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PHYSIOCHEMICAL AND BACTERIOLOGICAL ANALYSIS OF UNDERGROUND WATER SOURCE FROM AKIAMA AND MARCULAY COMMUNITIES IN BONNY ISLAND, RIVERS STATE. NIGERIA

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Abstract: The research is an investigative study carried out to determine the bacteriological and physiochemical parameter of underground water, well water in relation to portable water supply in Akiama and Marculay communities in Bonny Island, Rivers State, Nigeria. Water samples each of borehole water sources were collected using purposive sampling method within the communities in Bonny Island. Physiochemical parameters were determined using methods and procedure which include temperature, salinity, total dissolve solids(TDS),electrical conductivity and pH within the acceptable range and standard set by World Health Organization(WHO) and Nigeria Standard For Drinking Water Quality (NSDWQ). The total coliforms and identification of isolates were determined by pour plate technique. The analysis observed bacteria which Escherichia coli, Samonelia sp, Shigella sp, Enterococus sp, Proteus sp, Pseudomonas aeruginosa and Staphylococcus aureus were islated and found present in water samples. The study has shown that from microbiological parameters evaluated which indicate that water are not safe for consumption i.e bacteriological qualities shows health risk to the inhabitant while water samples from boreholes met the internationally recommended physicochemical standards for WHO and NSDWQ for potable water in Akiama and Marculay communities.

Keywords: *Physiochemical, water sources, parameters, portable water supply*

1. INTRODUCTION

In Nigeria as a country, it is only about 40% of the population that have access to safe water; with only about 25% of households in this group with access to pipe-borne water (Aluko, 2004). This only go further to show the level of decay and incompetence existing contamination of a number of surface water sources, as shown by several studies by (Nduka,Orisakwe & Ezenweke, 2008; Ifabiyi, 2008b ; Nguumbur 2003; Anyam, Aja). The inability of the State Water Boards to provide adequate water for its urban population is linked to a number of factors such as population growth, expansion of towns, technical and managerial problems and the ageing of water treatment plants and distribution systems. As a result, most urban dwellers have turned to alternative sources such as hand-dug wells, boreholes, streams and water vendors.

Groundwater refers to fresh water (from downpour or softening ice and snow) that douses into the earth (soil) and is stored away in the little spaces (pores) among rocks and particles of soil. Groundwater represents almost 95% of the nation’s fresh water resources. It can remain underground for a huge number of years, or it can rise to the top and help fill waterways, streams, lakes, lakes, and wetlands. Groundwater can likewise rise to the top as a spring or be siphoned from a well. Both of these are normal ways we get groundwater to drink. Around 50% of our civil, homegrown, and horticultural water supply is groundwater. Increasing urbanization is occurring along the seaside and this has brought about the deterioration of groundwater quality in the coastal areas either by natural means such as salt water intrusion or by anthropogenic interference. (Amadi et al, 2010). Ground water from borehole is the most well-known source of drinking water in Bonny Island for ages considering the fact that the island is located in the Atlantic Ocean. Poor water quality monitoring have existed for ages in Bonny. Ground water projects are not really managed by experts in Nigeria.

Most communities in Niger delta such as area as Brass, Andoni , Ogoni and Bonny L.G.A are in high demand of quality drinking water. Especially in Bonny island are facing an acute shortage of portable water due to problem of high iron water, salt water intrusion and tidal influences and consequently a lot of boreholes are abandoned in the area (Nwankwoala & Udom, 2008). The geographic location of Bonny Island is another source of concern since its inhabitants are surrounded by the ocean and cut away from foreign aid via transportation of portable water from other neighboring communities. Ground water in Bonny is highly polluted through uncontrolled disposal of domestic and industrial waste such as gas flaring, agricultural waste etc on the environment which ends up affecting the water cycle and its purity and ends up been stored in the soil as underground water. The main sources of microbiological contaminations are microorganisms from human and animal excreta which reaches human through contaminated water from waste water landfills or waste water treatment stations causing serious health problems, i.e. most of the gastrointestinal infections that may be transmitted via-oral pathway (WHO 2010). The effect of improvements in the quality of ground water was felt on the combat against endemic diseases such as typhoid and cholera in adults and diarrhea in children (AlKhatib & Orabi 2004). An appropriate assessment of groundwater requires the concentrations of the physical, chemical and biological parameters (WHO, 2010). Upsurge in the population in Bonny Island have resulted in the pollution of nearby river that would have supplemented the groundwater by various human activities in the area such as oil spillage and poor sanitation habits. (Amadi 2011, Nwankwoala 2010).

2. LITERATURE REVIEW

The United Nations (UN) set a goal in their Millennium Declaration to reduce the amount of people without safe drinking water by half in the year 2015 (UN, 2000). Safe drinking water for human consumption should be free from pathogens such as bacteria, viruses and protozoan parasites, meet the standard guidelines for taste, odour, appearance and chemical concentrations, and must be available in adequate quantities for domestic purposes (Kirkwood, 1998). However, inadequate sanitation and persistent faecal contamination of water sources is responsible for a large percentage of people in both developed and developing countries not having access to microbiologically safe drinking water and suffering from diarrhoeal diseases (WHO, 2002a; WHO, 2002b). Diarrheal diseases are responsible for approximately 2.5 million deaths annually in developing countries, affecting children younger than five years, especially those in areas devoid of access to potable water supply and sanitation (Kosek *et al.*, 2003; Obi *et al*., 2003; Lin *et al*., 2004; Obi *et al*., 2004). Political upheaval, high numbers of refugees in some developing countries, and the global appearances of squatter camps and shanty rural towns, which lack proper sanitation and water connections, have contributed to conditions under which disease-causing microorganisms can replicate and thrive (Leclerc *et al*., 2002; Sobsey, 2002; Theron & Cloete, 2002). The people most susceptible to waterborne diseases include young children, the elderly, people suffering from malnutrition, pregnant woman, immune compromised individuals, people suffering from chemical dependencies and persons predisposed to other illnesses like diabetes (Sobsey *et al*., 1993; Gerba *et al*., 1996; Grabow, 1996; Leclerc *et al*., 2002; Theron & Cloete, 2002). Furthermore, an increasing number of people are becoming susceptible to infections with specific pathogens due to the indiscriminate use of antimicrobial drugs, which have led to the selection of antibiotic resistant bacteria and drug resistant protozoa (WHO, 2002c; NRC, 2004).

