Comparative Analysis of Public and Private Borehole Water Supply Sources in Uruan Local Government Area of Akwa Ibom State

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Abstract

Comparative analysis of public and private borehole water supply sources in Uruan Local Government Area of Akwa Ibom State, Nigeria, was conducted in order to examine their qualities. A total of 13 water samples collected from 10 randomly selected private and 3 functional public boreholes in the area were analysed using standard analytical techniques and instruments. Most of the physicochemical parameters of samples from the two sources were within the acceptable limits of the World Health Organisation (WHO) for drinking water. Eight different bacteria species were isolated and identified. They include Escherichia coli (18.75%), Bacillus subtilis (15.625%), Streptococcus faecalis (15.625%), Proteus vulgaris (12.50%), Klebsiella aerogenes (12.50%), Micrococcus varians (9.375%), Clostridium perfringens (9.37%) and Staphylococcus aureus (6.25%). Total viable count on private borehole water samples ranged from $1.6x10^3$ to $5.5x10^3$cfu/ml while that of the public was $9x10^1$cfu/ml. In the private source, E.coli ranged from $1x10^0$ to $4x10^0$cfu/100ml, whereas $4x10^0$ to $3.4x10^1$cfu/100ml was recorded for the coliforms. Streptococcus faecalis and Clostridium perfringens ranged from $1x10^0$ to $3x10^0$cfu/100ml and $1x10^0$ to $2x10^0$cfu/100ml respectively, and did not meet the approved drinking water standard. There was no growth of indicator organism in samples from the public boreholes. Analysis of variance result shows no difference in the physicochemical variables of the 13 samples except in bacteriological quality where significant differences where observed. The t-test result reveals significant difference between the quality of the public and private borehole water supply sources in the study area. From the findings, it is recommended that private borehole water supply in the area be properly treated before human consumption and other domestic purposes.

Keywords: Public borehole, private borehole, water samples, physicochemical, variance and bacteriological quality.

1.0 Introduction

1.1 Background of the Study

Water is one of the most abundant and essential resources of man, and occupies about 70% of earth's surface. About 97% of this volume of earth's surface water is contained in the oceans, 21% in polar ice and glaciers, 0.3-0.8% underground, 0.009% in inland freshwaters such as lakes, while 0.00009% is contained in rivers (Eja, 2002). According to Botkin and Keller (1998), more than 97% of earth's water is in the oceans and ice caps, and glaciers account for another 2%. Also, the ocean comprises 97%, while 3% of the earth's water is fresh (Kulshneshtha, 1998).

Water in its pure state is acclaimed key to health and the general contention is that water is more basic than all other essential things to life (Edungbola and Asaolu, 1984). Man requires a regular and accessible supply of water which forms a major component of the protoplasm and provides an essential requirement for vital physiological and biochemical processes. Man can go without food for twenty eight days, but only three days without water, and two third of a person's water consumption per day is through food while one third is obtained through drinking (Muyi, 2007).

Basic household water requirements have been suggested at 50 litres per person per day excluding water to gardens (Boss, 2004). Batmanghelid (2009) reported that since the water we drink provides for cell function and its volume requirements, the decrease in our daily water intake affects the efficiency of cells and other body activities. In addition to human consumption and health requirements, water is also needed in agriculture, industrial, recreational and other purposes. Water is also considered a purifier in most religions (Foel and Nennewan, 1986). Though all these needs are important, water for human consumption and sanitation is considered to be of greater social and economic importance since health of the population influences all other activities (Gibson and Singer, 1971). According to Odiette (1999), environmental water usage includes artificial wet lands, artificial lakes intended to create wildlife habitat, fish ladders around dams and water releases from reservoirs to help fish spawn.

Ground water is the water beneath the surface where all the voids in the rocks and soil are filled. It is a source of water for wells, boreholes and springs. A borehole is an hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer. It is a narrow well drilled with machine. Borehole water is the water obtained from borehole drilled into the aquifer or ground water zone, which is usually a fully saturated subterranean zone, some distance below the water table (NWRI, 1997).

Ground water is already used extensively in Nigeria through wells and boreholes. Unfortunately borehole water like water from other sources is never entirely pure. It varies in purity depending on the geological conditions of the soil through which the ground water flows and some anthropogenic activities. Until very recently, ground water has been thought of as being a standard of water purity in itself, and to a certain extent, that is indeed true (Miller, 1992).

