigorously for at least 3 minutes. After 10 minutes, for each conical flask, the contents were respectively placed into the curvette and inserted into the spectrophotometer. The spectrophotometer (Hach DR 3900 UV-Vis spectrophotometer) was calibrated to zero using the 0.0 standard concentration (Blank) and following the manufacturer's directions. The resultant nil absorbance value was indicated in the absorbance column on the lab sheet. Rinse the sample cell three times with distilled water. Proceed with determining the absorbance for the respective water sample and compute nitrate concentrations from the samples directly from prepared standard curve

3.3.2. Ammonia-Nitrogen (NH_4-N_2) determination

Twenty-five (25) ml of the water sample was dispensed onto 50 ml volumetric flask. Ten (10) ml of phenol-nitroprusside buffer was added and the mixture was swirled gently to mix. Twenty-five (25) ml of hypochlorite reagent was then added to the 50 ml volumetric flask. A stopper was placed at the entrance of the flask and the mixture was inverted to ensure proper mixing. The flask was left for about 45 minutes to ensure the development of a blue color. The absorbance of the colored mixture was taken at 635 nm using a spectrophotometer (Hach DR 3900 UV-Vis spectrophotometer). A reagent blank was also prepared and the absorbance at 635 nm was also taken.

3.3.3. Iron (Fe), Manganese (Mn), Cadmium (Cd), Copper (Cu), Lead (Pb) and Chromium (Cr) Evaluation

The concentration of the respective heavy metals (Fe, Cd, Cu, Cr, Pb) and Mn present in the water samples were determined with the aid of an Atomic absorption spectrophotometer (shimadzu AA-7000). Appropriate standards of known concentrations of the respective metals were prepared and used to calibrate and auto zero the electrode. The water samples were dispensed onto sterile plastic bottles. After calibrating and auto zeroing the electrodes, the samples were read at specific wavelengths and printed results sheets were examined. The final concentration of the respective metals was deduced.

3.4. Determination and Enumeration of Mean Total and Fecal Coliform Counts

The total and fecal coliform counts for the respective water samples was determined using membrane filtration and agar plate technique as described by Forster and Pinedo (2015) as well as Cappuccino and Welsh (2020). The membrane filter utilized was a nitrocellulose membrane and had a diameter of 47 mm and a pore size of 0.45 µm. Prior to usage, all the membrane filters as well as the filtration column were sterilized by autoclaving at 121°C for 15 mins. A grid was printed on the membrane to assist with counting bacterial colonies after incubation. The tubing of the vacuum pump was inserted into the side arm of flask in connecting the pump to the sterilized filtration column. Forceps which were to used in the filtration procedure were sterilized by dipping in ethanol and passing through flame emanating from a Bunsen burner. The top chamber of the column was removed and with the aid of the sterile forceps, the sterile filter membrane was placed on the top of the catchment vessel. Using the squirt bottle, a small volume of sterile water was poured into the filtration set-up and the vacuum pump was switched on for a few seconds to get the membrane wet. The covering lid of the filtration column was placed back on the column before the vacuum pump was switched on.

About 100 ml of the respective sample was decanted onto the filtration column connected to the vacuum pump. During this process, which was done under aseptic conditions, the pump was switched on and the water samples were filtered through the membrane filter into the catchment chamber of the filtration column. During the procedure, care was always taken to prevent catchment chamber of the column to be completely filled with water which would cause water to be sucked into the pump, damaging the vacuum system. At the end of each filtration run for each sample, the squirt bottle which contained sterile water was used to rinse the walls of the tower. With the aid of sterilized forceps, the membrane filters were transferred into prepared MacConkey agar (MCA) plates and Eosin methylene blue agar (EMB) plates respectively. The MCA agar plates were incubated at 37 ^{O}C for 48 hours and the presence of distinguishable red colored coliform colonies were documented and enumerated as total coliform counts (Bridson, 2006). The EMB agar plates were incubated at 44^{O}C for 24 to 48 hours and the presence of differential coliform colonies having a unique green metallic sheen was documented and enumerated as *Escherichia coli* (Bridson, 2006).

3.5. Data Analysis

All the data obtained from the analysis of the water samples were subjected to the Mann-Whitney non parametric T test using the statistical software; SPSS version 22. This inferential unpaired T test was done at 0.05 level of confidence, after the test for normality revealed that the data were not normally distributed.

CHAPTER FOUR

RESULTS

4.1. Distances between Boreholes and Septic tanks (sanitary facilities)

The distances recorded between the septic tanks and the boreholes is presented on Table 1. Borehole B in Sapele Road had a distance of 32m which is above the NESREA recommended standard of 15m for siting water away from onsite sanitation facilities. Borehole D in Ikpoba Hill had a distance of 11.8m which was within NESREA recommended standard.