In developing countries, many people are living in rural communities and have to collect their drinking water some distances away from the household and transport it back in various types of containers (Sobsey, 2002). Microbiological contamination of the water may occur between the collection point and the point-of-use in the household due to unhygienic practices causing the water to become a health risk (Sobsey, 2002; Gundry *et al*., 2004; Moyo *et al*., 2004). To improve and protect the microbiological quality and to reduce the potential health risk of water to these households, intervention strategies is needed that is easy to use, effective, affordable, functional and sustainable (CDC, 2001; Sobsey, 2002). Many different water collection and storage systems have been developed and evaluated in the laboratory and under field conditions (Sobsey, 2002). In addition, a variety of physical and chemical treatment methods to improve the microbiological quality of water are available (Sobsey, 2002). The aim of this study was to improve the microbiological quality of drinking water in rural households by the implementation of intervention strategies which include the use of traditional storage containers as well as the CDC safe storage container, with or without the addition of a sodium hypochlorite solution at the point-of-use.

2.1 CONCEPT OF WATER

Water is one of the most important and most valuable natural resources. It is essential in the life of all living organisms from the simplest plant and microorganisms to the most complex living system known as human body. Water is significant due to its unique chemical and physical properties and is known to be the most abundant compound (70%) on earth]. Water in its pure form has a pH value of 7.0, freezing point of 0°C and boiling point of 100°C at 760 mmHg. It is also a colorless, transparent, odorless and tasteless liquid. Access to safe drinking water has improved over the last decades in almost every part of the world especially Nigeria, but approximately 1.1 billion people still lack access to safe water and over 2.6 billion worldwide lack access to adequate sanitation which causes water illnesses such as Cholera, diarrheal disease, Botulism, *E. coli* infection, Dysentery, Legionellosis, Leptospirosis, Salmonellosis, Typhoid fever, and Vibrio illness. The presence of nitrate compounds, heavy metals, pesticides etc. in our drinking water can also constitute undesirable pollutant when they are not within World Health Organization (WHO) guidelines for drinking water. However, inadequate sanitation and persistent faecal contamination of water sources is responsible for a large percentage of people in both developed and developing countries not having access to microbiologically safe drinking water and suffering from diarrhoeal diseases (WHO, 2002a; WHO, 2002b). Diarrhoeal diseases are responsible for approximately 2.5 million deaths annually in developing countries, affecting children younger than five years, especially those in areas devoid of access to potable water supply and sanitation (Kosek *et al.,* 2003; Obi *et al*., 2003; Lin *et al*., 2004; Obi *et al*., 2004).

2.2 SOURCES OF WATER SUPPLY

The World Health Organization (WHO) classifies source water supplies as either improved or unimproved (WHO, 2000; Gundry *et al*., 2004). Unimproved water sources include unprotected wells, unprotected springs, vendor-provided water, rivers as well as tanker truck provision of water (WHO, 2000; Gundry *et al*., 2004). Water supplies in developing countries are devoid of treatment and the communities have to make use of the most convenient supply (Sobsey, 2002; Moyo *et al*., 2004). Many of these water supplies are unprotected and susceptible to external contamination from surface runoff, windblown debris, human and animal faecal pollution and unsanitary collection methods (Chidavaenzi *et al*., 1998; WHO, 2000; Moyo *et al*., 2004). The World Health Organization

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(WHO) classifies source water supplies as either improved or unimproved (WHO, 2000; Gundry *et al*., 2004). Improved water sources include public standpipes, household connections, boreholes, protected dug wells, protected springs, boreholes and springs connected via a pipe system to a tap, as well as rainwater collection (WHO, 2000; Gundry *et al*., 2004). Unimproved water sources include unprotected wells, unprotected springs, vendor-provided water, rivers as well as tanker truck provision of water (WHO, 2000; Gundry *et al*., 2004). Several studies carried out in developing countries have determined the microbiological quality of these improved and unimproved water sources and depending on the water source, different results were obtained (Pournadeali & Tayback, 1980; Obi *et al*., 2002; Sobsey *et al*., 2003; Gundry *et al*., 2004; Obi *et al*., 2004). Studies conducted in Iran (Pournadeali & Tayback, 1980) and in northern Sudan (Musa *et al*., 1999) have both showed that water at communal taps were microbiologically of a better quality than untreated irrigation canal water. Contrary to these findings, a study in Burma (Han *et al*., 1989) has showed that tube well and shallow well water supplies were microbiologically of a better quality than municipal tap water and pond water source supplies.