Apart from the essential role played by water in supporting human life, it also has, if polluted, a great potential for transmitting a wide variety of diseases. According to Akpan, et al (1996), in most developing countries like Nigeria where dangerous and highly toxic industrial and domestic wastes are disposed of by dumping them on the earth; into rivers and streams with total disregard for aquatic lives and rural dwellers, water becomes an important medium for the transmission of enteric diseases in most communities. Poisonous chemicals are known to percolate the layers of the earth and terminate in ground waters thereby constituting public health hazards. In Uruan Local Government Area, certain anthropogenic activity like the improper waste disposal can contribute to ground water pollution. This area suffers from non-provision of potable water supply. The inhabitants are therefore depending largely on private borehole water supply which is of doubtful quality.

Public water supply in the area under study is grossly inadequate and the inhabitants have been compelled to depend on private borehole water supply whose quality is doubtful. Consumption of such water can cause water borne diseases such as typhoid and paratyphoid fevers *(salmonellosis)* as most of the enteric diseases are transmitted through water. Other principal microbial water borne diseases include cholera, bacillary dysentery *(shigellosis)* and infectious hepatitis. Preliminary investigation in the study area indicates that there are many reported cases of these enteric diseases in the health centres. The consequences of these enteric diseases are that the quality of life in the area (Uruan Local Government Area) is low and apparent low human production.

The aim of the study is to compare the quality of public and private borehole water supply sources in Uruan Local Government Area. To achieve the above stated aim, the objectives are to:

i. identify and locate the sites of public and private borehole water supply sources in Uruan Local Government Area;
ii. compare the quality of public and private borehole water supply sources with the World Health Organization (WHO) and the Federal Ministry of Environment (FMEnv.) drinking water standards.
iii. examine the levels of variations in water quality between the two sources of water supply in the study area
iv. examine the implications of the findings in water supply; and
v. suggest measures for maintaining acceptable quality of portable water supply in the area under study

1.2 Research Hypothesis

For this study, the following hypotheses are generated:

(i) Null hypothesis (H_o): There is no significant difference between the quality of public and private borehole water supplies.

(ii) Alternative hypothesis (H_1): There is significant difference between the quality of public and private borehole water supplies.

The study will help ascertain the quality of public and private borehole water supply sources consumed in the study area, and will also help in solving the problems of water related issues. The study will serve as a guide for borehole water development in the area and beyond.

The scope of this study covers the identification and collection of water samples from the public and private borehole water supply sources to ascertain their quality and suitability for drinking and other domestic purposes. The variations in the quality of the two sources of water supply in the area and implications of the findings in water supply will also be covered in the study.

1.3 Study Area

The study area is Uruan Local Government Area of Akwa Ibom State. Uruan Local Government Area was created in 1989 by the Federal Government of Nigeria with the Headquarters at Idu. Before the creation of new Local Government Areas in the country, the present Uruan Local Government Area was one of the parts which constituted Uyo Local Government Area.

Uruan Local Government Area occupies a large land mass of about 403,030 square kilometers. It extends from latitude 4^o52’ to 5^o08’ north of the equator and from longitude 7^o55’ to 8^o10’ east of the Greenwich meridian. It is bounded in the east by Cross River, in the south by Okobo and Nsit Atai Local Government Areas, in the west by Uyo and Ibesikpo Asutan Local Government Areas and in the north by Itu Local Government Area.

1.4 Quality of Borehole Water

Physically, ground water is generally clear, colourless, with little or no suspended matter and has a relatively constant temperature. It is also generally free from the very minute organisms which cause diseases. This is another benefit that results from the slow filtering action provided as the water flows through the ground. Also the lack of oxygen and nutrients in the ground water makes it an unfavourable environment for disease producing organisms to grow and multiply. The chemical quality of ground water is also considerably influenced by its relative slow rate of travel through the ground (Gibson and Singer, 1971).

According to Itah *et al*, (1996), ground water is known to be purer than the surface water. Unfortunately it becomes chemically contaminated by pesticides, herbicides and fertilizers which have been a boom to the world farmers, but a bomb to the earth’s water. Changes in borehole water quality may be due to ground water pollution. Water pollution is the modification of the physical, chemical and biological properties of water restricting or preventing its application (Sax, 1994).