Table 1: Measured distances (m) between the boreholes and the nearest sanitary facility

Boreholes	Distance to onsite Sanitation facility (m)	NESREA limit
A	24	Within limit
B	32	Within limit
C	12	Below limit
D	11.8	Below limit

Key: A= Sapele Road (house 1), B= Sapele Road (house 2), C= Ikpoba Hill (house 1), D= Ikpoba Hill (house 2)

4.2. Physicochemical profiles of the respective water samples

The results of the physicochemical assessment of the ground water samples are shown in Table 2. The pH values ranged from 4.3±0.01 for borehole D to 5.2±0.5 for borehole A, while the Electrical conductivity (EC) values varied from 19 µs/cm±0 to 133 µs/cm±0 in borehole C and borehole B respectively. The total dissolved solids (TDS) values ranged from 9±0 mg/L to 66±0 mg/L in borehole C and borehole B respectively. Ammonia-nitrogen and nitrate values ranged from 0.85mg/L±0.17 for borehole C to 1.50 mg/L ±0 for borehole B and 0.46 mg/L ±0.11 for borehole A to 0.71 mg/L ±0.04 for borehole D. The observed differences among the pH, EC, TDS, ammonia-nitrogen and nitrate values were not significant ($p > 0.05$) (Appendix 1).

Table 2: Physiochemical qualities of the water samples

Physiochemical parameters	BOREHOLE A	BOREHOLE B	BOREHOLE C	BOREHOLE D	NERSEA LIMITS
Ph	5.2 ± 0.5	4.7± 0.6	4.4 ± 0.007	4.3 ± 0.01	6.5-8.5
Electrical conductivity (µs /cm)	40 ± 0	133 ± 0	19 ± 0	53 ± 0	1000
Total dissolved solids(mg/L)	21 ± 0.7	66 ± 0	9 ± 0	26 ± 0	500
Nitrate (mg/L)	0.46 ± 0.11	0.67 ± 0.07	0.53 ± 0.09	0.71± 0 0.04	10
Ammonia-Nitrogen (mg/L)	1.01 ± 0.03	1.50 ± 0.77	0.85 ± 0.17	1.04 ± 0.02	0.5

The results of fecal and total coliform enumeration in all water samples from all boreholes revealed that there was no fecal and total coliform present per 100ml of water sampled. This was within the NESREA limit of zero (0)/100m.

CHAPTER FIVE

DISCUSSION

The results of this study provide critical insight into the influence of on-site sanitation systems on groundwater quality in parts of Benin City, specifically Ikpoba Hill and Sapele Road. The measured distances between boreholes and septic tanks ranged from 11.8 m to 32 m, indicating that two boreholes (A and B) met and exceeded NESREA minimum recommended separation distance of 15m, while boreholes C (12m) and D (11.8m) were situated below the required standard. This suggests a potential vulnerability to groundwater contamination in locations where siting distances was inadequate, particularly under conditions of shallow water tables or high soil permeability. However, the physicochemical and bacteriological analyses revealed results that were within safe limits for most parameters, indicating a relatively low current risk of contamination.

The pH values (4.3±0.01-5.2±0.5) observed across all samples fell slightly below the NESREA permissible range (6.5–8.5), showing that the groundwater in both study locations is slightly acidic. Such acidity may result from the dissolution of carbon dioxide and organic acids within the soil profile or from leaching of acidic compounds from nearby sanitation leachates and organic matter decomposition. Similar trends of low pH have been reported by Aydin (2007) in studies of groundwater influenced by septic systems. Although the pH is not immediately harmful, prolonged exposure to acidic water can cause corrosion of plumbing materials and alter the solubility of heavy metals.

Electrical conductivity (EC) and total dissolved solids (TDS) ranged from 19±0-133±0 µS/cm and 9±0 – 66±0 mg/L, respectively. These values indicate low mineralization and ionic content, implying limited leachate infiltration or mineral dissolution. The statistical analysis (Mann–Whitney U test, $p > 0.05$) confirmed that there was no significant difference between groundwater from Ikpoba Hill and Sapele Road. This suggests that both environments currently exhibit similar hydrogeological characteristics and pollutant profiles. Low EC and TDS values align with the findings of Erah *et al.*

(2002), who observed that well-drained sandy soils in Benin Formation enhance percolation but also facilitate natural attenuation of pollutants.

Nitrate concentrations ranged from 0.46±0.11mg/L – 0.713±0.04 mg/L, which was below NESREA limits of 10 mg/L, while ammonia-nitrogen values varied between 0.85±0.17 mg/L – 1.50±0.77 mg/L, which was above NESREA limits of 0.5 mg/L. The presence of low nitrate levels, even at short distances between wells and septic tanks, implies that denitrification and soil filtration processes are effectively limiting nitrogen mobility. According to Lapworth *et al.* (2017), nitrogen transformation through nitrification and denitrification in unsaturated zones significantly reduces nitrate loading to groundwater when the water table is relatively deep and soil aeration is good. The slightly elevated ammonia levels at some points could indicate localized anaerobic decomposition of organic matter within the septic leachate zone.