2.2.1 WATER COLLECTION FROM THE SOURCE WATER SUPPLY

In most developing countries, women are responsible for the collection of water (Sobsey, 2002). The work involved in fetching the water may differ in each region, it may vary according to the specific season, it depends on the time spent queuing at the source, the distance of the household from the source and the number of household members for which the water must be collected (WHO, 1996b; WHO, 1996c). Water for domestic use is collected either by dipping the container inside the water supply, collecting rainwater from a roof catchment system or by using different types of pumps connected to the water supply system (Sobsey, 2002). The transportation of the water from the source water supply could be either by a wheelbarrow, a donkey car, a motor vehicle, using a rolling system or by carrying the container by hand or on the head (CDC, 2001). A common practice often seen in rural areas was the use of leaves or branches with leaves to stop water slopping out during transit in wide-neck storage and transport containers (Sutton & Mubiana, 1989). Consequently, a study by Sutton and Mubiana (1989) has showed that these leaves can be an additional source of coliform bacteria to the drinking water.Water sources could be some distance away from the households, particularly in rural areas (WHO, 1996b; WHO, 1996c). In studies conducted in Malawi, Kenya, Uganda and Tanzania (Lindskog & Lundqvist, 1989; White *et al*., 2002), it was found that if the water taps were situated closer to the dwelling, the amount of water collected/person/day increases from 9.7 to 15.5 litres. Studies in Mosambique (Cairncross & Cliff, 1987) showed that households collect on average 11.1 litres of water/person/day if the source is less than 300 m from the dwelling, while the households who have to walk more than 4 km collected on average 4.1 litres of water/person/day. In Lesotho, Esrey and co-workers (1992) made a rough estimate of 10 litres of water/person/day based on direct observations of households in rural communities. Studies in rural communities in the Limpopo Province of South Africa (Verweij *et al*., 1991) showed that on average 11.4 litres of water/person/day was collected if the source was close to the household, compared to an average of 8.6 litre of water/person/day if the sources were more than 1 km from the household. The Department of Water Affairs and Forestry in South Africa recommends 25 litre/person/day from a source within a distance of 200 m from the dwelling (DWAF, 1994) and the WHO estimates a minimum of 20 litres of water/person/day is sufficient (WHO, 1996b), while Gleick (1998) recommends 50 litres of water/person/day is efficient.

These studies indicated that more water was collected per person per day if the source was closer to the dwelling

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(White *et al*., 2002; Lindskog & Lundqvist, 1989; Verweij *et al*., 1991).Very few studies have investigated the microbiological quality of water during collection and transportation. In a study in Rangoon, Burma (Han *et al*., 1989) the water at the source and during collection were analysed and indicated that the faecal coliform counts in the collection samples were higher than the counts in the source water samples (Han *et al*., 1989). The increase in faecal contamination of the water in the collection containers after collection from the source could have been due to unhygienic handling of the water and posed a potential health risk of diseases to the consumers (Sobsey, 2002). In a study in Sri Lanka (Mertens *et al*., 1990) it was found that only 5% of tube well water samples were contaminated if the pump was sterilised prior to collection of the sample compared to 50% if the pump was not sterilised. This implied that the taps were contaminated by hands or animals during collection (Mertens *et al*., 1990).In another study in rural communities in South Africa (Verweij *et al*., 1991), water samples were taken immediately after collection from communal taps and unprotected borehole and springs. Special precautions were taken to prevent contamination during collection, which included rinsing of the container before filling, using a calabash to scoop water from the source and demarcation of a special area for water collection (Verweij *et al.*, 1991). The results from this study indicated no significant difference between faecal coliform counts at the source and immediately after collection of the water (Verweij *et al.*, 1991). The drawbacks of this study however included the sample size (only 8 households were studied), and inadequate information given regarding who collected the water samples e.g. a technician or a woman from the study households (Verweij *et al*., 1991). A study carried out in a Malawi refugee camp has found that hands are primarily responsible for contamination of collected water because the women rinses the container with small amounts of water using their hands to rub around the container opening in an effort to clean it (Roberts *et al*., 2001). A study by Dunker (2001) has concluded that rural communities in South Africa spent little time on proper cleaning of the collection containers, especially if water has to be collected more than once a day.These studies have shown that although the microbiological quality of the source water could be classified as safe for domestic purposes, the water collected by the households from these sources, become contaminated after collection (Sobsey, 2002).

2.3 WATER QUALITY PARAMETERS

Water quality is determined by physical, chemical, and microbiological with wide variability. These include:

2.3.1 PHYSICAL CHARACTERISTICS OF WATER*:* these are (temperature, color, taste, odor, turbidity, solids) and are determined by senses of touch, sight, smell, and taste.

- **Temperature** of water affects the thermal capacity, density, specific weight, viscocity, surface tension, specific conductivity, salinity, chemical and biological reaction rate, solubility of dissolved gasses. The temperature of streams and rivers around the world varies from 0 to 35^{0}C.
- **Color** in water is primarily a concern of water quality, colored water gives the appearance of being unfit to drink, even though the water may be safe for public use. Color can indicate the presence of organic substances as algae or humid compounds. More recently, color has been used as a qualitative assessment of the presence of potentially hazardous or toxic organic materials in water. Color can be caused by decaying leaves, plants, organic matter, copper iron, and manganese which may be objectionable. Color also indicates large amount of organic chemicals, inadequate treatment etc.
- **Taste and odor**, there are different perception of taste which include: sour (hydrochloric acid), salty (sodium chloride), sweet (sucrose) and bitter (caffeine). Certain odors may be indications of organic or inorganic contaminants that originate from municipal or industrial waste discharges or from natural sources. Materials

discharged directly into water such as runoff etc. are sources of taste and odor producing compounds released during biodegradation in water.

- **Turbidity** is a measure of the light transmitting properties of water and is comprised of suspended and colloidal materials. It is important for health and aesthetic reasons. Turbidity is caused by the presence of suspended matter such as clay, silt, and fine particles of organic and inorganic matter, plankton, and other microscopic organism. It indicates a measure of how much light can filter through the water sample.

Solids are classified as settle able solids, suspended solids, and filterable solids. Settle able solids (silt and heavy organic solids) are the ones that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass fiber filters. The total soled of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight.