Ground water pollution arises when leachate or pollutant percolates through the soil down to the phreatic surface. Once the leachate reaches the ground water, the path way of these contaminants is that of ground water flow, and factors such as permeability of the cover deposits, depth of impermeable layers and hydraulic head gradient in the aquifer become important. The depth of penetration in the aquifer is also dependent on the distance from the nearest ground water divide, and from the nearest drainage channel (Eja, 2002). According to the author, the pollutants may be introduced in a natural way e.g. through rain water, sea water, earth crust and biological activities. Pollutants introduced by human activities may come from point sources and non-point sources. Pollution originating from farming practice, the application of agro chemicals and the use of sewage sludge as fertilizer supplements represents the point sources. In contrast, point sources of pollution are differentiated primarily from the non-point sources by the precision with which the source of contamination can be identified e.g. the discharge of wastes to landfill sites, the surface injection of wastes via deep boreholes and the disposal of effluents by irrigation to land constitute the major persistent sources of point pollution.

The main factors that influence the deterioration of water quality are agricultural wastes, domestic and municipal sewage, commercial and industrial wastes. Also the various water pollutants known are derived from the afforestated factors and are enumerated to include organic and inorganic materials, salts, nutrients, heavy metals, radioactive wastes, pesticides, pathogens, oil and heat (Ademoroti, 1996). Other sources and types of contaminants include widely used substances such as highway salt, fertilizers that are spread across the land surface.

In the portability study of ground water in Enugu town, South Eastern Nigeria, 88 ground water samples were analysed in order to evaluate their portability. The result showed that about 22% of the samples had concentrations of NO_3 higher than the World Health Organisation (WHO) standard, while 8 out of the samples analysed for bacteriological quality showed evidence of sewage contamination. Also the identification of *Escherichia coli* in the water indicated faecal contamination (Onwuka, *et al,* 2004).

The NAFDAC laboratory, Oshodi, during the year 2003 analysed some borehole water samples for registration purpose, and the majority of the samples analysed showed high microbial load (NAFDAC, 2004). Studies carried out by Ibanga *et al,* (1999) on selected water sources including underground water in Calabar indicated that the physicochemical parameters, biological oxygen demand (BOD), silica and pH were positively correlated with indicator bacteria with counts reaching a maximum of 520 faecal coliforms per 100ml. The quality of the water samples therefore did not conform to the approved WHO standard for drinking water.

In a survey on water quality at the oil depots of the Nigeria National Petroleum Corporation (NNPC) Ejigbo, Lagos State and Apata in Ibadan, the hydro chemical analysis results revealed that the ground water in the areas (Lagos and Ibadan Depots) were of $Ca\ (HCO_3)_2$ type which was influenced by the geologic materials. The water was acidic to neutral in character, very hard and fresh. Water from the wells did not meet the WHO drinking water standard and were declared unfit for human consumption due to total hydrocarbon and bacteriological pollution. According to the author, total hydrocarbon, household waste disposal and seepage from septic tanks were the major sources and causes of the ground water pollution (Afbede and Oladejo, 2003). Strahler and Strahler (1993) asserted that source of pollution of ground water supplies is from high ways and streets through spillage of chemicals and from deciding salt applied during the winter months.

1.5 Variations in Borehole Water Quality

The quality of a water resource depends on the management of anthropogenic discharges as well as the natural physicochemical characteristics of the catchment area. In the analytical study of borehole water quality in both sedimentary terrain and basement by Fasunwon *et al*, (2010), it was discovered that the composition of the terrains had influence on the water quality. It was observed that the pH ranged from 5.30 to 7.60. Iron, nitrite, nitrate and manganese contents had maximum values of 2.70, 2.00, 7.30 and 0.10mg/l respectively. Total alkalinity ranged from 21.00 to 275mg/l, salinity ranged from 15.00 to 566mg/l, chloride ranged from 5.50 to 70.00mg/l, but sulphate was absent in all the water samples. The results obtained showed how elemental compositions vary with lithogy.