Microbiological assessment revealed no detectable total or fecal coliforms in all samples. This result suggests that the boreholes are properly constructed, sealed, and protected from direct surface infiltration. The absence of *Escherichia coli* and other coliform bacteria demonstrates that the soil medium still provides effective natural filtration and pathogen attenuation. This finding supports the observation of Pedley and Howard (1997) that microbial contaminants are largely filtered or die off within a few meters of percolation through unsaturated soils, provided the water table is not too shallow.

Overall, while the data indicate minimal contamination at present, the close proximity of some boreholes to septic tanks (less than 15 m) remains a potential threat to future water quality, particularly in the face of fluctuating water tables, seasonal flooding, or increased urbanization. The results highlight the importance of maintaining proper siting distances, ensuring borehole integrity, and conducting periodic water quality monitoring. Hence, even though the physicochemical and microbiological quality of groundwater in Ikpoba Hill and Sapele Road currently meets safety standards, continuous vigilance is necessary to prevent future degradation.

5.1. Conclusion and Recommendations

This study revealed that aside from the ammonia-nitrogen content, all other physiochemical and bacteriological (coliform) parameters determined for the water samples were within the regulatory limits. Aside from borehole C and D the other boreholes (A and B) were sited well above the minimum distance (15m) from the nearest sanitary facilities (septic tank).

From this study it is recommended that sensitization be conducted to enlighten intending property owners with respect to the health implications of siting water sources from onsite sanitation facilities.

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APPENDICES

APPENDIX I

Mann-Whitney Test

Ranks

	Samples	N	Mean Rank	Sum of Ranks
pH	1	4	5.50	22.00
	2	4	3.50	14.00
	Total	8		

Test Statistics[a]

	Ph
Mann-Whitney U	4.000
Wilcoxon W	14.000
Z	-1.155
Asymp. Sig. (2-tailed)	.248
Exact Sig. [2*(1-tailed Sig.)]	.343[b]

a. Grouping Variable: Samples

b. Not corrected for ties.

Ranks

	Samples	N	Mean Rank	Sum of Ranks
EC	1	4	5.50	22.00
	2	4	3.50	14.00
	Total	8		

Test Statistics[a]

	EC
Mann-Whitney U	4.000
Wilcoxon W	14.000
Z	-1.183
Asymp. Sig. (2-tailed)	.237
Exact Sig. [2*(1-tailed Sig.)]	.343[b]

a. Grouping Variable: Samples

b. Not corrected for ties.

Ranks

	Samples	N	Mean Rank	Sum of Ranks
TDS	1	4	5.50	22.00
	2	4	3.50	14.00
	Total	8		

Test Statistics[a]

	TDS
Mann-Whitney U	4.000
Wilcoxon W	14.000
Z	-1.176
Asymp. Sig. (2-tailed)	.240
Exact Sig. [2*(1-tailed Sig.)]	.343[b]

a. Grouping Variable: Samples

b. Not corrected for ties.

Ranks

	Samples	N	Mean Rank	Sum of Ranks
NH_3-N_2	1	4	4.88	19.50
	2	4	4.13	16.50
	Total	8		

Test Statistics[a]

	NH_3-N_2
Mann-Whitney U	6.500
Wilcoxon W	16.500
Z	-.436
Asymp. Sig. (2-tailed)	.663
Exact Sig. [2*(1-tailed Sig.)]	.686[b]

a. Grouping Variable: Samples

b. Not corrected for ties.

Ranks

	Samples	N	Mean Rank	Sum of Ranks
NO_3	1	4	4.00	16.00
	2	4	5.00	20.00
	Total	8		

Test Statistics[a]

	NO_3
Mann-Whitney U	6.000
Wilcoxon W	16.000
Z	-.577
Asymp. Sig. (2-tailed)	.564
Exact Sig. [2*(1-tailed Sig.)]	.686[b]

a. Grouping Variable: Samples

b. Not corrected for ties.

APPENDIX II

Composition and preparation of media

Eosin Methylene Blue Agar (Oxoid)

Peptone	10.0g/l
Lactose	10.0g/l
Dipotassium hydrogen phosphate	2.0g/l
Eosin Y	0.4g/l
Methylene blue	0.065g/l
Agar	15.0g/l

Final pH 6.8 ± 0.2

Thirty-seven point five (37.5) grams of weighed powder was suspended in 1 L of distilled water. The mixture was stirred and autoclaved at 121^0 C for 15 minutes.

MacConkey Agar (Biolife)

	gm/litre
Peptone	20.0
Lactose	10.0
Bile salts	5.0
Sodium chloride	5.0
Neutral red	0.075
Agar	12.0

Final pH 7.4 ± 0.2 at 25^0C

Fifty-two (52) grams of the weighed powder was dissolved in 1 litre of distilled water. The mixture was stirred and mixed thoroughly. It was then sterilized by autoclaving at 121°C for 15 min.