2.3.2 CHEMICAL CHARACTERISTICS OF WATER*:* the chemical characteristics of water are a reflection of the soils and rocks with which the water has been in contact. These include:

- **Cations** such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) are found in water. Calcium is the most prevalent cation in water and second inorganic to bicarbonate in most surface water.
- **Anions** such as chloride (Cl^{-}), sullphate (SO_4^{2-}) and nitrates (NO^{3-}) is the principle anion found in water. They are responsible for great measure of alkalinity of water.
- **P^H and alkalinity:** P^H is the measure of alkalinity and acidity in water. Alkalinity is defined as the capacity of water to neutralize acid added to it. Acidity is the quantitative capacity of aqueous media to react with hydroxyl ions.
- **Hardness** is correlated with TDS (total dissolved solids). This is a result of metallic ions dissolved in water, reported as concentration of calcium carbonate. Calcium carbonate is derived from dissolved limestone or discharge from operating or abandoned mines. It represents total concentration of Ca^{2+} and Mg^{+} ions in water. Also Fe^{2+} may contribute.
- **Total dissolved solids (TDS)** is a measure of salt dissolved in a water sample after removal of suspended solids.
- **Conductivity** is related to TDS. Conductivity measures the capacity of water to transmit electrical current. As the conductivity increases, the TDS increases. Conductivity and TDS affects the water sample and the solubility of slightly soluble compounds and gases in water.
- **Biological oxygen demand (BOD)** is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic matter. The BOD5 is widely used, it is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 200C.

Chemical oxygen demand (COD) test of natural water yields the oxygen n equivalent of the organic matter that can be oxidized by strong chemical oxidizing agents in an acidic medium.

2.3.3 BIOLOGICAL CHARACTERISTICS OF WATER: these include plants, protists, and animal. Coliform organisms have been used to determine the biological characteristics of natural waters. The coliform group of bacteria are aerobic and/ or facultative gram negative, non-spore forming rod shaped bacteria that ferment lactose to gas. *Echerichia* coli is commonly used as an indicator organism. This organism is present in the intestine of warm blooded Water supplies in developing countries are devoid of treatment and the communities have to make use of the most convenient supply (Sobsey, 2002; Moyo *et al*., 2004). Many of these water supplies are unprotected and susceptible to external contamination from surface runoff, windblown debris, human and animal faecal pollution and un sanitary collection methods (Chidavaenzi *et al*., 1998; WHO, 2000; Moyo *et al*., 2004). Detection of each pathogenic microorganism in water is technically difficult, time consuming and expensive and therefore not used for routine water testing procedures (Grabow, 1996). Instead, indicator organisms are routinely used to assess the microbiological quality of water and provide an easy, rapid and reliable indication of the microbiological quality of water supplies (Grabow, 1996).

Although many microorganisms have desirable features to be considered as possible indicators of faecal pollution, there is no single microorganism that meets all of these requirements (Moe *et al*., 1991; Payment and Franco, 1993; Sobsey *et* al., 1993; Sobsey *et al*., 1995). Several studies have showed the limitations of some of the current indicator organisms, which include the following: Indicator organisms may be detected in water samples in the absence of pathogens (Echeverria *et al.*, 1987). Some pathogens may be detected in the absence of indicator organisms (Seligman & Reitler, 1965; Thompson, 1981). Echeverria (1987) has showed that *Vibrio cholera* (*V. cholera*) persists in water exposed to solar disinfection well after *E. coli* was inactivated. El-Agaby (1988) has showed that potable water supplies in Egypt contained bacteriophages, with zero total and faecal coliform counts, which indicated the possible risk of the presence of human enteric viruses. Thompson (1981) has showed that *E. coli* bacteria have a short die-off curve with temperature playing an important role. McFeters (1986) have showed that injured coliform bacteria can be undetected due to several chemical and physical factors and were unable to grow on commonly used media. LeChevallier (1996) have showed that improper filtration, temperature, inadequate disinfection and treatment procedures, biofilms and high assailable organic carbon (AOC) levels, could all be responsible for the regrowth of coliform bacteria in water samples. Regli (1991) has showed that the prevalence of viruses in water may differ from that of indicator organisms. Low numbers of viruses are present in water samples compared to indicator organisms, viruses are only excreted for short periods of time while coliform bacteria is excreted continuously, and the structure, size, composition and morphological differences between viruses and bacteria also had an influence on behavioral and survival patterns of these microorganisms (Regli *et al*., 1991; Hot *et al.*, 2003).In spite of the shortcomings of indicator microorganisms, it is better to use a combination of indicator microorganisms to give a more accurate picture of the microbiological quality of water (DWAF, 1996; NRC, 2004).

In general, every country has its own set of guidelines for drinking water. However, most of these guidelines are similar for different countries and the same indicator microorganisms to indicate the presence of pathogenic microorganisms are used. The most commonly used indicator microorganisms include heterotrophic plate counts, total coliform bacteria, faecal coliform bacteria, *E coli*, faecal enterococci, *C. perfringens* as well as somatic and male specific F-RNA bacteriophages (WHO, 2000). The presence of *Echerichia* coli in water samples indicates the presence of fecal matter and then the possible presence of pathogenic organism of human origin. The concentration of indicator organisms is reported in MPN/100ml (MPN=most portable number) or CFU/100ml (CFU= colony forming units).

2.4 GROUND WATER CONTAMINATION

Ground water contamination is defined as the addition of undesirable substances to groundwater casused by human activities (government of Canada 2017). Ground water contamination occurs when man-made products such as gasoline, oil, salts, uncontrolled hazardous wastes, landfills, septic systems, bacteria and chemicals get into the groundwater and cause it to become unsafe and unfit for human use. Materials from land surface can end up in the groundwater. (Ground water foundation, 2019). The numbers or classes of contaminants in ground water can be classified into three major types namely: (1) chemical contaminant (2) biological contaminants (3) radioactive contaminants. These contaminants can come from natural and anthropogenic sources (Environmental Contamination and Toxicology, 80, 1-10(2021). When human activities upset natural environmental balance, it can lead to depletion of aquifers leading to saltwater intrusion, acid mine drainage as a result of exploitation of mineral resources and leaching of hazardous chemicals as a result of excessive irrigation. (Su et al. 2020).

Any human activity at and near the land surface can be a source of contaminants to ground water as long as water and possibly other fluids move from the land surface to the water table. Chemical contamination of drinking water sources in Nigeria Exposure of several individuals to unsafe levels of chemical contaminants in drinking water has been reported (WHO, 2010). This lends credence to the importance of monitoring the level of metals in surface or ground water sources in other to determine their portability (UNEP, 2007). Chemicals are among the major ground and surface water contaminants affecting ground water quality. This is possible through vertical migration of chemical contaminants to the aquifer and extending to the borehole, or by horizontal migration through permeable soils to water supplies that are poorly constructed (MacDonald and Calow, 2009).