Obiri-Danso *et al*, (2002) also carried out studies on borehole water quality and observed that higher bacterial counts were recorded during the wet (rainy) season compared to the dry (harmattan) season. Faecal coliforms count in three borehole samples ranged between $3x10^1$ and $3.5x10^7$cfu/100ml. Manganese and iron levels were within the WHO standards for all the nine sites, but lead levels except for one site were all higher than the WHO standards for drinking water. According to the author, a brief sanitation survey at each site suggested that wells and boreholes were frequently cited near latrines, refuse tips and other social amenities, and in the vicinity of domestic or grazing animals.

1.6 Quality of Water and Health

Water plays essential roles in supporting human life. It also has if contaminated great potential for transmitting a wide variety of diseases and illness. In the developed world, water related diseases are rare, due essentially to the presence of efficient water supply and waste water disposal systems. However, in the developing world perhaps a lot of people are without safe water supply and adequate sanitation (Tebbut, 1983). As a result, the toll of water-related diseases in these areas is frightening in its extent.

In the developed world, there is a concern about the possible long term health hazards which may arise from the presence of trace concentration of impurities in drinking water, particularly attention being paid to potentially carcinogenic compounds. There are also several contaminants which may be naturally occurring or man-made, having known effects on the health of consumers. It is therefore important that the relationship between water quality and health be fully appreciated by the engineers and scientist, concerned with water quality control (Tebbut, 1983).

The significance of water route in spread of diseases varies both with the diseases and the local circumstance (Adesiyn *et al*, 1983). Wolf (2001) added that harmful chemicals such as pesticides from agriculture and heavy metals like lead and mercury from industries can build up in the food chain where they can reach toxic levels in fish and other sea animals.

The effects of water pollution by chemicals include cancer, arthritis, skin irritation and eruption, heart diseases, central nervous system problems, skin rashes, kidney problems and bronchitis. The principal microbial water borne diseases are typhoid and paratyphoid fevers (salmonellosis), cholera, bacillary dysentery (shigellosis), infectious hepatitis, dracontiasis and schistosomiasis (Udoessien, 2003). Others are food poisoning, amoebic dysentery, giardiasis, gastro enteritis, hepatitis A and poliomyelitis.

1.7 Water Quality Standards

The incidents of water borne disease and epidemics nationwide arising from drinking water of doubtful quality have become of great concern. The primary purpose of the guideline for drinking water quality is the protection of public health (WHO, 2006). As described by Horsefall and Spiff (1998), water quality standard is a measure, principle or rule established by authority set to protect the water resource for uses such as drinking water supply, recreational uses and aesthetics, agriculture (irrigation and livestock watering), protection of aquatic life and industrial water supplies.

In order to maintain water quality, guidelines for drinking water was set up by the World Health Organisation. A guideline value represents the level (a concentration or number) of a constituent that ensures aesthetically pleasing water and does not result in any significant risk to the health of the consumer (WHO, 1984 and 1985).

1.8 Quality of Drinking Water

In general, certain requirements must be met for water to be fit for human consumption. If these requirements are met, the water can be described as ‘wholesome’, ‘potable’ or simply ‘water supply’. According to Eja (2002), the requirements are:

(i) Freedom from organism and chemical substances which might be injurious to health. This is the most important requirement.
(ii) Drinking water should be of such composition that consumers do not question the safety of the water. This requirement implies that turbidity, colour, taste and odour should be low. Macro organisms (e.g. warms, aquatic and fly nymphs) should be absent.
(iii) Drinking water should be suitable for house keeping and for this reason, iron and manganese content should be low, because these substances colour laundry (like shirt) during washing. Iron causes a brown colour, while manganese causes a black colour. Hardness should be low, because water with a high hardness causes scale formation in water heaters by precipitation of calcium carbonates. Moreover, a high hardness implies that a high dosage of detergents is required for washing.
(iv) Drinking water should not be aggressive to materials such as lead, copper, asbestos, cement and concrete, cast iron, galvanized steel, PVC (Polyvinylchloride) and PE (Polyethylene). This is because pipes, tubes and apparatus used in distribution systems and plumbing installations may consist of these materials. Pipes, tubes and apparatus affected by water cause many problems.

2.0 Materials and Method

2.1 Sample Size and Sampling Technique

Water samples were collected from the 3 functional public borehole water supply sources in the study area. The private borehole population of 48 in number were numbered from 1 to 48 and 20.83% of the population (10 boreholes) were selected using the Random Sampling Technique. That was achieved through the use of table of random numbers, bringing the total number of samples to 13. Figure 1 shows the locations of the sampling points and villages on the map of Uruan Local Government Area.