The surge in anthropogenic activities and natural processes such as erosion, precipitations, weathering and degradation have made most water sources unsuitable for purpose (Furhan et al., 2004). Livestock production activities and waste have been implicated as a major source of pollution to river bodies, especially when poorly managed (Kato et al., 2009). In the process, animal faeces and urine are released, which contaminate the water bodies and thus, render the water body unsafe for consumption by the surrounding communities. This problem is aggravated since in many communities in Nigeria, there are no access to treated pipe borne water for drinking and as well as for other domestic uses. The Nwinyi et al., 2020). Runoff of animal waste into surface water is reported to pose great risk of pollution (Kwadzah and Iorhemen, 2015). Rim-Rukeh et al. (2006) evaluated how agricultural activities impacted on the quality of Orogodo River in Delta State, Nigeria. This was carried out in a research study that involved 100 farmers' from Agbor and Owa communities. These farmers were asked questions on the frequency and method of irrigation practices they have adopted during different farm practices, most especially the use of fertilizers which normally result in water pollution. The sampling of the river was carried out at five different sampling stations along the river selected by testing the physicochemical properties of the river. The authors reported that the method adopted by the farmers constituted a major reason why the selected river was highly polluted. The difference in the selected parameters tested was linked to the runoff from farmlands and the capability of the river to undertake self-purification. The study also suggested that the contamination of Jakara River at both upstream and downstream and its use for irrigation purposes on vegetables could lead to the bioaccumulation of such heavy metals along the food chain (Rim-Rukeh et al., 2006). Orheruata and Omoyakhi (2008) also reported agricultural waste from poultry as an important source of pollution affecting the quality of drinking water in Nigeria. Adegbola and Adewoye (2012) assessed the effect of some sources of pollution on groundwater quality in wells from Gambari community in Ogbomosho, Nigeria. They reported that the most polluted wells that shown minimal satisfactory level were linked to their proximity to cassava processing and milling industry.

Other important source of water pollution in Nigeria is the indiscriminate discharge of untreated abattoir effluents directly into ground or surface water bodies, resulting in serious surface and ground water contamination. Abattoirs are located indiscriminately in Nigeria and usually near water sources since the process requires a lot of water and for ease of disposal of wastes (Omoruyi et al., 2011). Abattoir effluents have been reported to markedly increase the amounts of nitrogen, phosphorus and total solids in contiguous water bodies (Bello-Osagie and Omoruyi, 2012). The high biochemical oxygen demand (BOD), nutrients and pathogen content in abattoir waste poses pollution risk to water bodies (Matsumura and Mierzwa, 2008; Keskes et al., 2012). In Nigeria, study of Omole and Longe (2008) showed that the quality of a surface water was impacted negatively by the activities of abattoir, with water quality parameters including Total Suspended Solid (TSS), dissolved oxygen (DO), BOD, chemical oxygen demand (COD), and heavy metals including cadmium (Cd), lead (Pb) and copper (Cu) above the permissible limits by regulatory authorities.

In another study in Nigeria, animal processing and trading activities at Tudun Wada abattoir altered River Kaduna water quality (Kwadzah and Iorhemen, 2015). The study found higher concentrations than normal of BOD, COD, nitrate-nitrogen, ammonia nitrogen, total nitrogen and total phosphorus in the river water. In addition, higher concentrations of these parameters were found downstream than upstream, an indication of the negative impact of the abattoir wastewater discharge into the river. However, dilution factor in the high-strength abattoir wastewater was not sufficient to mitigate the parameters to acceptable levels in the river water (Kwadzah and Iorhemen, 2015). Industrial effluents Industrial effluent is another major source of chemical contaminants of drinking water sources in Nigeria. Industrial effluents mostly contain heavy metals, hydrocarbons, and atmospheric deposition (Alam et al., 2007). Industrial effluents loaded with heavy metals and harmful microbes can be hazardous when it gets into the food chain through the soil and water bodies and can affect plants, animals and humans adversely (Deshmukh et al., 2011; Bai et al., 2012). Wastewaters from most industries in Nigeria are disposed into water bodies (Kanu and Achi 2011). Interestingly, many of these industrial effluents are discharged untreated into water bodies, partly because of weak regulations, thereby contaminating the receiving surface and ground waters. Reports have shown that effluents from pharmaceutical industry (Bakare et al., 2009; 2011), hospitals (Iyekhoetin et al., 2011), universities (Alabi et al., 2012), tobacco industry (Alabi et al., 2014), automobile workshops (Alabi et al., 2016) and cocoa industry (Alabi et al., 2017) contained heavy metals and other chemical constituents in high concentrations capable of contaminating drinking water sources and lead to public health detrimental effects.

Also, groundwater around a municipal landfill site has been reported to contain inorganic contaminants to the extent that shallow ground water near landfill sites are considered unsuitable for drinking (Han et al., 2014). Porowska (2015) used stable carbon isotopes to determine the source of inorganic carbon in groundwater near a reclaimed landfill and found 47-80% of dissolved inorganic carbon reportedly from the biodegradation of organic matter in the landfill and then positioned that the surrounding groundwater was contaminated by leachate from the landfill. Oil spill Oil spill has polluted Nigeria water sources with chemical contaminants. Crude oil is a mixture of many different hydrocarbons which is known to be highly toxic, causing damage to natural and semi natural ecosystems including aquatic systems (Dawes, 1998). During oil spill, pollutants such as benzene, poly aromatic hydrocarbon (PAHs), grease, oil, heavy metals etc. are introduced into aquatic ecosystems. In southern Nigeria, Ifelebuegu et al. (2017) showed alteration of the physicochemical parameters of drinking water sources due to pollution by petroleum hydrocarbon indicated significant alteration of water quality in some rivers due to oil exploration and other related activities. Many aquatic lives have been lost and human consumption of organisms from these contaminated waters poses serious health problems due to bioaccumulation of chemical contaminants in the food chain. Due to the persistent nature of oil spillage, contamination of water sources remains a serious problem which would persist for a long period of time, thereby causing quality water shortage.

In the Niger Delta region, many studies have documented the effects of oil spillage on water sources (UNEP, 2011; Linden and Palsson, 2013; Alinnor et al., 2014; Onyegeme-Okerenta, 2017). A study by Lindén and Pålsson (2013) reported high level of petroleum hydrocarbon contamination of rivers, creeks, and ground waters in Ogoni land. This is of serious negative impact on human health and the ecosystem. It is not uncommon that a plethora of petroleum hydrocarbon spills sometimes occur due to leaks from decrepit infrastructure, aged facilities and pipelines as well as oil spillage during transportation, and other man-made causes (Ite et al., 2013; Lindén and Pålsson, 2013).

A recent study by Onyegeme-Okerenta (2017) showed that water quality of some rivers and streams in Uzere, a community in Niger Delta, is impaired following the incidence of crude oil spillage in the community. Similarly, Ifelebuegu et al. (2017) investigated the impact of crude oil spills on the physicochemical, microbial and hydro biological properties of the Nun River and reported that the physicochemical parameters and heavy metals (e.g. Cr, Cd Pb, Cu, Ni and Zn), total dissolved solid, turbidity, total suspended solid, dissolved oxygen, electrical conductivity, of the river failed to meet the adequate and recommended limits for drinking water. Also, the water quality parameters were seriously compromised due to oil exploration and other related activities. In another recent study, Tongo et al. (2017) showed that acenaphthylene, naphthalene, and fluoranthene were common pollutants in Ovia river in Edo State, Nigeria. Furthermore, the concentrations of individual PAHs recorded in Ovia river were significantly higher than the recommended or permissible concentration [0.05 μg/l]. Due to contamination of drinking water sources, especially in the southern parts of Nigeria, most locals resort to drilling borehole as their drinking water source. However, discharged petroleum hydrocarbons often sink into groundwater thereby polluting these ground waters (Frynas, 2000; Yakubu, 2017). Alinnor et al. (2014) collected and analysed groundwater from five communities in the Niger Delta region and reported that the water samples from varying depth were contaminated with petroleum hydrocarbons.

Following an analyses of some drinking water samples from wells, also in the oil rich Niger Delta region, the United Nations Environment Programme detected high levels of benzene concentrations. The benzene levels were about 1800 fold higher than the drinking water tolerable limit set by the United States Environmental Protection Agency (USEPA) (UNEP, 2011; Kponee et al., 2015) and over 900 fold higher than the acceptable limit set by the WHO for drinking water (UNEP, 2011).

3 METHODOLOGY

The research study employed the use of experimental design approach where samples of water were collected at different site locations of Akiama and Marculay communities in Bonny Island Rivers State.

Purposive sampling method was employed in the sample collection of this study, also the grab and composite sampling methods were used in collecting water samples from the pumped boreholes water quantities at various locations. Water samples were collected from two different borehole sampling points at morning hours for 3 days. The average sampling time was 6am each day of sampling. Table 1 showed the description of the sampling sites. Before collection, the mouth and the outer parts of the borehole taps were sterilized and allowed to cool by running the water for about 1 minute. Sample collection site location was determined using a global position system (GPS) coordinates.

Each sample for analysis was collected using a clean one-liter plastic container with a screw cap which was thoroughly washed with detergent, and rinsed with distilled water. At the point of collection, the container was rinse three times with the water sample. The sampling site comprises of Akiama Community and Macaulay Community was selected purposively based on the availability and use of borehole water. A total of 8 borehole water samples (one samples per site) were collected from randomly selected boreholes in two sites for 3 days. The sample was labeled, indicating the source, date and time of collection. The sample was transferred to the laboratory for physicochemical and bacteriological examination.

The table 1 below shows breakdown showing time, date, sample number, site and coordinates

SAMPLE NUMBER	SAMPLING SITE	DATE	TIME	ANALYSIS	SAMPLING SITE COORDINATES
SAMPLE 1(DAY1)	AKIAMA	21ST APRIL 2021	5:33AM	PHYSICOCHEMICAL	N4^{0}26’3.15024” E7^{0}11’10.69584”
SAMPLE 1(DAY 1)	MACAULAY	21ST APRIL 2021	5:53AM	PHYSICOCHEMICAL	N4^{0}26’6.0018” E7^{0}10’39.03852”
SAMPLE 2 (DAY2)	AKIAMA	22ND APRIL 2021	5:55AM	PHYSICOCHEMICAL	N4^{0}26’3.15024” E7^{0}11’10.69584”
SAMPLE2 (DAY 2)	MACAULAY	22ND APRIL 2021	6:10AM	PHYSICOCHEMICAL	N4^{0}26’6.0018” E7^{0}10’39.03852”
SAMPLE 3(DAY3)	AKIAMA	23RD APRIL 2021	6:30AM	PHYSICOCHEMICAL	N4^{0}26’3.15024” E7^{0}11’10.69584”
SAMPLE 3 (DAY3)	MACAULAY	23RD APRIL 2021	6:47AM	PHYSICOCHEMICAL	N4^{0}26’6.0018” E7^{0}10’39.03852”
SAMPLE 1(DAY 3)	AKIAMA	23RD APRIL 2021	6:31AM	BACTERIOLOGICAL	N4^{0}26’3.15024” E7^{0}11’10.69584”
SAMPLE1 (DAY3)	MACAULAY	23RD APRIL 2021	6:58AM	BACTERIOLOGICAL	N4^{0}26’6.0018” E7^{0}10’39.03852”

3.1 PHYSICOCHEMICAL ANALYSIS OF THE WATER SAMPLES

The water samples were analyzed for color, temperature, pH, total dissolved solid (TDS), Salinity. The pH and temperature was determined using a pH and temperature meter.