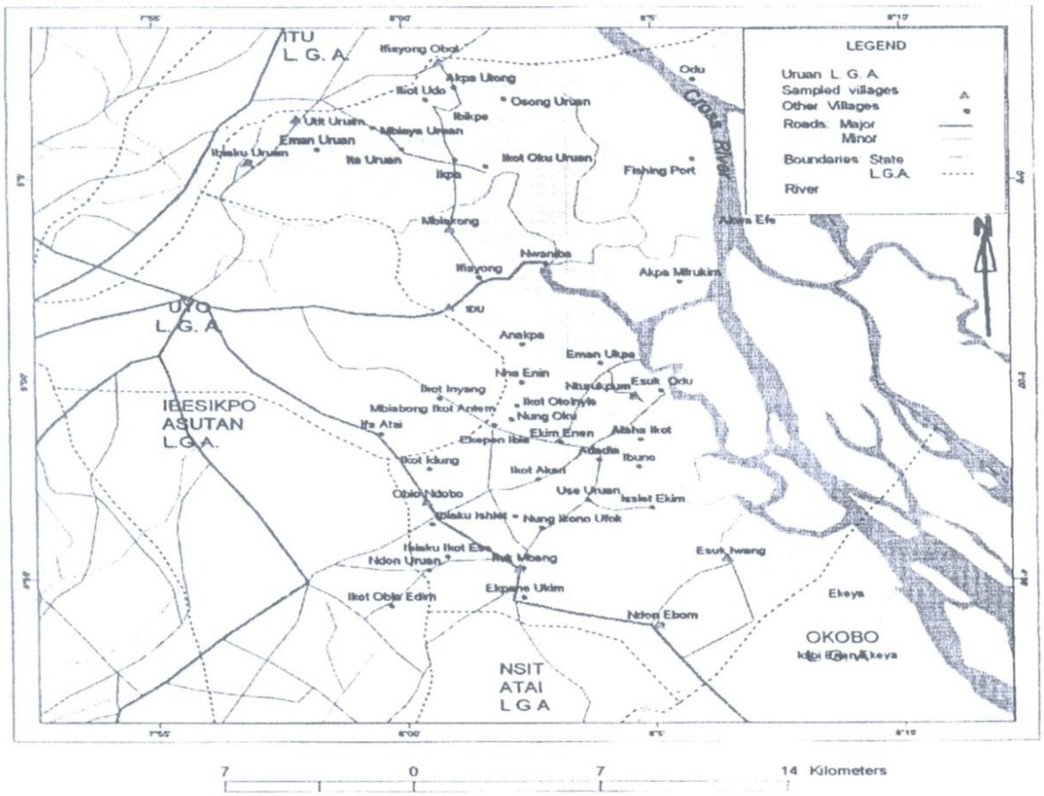

Fig. 1: Locations of the Sampling Points and Villages on the map of Uruan Local Government Area

2.2 Collection of Water Samples

Water samples were collected using clean containers, labeled and transported immediately to the laboratory in a container of ice for physicochemical analysis. For bacteriological analysis, 5 drops of aqueous sodium thiosulphate solution were added to the sample bottles and sterilized in a hot box oven at 160^{o}C for one hour. The addition of the solution was to neutralize any available chlorine in the samples. The taps were disinfected, opened fully and the water allowed to rush for two minutes before collection. The samples were labeled and transported to the laboratory in a cooler (container) of ice. Table 1 shows randomly selected sample locations, sources and sample identification code.

Table 1: Randomly selected sample locations, sources and sample identification code

Sample Location	Source of Supply	Sample Identification Code
Obio Ndobo	Private borehole	S_1 (Sample 1)
Ituk Mbang	Private borehole	S_2 (Sample 2)
Ndon Ebom	Private borehole	S_3 (Sample 3)
Ndon Ebom	Public borehole	S_4 (Sample 4)
Esuk Inwang	Private borehole	S_5 (Sample 5)
Nturukpum	Private borehole	S_6 (Sample 6)
Utit Uruan	Private borehole	S_7 (Sample 7)
Utit Uruan	Public borehole	S_8 (Sample 8)
Ibiaku Uruan	Private borehole	S_9 (Sample 9)
Ifiayong Obot	Private borehole	S_{10} (Sample 10)
Idu	Public borehole	S_{11} (Sample 11)
Idu	Private borehole	S_{12} (Sample 12)
Mbiakong	Private borehole	S_{13} (Sample 13)

Source: Author's field work (2011)

2.3 Data Requirement

The following data were required for the study:

i) total number of public and private borehole water supply sources and their locations in the study area.
ii) physicochemical parameters of the samples such as appearance, temperature, colour, odour, taste, turbidity, electrical conductivity, total dissolved solids, alkalinity, hardness, dissolved oxygen, biochemical oxygen demand, chloride, nitrate, pH, nitrite, fluoride, sulphate, phosphate, sodium, calcium, magnesium, potassium and trace metals.
iii) biological parameters such as the indicators of faecal pollution of water *(Escherichia coli, Streptococcus faecalis, Clostridium perfringens)* and total heterotrophic bacteria.
iv) secondary data obtained from relevant published and unpublished documents and from internet.

2.4 Methods of Data Collection and Presentation

Water samples were collected from public and private boreholes for physicochemical and bacteriological analysis using standard analytical techniques and instruments such as portable pH meter (HACH Sension 3) to measure pH, an atomic absorption spectrometer (UNICAM 969 AA) to measure the concentration of trace metals and dissolved oxygen meter (JYD-1A) to measure the dissolved oxygen. Other physicochemical parameter like appearance, temperature, colour, odour, taste, turbidity, electrical conductivity, total dissolved solids, alkalinity, hardness, biochemical oxygen demand, chloride, nitrate, nitrite, fluoride, sulphate, phosphate, sodium, calcium, magnesium and potassium were determined using the appropriate instruments. Membrane filtration and pour plate technology were used for detention of biological parameters *(Escherichia coli, Streptococcus faecalis, Clostridium perfringens)* and total heterotrophic bacteria.

2.5 Methods of Data Analysis

Data collected were analysed using analysis of variance (ANOVA) and t-test. ANOVA was used to measure the variance between quality of water from the boreholes, while t-test was used to test the formulated hypothesis.

2.6 Physicochemical Analysis of Samples

The temperature was determined in-situ using the mercury-in-glass thermometer. The reading was allowed to be steady and the result recorded. The colour was determined as described by Oni (1997) using the Lovibond comparator. The odour of the sample was detected by sniffing while the taste was determined using the sensory organs (taste buds) in the mouth.

The HACH 2100P turbidimeter was used to determined the turbidity of the water samples. The test was conducted in accordance with (AOAC, 1985). The conductivity and total dissolved solids were determined using the HACH 44600 conductivity and total dissolved oxygen (DO) was determined using the dissolved oxygen (DO) meter (JYD-1A). The pH of the samples were determined using the HACH Sension 3 pH meter. The total alkalinity and total hardness was determined by the titrimetry methods. Also the estimation of magnesium concentrations in water were obtained from the EDTA calcium hardness and total hardness titration in accordance with the (APHA, 1998) method.

The dissolved oxygen (DO) wad determined using the (DO) meter (JYD-1A), while in determining the Biochemical Oxygen Demand (BOD_5), the (DO) was first determined and the result recorded as DO day one (DO_1). The remaining samples were incubated in the dark at 25^oC for 5 days and the DO test repeated (DO_5). The BOD_5 was then estimated as the difference between DO, and DO_5 (AOAC, 1985).

Determination of Trace Metals

The atomic absorption spectrometer (UNICAM 969 AA) was used for determination of concentration of trace metals in the water samples. Standard solutions of the metals were prepared. The instrument (AAS) was switched on and allowed to warm for 40 minutes. The hollow cathode lamp for each metal was fitted and aligned properly with the in-built Deuterium lamp. The gas was opened and the hoses checked to ensure that there was no leakage. The “set up optics” was clicked for the optical properties to adjust to suit the selected metal. The “Optimise” and ‘Auto zero” were clicked. The sequence pull down menu was checked to ensure that the sample identities were correctly entered. The calibration page was clicked to ensure that the right concentrations were entered. The “Analyse” was clicked to do the following:

a) Aspirating the deionized water for zero absorbance
b) Aspirating the blank, i.e. HNO_3 (1+499)
c) Aspirating the standards in their sequence
d) Aspirating the samples in their sequence as identified; and
e) Performing quality control check