Determination of total dissolved solids (TDS) salinity and electrical conductivity was determined using a TDS, Electrical Conductivity(EC),and salinity meter.

3.2 MICROBIOLOGICAL ANALYSIS OF THE WATER SAMPLES

The total coliform count was determined by pour plate technique using standard method.

Materials used: macconkey agar, incubator, pipette, weighing scale, autoclave, petridish, test tubes, measuring cylinder, matches, stove, kerosene, foil paper, cotton wool, masking tape, conical flask.

Procedure: 11.6g of macconkey agar was measured using a weighing scale. 250ml of distilled water was measured in a measuring cylinder. The agar was poured into a conical flask then water was added and shaked to form a solution.

The conical flask was properly covered with a foil paper and taped with masking tape to ensure it's tightly covered. Also, test tubes and petri dishes were properly and carefully wrapped in foil paper and taped with masking tape.

The wrapped conical flask containing agar solution, test tubes and petri dishes were transferred to the autoclave for sterilization (ascetic technique). Serial dilution was done by pipetting 9ml of saline solution into the test tubes and labeling them(10^{-1}m, 10^{-2}m, 10^{-3}m, 10^{-4}m, 10^{-5}m for Macaulay samples) and (10^{-1}A, 10^{-2}A, 10^{-3}A, 10^{-4}A, 10^{-5}A for Akiama sample). 1ml of the selected and collected Water sample was pipetted into each pipette through serial dilution. The stove was lighted and the flame was used as an ascetic technique to prevent bacteria contamination when pouring the agar solution into the petri dishes and when dropping the water sample (10^{-1}m, 10^{-3}m, 10^{-5}m and 10^{-1}A, 10^{-3}A, 10^{-5}A) using pipette into the agar solution in the petri dish. The petri dishes was labeled and incubated at 37^0c for 24hours.

Table 2 shows **ACCEPTABLE STANDARD VALUES OF THE PHYSICOCHEMICAL PROPERTIES OF CLEAN POTABLE WATER ACCORDING TO WHO, NAFDAC AND NSDWQ.**

Parameters	**WHO**		**NAFDAC**	**NSDWQ**
	Highest Desirable Level	**Maximum Permissible Level**		
Temperature (ºC)	-	40	-	Ambient
Colour (TCU)	6	-	15	15
Turbidity (NTU)	5.0	25	-	5.0
pH	7.0 - 8.5	6.5 - 9.2	6.5 - 8.5	6.5 - 8.5
Total Dissolved Solid (TDS)	500	1500	500	500
Nitrate (mg/L)	-	50	-	0.2
Iron (mg/L)	-	-	-	0.3
Chromium (mg/L)	-	-	-	0.06
Copper (mg/L)	-	-	-	1.0
Fluoride (mg/L)	-	-	-	15

Abbreviations: *WHO (World Health Organization), NAFDAC (National Agency for Food and Drug Administration) and NSDWQ (Nigerian Standard for Water Quality)*

TABLE 3: THE ACCEPTABLE STANDARDS VALUES OF THE MICROBIOLOGICAL ANALYSIS FOR DRINKING WATER ACCORDING TO WHO AND NSDWQ

Parameter	WHO	NSDWQ
Total Coliform Count (TCC (CFU/100 mL)	0	10
Abbreviations: *TCC (total coliform count) CFU (colony-forming unit) WHO (World Health Organization), NSDWQ (Nigerian Standard for Water Quality)*		

4.RESULTS AND DISCUSSION.

4.1 PHYSICOCHEMICAL ANALYSIS RESULT: Chemical analysis includes the onsite analysis (pH, Salinity, TDS, Temperature and conductivity).

PH: this is classed as one of the most important water quality parameters. Measurement of pH relates to the acidity or alkalinity of the water. A sample is considered to be acidic if the pH is below 7.0. Meanwhile, it is alkaline if the pH is higher than 7.0. Acidic water can lead to corrosion of metal pipes and plumping system. Meanwhile, alkaline water shows disinfection in water. The normal drinking water pH range mentioned in WHO and NDWQS guidelines is **between 6.5 and 8.5** The pH values of all the water samples are found to be in the **range between 7.7and 7.8.**

ELECTRICAL CONDUCTIVITY: Electrical conductivity is the ability of any medium, water in this case, to carry an electric current. The presence of dissolved solids such as calcium, chloride, and magnesium in water samples carries the electric current through water. According to NDWQS the maximum allowable level of conductivity **is 1000μS/cm.** The results show that the measured conductivity of the water samples ranges from **241 μS/cm to 268μS/cm.** Moreover, according to Azrinaetal, the wide differences among the values of the electrical conductivity of tap water are not yet known. Scatena explained the differences based on various factors such as agricultural and industrial activities and land use, which affect the mineral contents and thus the electric conductivity of the water. Conductivity does not have direct impact on human health.

It is determined for several purposes such as determination of mineralization rate (existence of mineral such as potassium, calcium, and sodium) and estimating the amount of chemical reagents used to treat this water. High conductivity may lead to lowering the aesthetic value of the water by giving mineral taste to the water. For the industrial and agricultural activity, conductivity of water is critical to monitor. Water with high conductivity may cause corrosion of metal surface of equipment such as boiler. It is also applicable to home appliances such as water heater system and faucets.

TOTAL DISSOLVED SOLIDS (TDS): TDS are the inorganic matters and small amounts of organic matter, which are present as solution in water. The standard or allowable value of the TDS set by NDWQS is **1000mg/L**. The highest TDS value found in the water sample **is 214mg/L** and the lowest TDS values found **is 193mg/L.**

SALINITY: salinity is the total concentration of all dissolved salts in water. The salinity of the water samples from the study areas **ranges from 115ppm to126ppm**. The acceptable range according to WHO is **less than 600ppm.**

TEMPERATURE: the temperature of water sample from the study areas ranges from **28.3^{0}c to 29.7^{0}c. High** temperature negatively impact water quality by enhancing the growth of microorganisms which may increase taste. Temperature affects biological, physical and chemical activities in water. WHO allowable range for temperature of drinking water is **less than 40^{0}c.**

TABLE4: SHOWING PHYSICOCHEMICAL RESULT FROM ANALYSIS ON SITE IN COMPARISON WITH W.H.O AND NSDWQ STANDARD

PARAMETERS	AKIAMA			MACAULAY			W.H.O	NSDWQ
	DAY 1	DAY 2	DAY 3	DAY 1	DAY 2	DAY 3		
TEMPERATURE(^{O}C)	28.8	29.7	28.3	29.3	29.6	28.8	40	Ambient
SALINITY(PPM)	126	117	115	124	118		600ppm.	_
TDS (MG/L)	214	198	193	210	199	201	_	1000mg/L.
ELECTRICAL CONDUCTVITY($_{US}$)	268	249	241	263	249	252	_	1000μS/cm.
PH	7.8	7.8	7.7	7.8	7.8	7.7	6.5 - 9.2	6.5 - 8.5

4.2 BACTERIOLOGICAL ANALYSIS RESULT:

Coliform bacteria which include Escherichia coli, Salmonella spp, Shigella spp, Enterococcus spp, Proteus spp, Pseudomonas aeruginosa and Staphylococcus aureus were isolated from the borehole water. On Macconkey agar, E. coli strains appeared as pink colonies, Aerobacter aerogenes appeared as large pinkish mucous colonies, Enterococcus species appeared red and round, Staphylococcus species appeared pale pink and opaque, Pseudomonas species appeared green brown with florescent growth.

All the borehole water samples were not free of total coliforms which were probably from the environmental sources and were non faecal in origin. WHO specified that potable drinking water should be devoid of total coliform in any given sample. It is note-worthy to mention that the borehole water samples had high total coliform counts.

E. coli was present in both borehole water samples (Akiama & Macaulay) analyzed for bacteriological quality. The presence of this microorganism the borehole water sample is unacceptable from the public health point of view. These organisms could be pathogenic. Therefore, there is need for caution when using these contaminated water sources for any purposes. Gram negative bacteria like E coli are common cause of bacterial gastroenteritis, which is characterized by diarrhea, vomiting, and abdominal cramping, fever, respiratory illness and urinary tract infections.

Sanitary survey of the borehole sites revealed the proximity of some of the boreholes to solid waste dump site and animal droppings being littered around them. All well waters sampled for analyses were being used for drinking, cooking and washing purposes by the households and some other inhabitants of the community.

TABLE 5: SHOWING COLIFORM BACTERIA IN WATER SAMPLES

MICOORGANISM	GRAM STAIN	SHAPE	APPEARANCE	REMARK
Escherichia coli	-	Rod	Pink	Non mucoid
Enterococcus spp	+	Coci	Red	Round
Staphylococcus spp	+	Coci	Pale pink	Opaque
Salmonella spp	-	Rod	Colorless	Colonies

Pseudomonas	**-**	**Rod**	**Green-brown**	**Fluorescent**
Aerobacter	**-**	**Rod**	**Pink**	**Mucoid**

4.3 DISCUSSION

The results of bacteriological analysis revealed the unsanitary condition of the water samples. The recovery of faecal coliform bacteria, Escherichia coli in the samples is of particular concern. The presence of E. coli in the samples implies faecal contamination of such samples and strongly suggests the possible presence of enteric pathogenic bacteria like Salmonella typhi, Salmonella paratyphi, Vibrio cholera, Aeromonas hydrophilla and Yersinia enterocolitica as well as other parasites. Samples containing indicator bacteria especially E. coli, high levels of coliform density and high viable bacterial count are unfit for human consumption. This is because according to WHO (1989), a coliform count of not more than 100 is recommended for unchlorinated water supplies while the presence of E. coli is intolerable and on no circumstance must it be found in water meant for consumption or domestic services.

Although the samples met physicochemical requirements, they failed to meet the minimum bacteriological standards, therefore were still declared unfit for human consumption. Sometimes accidental backflow or back sippage of polluted water from toilets and wash bowls may occur resulting in contamination of water supply pipes through leakages in supply line passing through the drain field. Faecal coliform (E. coli) may be introduced into borehole water in this way. Staphylococcus aureus encountered in this work is a known enterotoxin producer and food poisoning aetiologic agent. They also exhibit multiple resistances to various antibiotics.

The results of the research have revealed the unsanitary state of water consumed in this part of Bonny Island under study as most of the samples contained bacterial indicators of fecal pollution and of which were found to be above the recommended WHO and NSDWQ standards for drinking water.

5 CONCLUSION

5.1 PHYSICOCHEMICAL

It has been established that analyzed water samples from boreholes met with the internationally recommended physicochemical standards (WHO) for potable water. The values of water quality parameters such as pH, conductivity, TDS, salinity, and temperature from both samples collected from Akiama and Macaulay community found to be within the recommended limits of WHO and NDWQS.

5.2 BACTERIOLOGICAL

The bacteriological results from this analysis do not conform to the standard both nationally and internationally. This study suggests that not all borehole waters are safe for consumption and waters were of poorer bacteriological qualities indicative of health risk to the inhabitants of Bonny Island. The sites of boreholes and wells are very important as clean and hygienic environment promote safety of water.

Since This BUC (Bonny Utility Company) water boards serve as the major source of water for domestic use by the people of Bonny Island**.**

Based on the result obtained it is necessary to carry out microbiological and physicochemical examination of these boreholes periodically so as to access the suitability of the water for consumption. This approach is very important which helps to investigate other potential water contaminations such as chemicals and microbial and radiological materials for a longer period of time, including human body fluids, in order to assess the overall water quality, the communities and bonny island at large.

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