2.6.1 Bacteriological Analysis of Samples

i) **Sterilization of Glassware:** All glassware used for this study were sterilized in a hot box oven at 160^{o}C for one hour.
ii) **Serial Dilution of Samples:** Nine milliliters of sterile water was transferred into 5 sterile tubes labeled 10^{-1} to 10^{-5}. One milliliter of the sample aseptically transferred into the first test tube (10^{-1}) with a sterile pipette and mixed. From the first test tube, one millimeter was equally transferred to the test tube labeled 10^{-2} and mixed using fresh pipette. This was repeated until the test tube labeled 10^{-5}.
iii) **Total Plate Count (Total Viable Bacteria):** The Pour Plate Technique was used and the culture medium was Nutrient Agar. One milliliter of the sample from 10^{-2} test tube was aseptically transferred into sterile Petri dishes using sterile pipette. The Nutrient Agar was prepared according to the manufacturer's instruction and allowed to cool to 45^{o}C. Twenty milliliters of the culture medium was poured into the Petri dish and properly mixed with the sample. This was done in triplicates. A control was equally prepared, but without adding the sample. The plates were labeled, allowed to solidify, inverted and finally incubated at 37^{o}C for 24-48 hours. The plates were observed for development of bacterial colonies.

3.0 Presentation of Data, Analysis and Discussion

3.1 Physicochemical Analysis Result

The results of physicochemical parameters of the samples were expressed in their different units of measurement and included temperature, colour, turbidity, electrical conductivity, total dissolved solids, alkalinity, hardness, dissolved oxygen, biochemical oxygen demand, chloride, nitrate, pH, nitrite, fluoride, sulphate, phosphate, residual chlorine, sodium, calmium, iron, chromium and manganese). Table 2 shows the physicochemical analysis results of the two borehole water supply sources in the study area.

Table 2: Physicochemical analysis results of private and public borehole water samples in Uruan Local Government Area

Physicochemical parameters	**S1**	**S2**	**S3**	***S4**	**S5**	**S6**	**S7**	***S8**	**S9**	**S10**	***S11**	**S12**	**S13**
Temperature (°C)	26.80	26.30	27.10	27.40	26.30	26.70	26.90	27.20	27.60	26.50	27.70	27.10	26.80
Colour (ILU)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Turbidity (NTU)	0.84	0.67	0.72	0.38	0.81	0.96	0.92	0.41	0.80	0.69	0.32	0.73	0.86
Electrical Conductivity (µs/cm)	27.50	18.13	38.62	89.18	19.70	26.25	24.83	97.75	32.33	25.42	103.24	20.51	24.60
Total Dissolved Solids (mg/l)	12.68	8.07	18.31	42.59	7.83	13.10	12.26	49.88	15.17	13.64	50.62	9.65	11.30
Alkalinity (mg/l)	1.30	1.30	1.00	1.00	1.60	1.33	1.60	1.00	1.30	1.30	1.00	1.60	1.30
Total Hardness (mg/l)	22.23	19.67	26.70	12.33	18.00	25.70	23.30	13.33	25.70	22.70	13.30	19.30	20.30
Dissolved Oxygen (mg/l)	1.30	1.20	1.40	1.80	1.20	1.30	1.50	1.70	1.40	1.30	1.90	1.50	1.30
Biochemical Oxygen Demand (mg/l)	1.20	1.07	1.21	0.32	1.17	1.28	1.23	0.72	1.22	1.25	0.30	1.16	1.20
Chloride (mg/l)	7.83	8.97	7.60	8.10	8.87	8.50	8.20	8.70	8.10	7.17	7.53	8.10	8.53
Nitrate (mg/l)	0.10	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pH	5.28	5.47	5.35	6.88	5.32	5.61	5.44	7.60	5.57	5.43	7.56	5.34	5.48
Nitrate (mg/l)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fluoride (mg/l)	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00
Sulphate (mg/l)	1.43	2.35	2.42	0.47	2.64	2.58	1.89	0.50	3.10	2.45	0.38	2.24	1.96
Phosphate (mg/l)	0.05	0.07	0.07	0.02	0.08	0.06	1.07	0.05	0.13	0.07	0.01	0.06	0.07
Residual Chlorine (mg/l)	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Sodium (mg/l)	3.00	2.80	2.20	2.50	3.00	2.40	3.80	3.60	4.00	3.10	3.40	3.00	0.50
Calcium Hardness (mg/l)	11.70	8.30	13.30	6.00	8.30	11.70	10.70	7.30	12.30	11.70	4.00	8.00	11.60
Potassium (mg/l)	0.70	0.60	0.50	0.50	0.70	0.50	0.80	0.60	1.00	0.70	0.70	0.50	0.50
Magnesium Hardness (mg/l)	2.59	2.77	3.27	1.54	2.37	3.42	3.07	1.47	3.26	2.68	2.26	2.75	2.12
Copper (mg/l)	0.100	0.180	0.020	0.10	0.150	0.130	0.040	0.150	0.060	0.120	0.140	0.160	0.080
Zinc (mg/l)	0.300	0.000	0.030	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.160	0.080
Lead (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nickel (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cadmium (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Iron (mg/l)	0.040	0.030	0.050	0.040	0.060	0.050	0.080	0.070	0.080	0.040	0.030	0.030	0.040
Chromium (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Manganese (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: *Author's field work (2011)*

- ● = Private borehole
- * = Public borehole

The mean temperature of the private borehole water samples was 26.81°C while that of the public was 27.43°C. Turbidity value of 0.80 NTU and 0.37 NTU were obtained for private and public borehole water samples respectively. The mean value of electrical conductivity for the private source was 12.10µs/cm and that of the public was 47.69µs/cm. The colour value for the two borehole water supplies remained constantly at 5.00HU. Total dissolved solids value of 12.10mg/l was recorded for private source while 96.72mg/l was obtained for public borehole water samples.

The mean pH of private and public borehole water samples stood at 5.42 and 7.34 respectively. Hardness level for the private source was 22.36mg/l while that of the public was 12.98mg/l. The mean concentration of biochemical oxygen demand (BOD) in private borehole water samples was 1.19mg/l whereas 0.45mg/l was for the public source. Dissolved Oxygen (DO) level for the private source was 1.34mg/l, while 1.80mg/l was recorded for the public borehole water samples.

The mean value of the inorganic (chloride, nitrate, nitrite, fluoride, sulphate, phosphate, residual chlorine, sodium, calcium, potassium and magnesium) were 8.18mg/l, 0.03mg/l, 0.01mg/l, 0.003mg/l, 2.23mg/l, 0.07mg/l, 0.00 mg/l, 2.78mg/l, 11.49mg/l, 0.65mg/l and 2.83mg/l respectively for the private borehole water samples, while those of the public were 8.1mg/l, 0.03mg/l, 0.001 mg/l, 0.003 mg/l, 0.45, 0.02mg/l, 0.10mg/l, 3.16mg/l, 5.7mg/l, 0.60mg/l and 1.75mg/l respectively for the same inorganic.

The mean levels of heavy metals (copper, zinc and iron) stood at 0.10 mg/l, 0.043 mg/l and 0.05 mg/l respectively for the private borehole water source, while 0.13mg/l, 0.01mg/l and 0.04mg/l levels of concentrations were obtained for the public source for the same heavy metals respectively. Others (lead, nickel, cadmium and chromium) had a concentration of 0.000mg/l for the two sources of water supplies.

3.2 Bacteriological Analysis Results

Table 3 shows bacteriological analysis results of private and public borehole water samples in the study area.

Table 3: Bacteriological analysis results of private and public borehole water samples in Uruan Local Government Area

Sample Code	Total Viable Bacteria (Cfu/ml)	Total Coliform Count (Cfu/100ml)	Escherichia coli Count (cfu/100ml)	Streptococcus faecalis count (cfu/100ml)	Clostridium perfringens count (cfu/100ml)
●S_1	1800	4	0	0	0
●S_2	3400	13	0	0	0
●S_3	1600	28	2	0	0
*S_4	0	0	00	0	0
●S_5	3000	19	1	3	1
●S_6	4400	12	3	1	0
●S_7	3700	20	4	2	2
*S_8	90	0	0	0	0
●S_9	1600	34	2	2	1
●S_{10}	5500	0	0	0	0
*S_{11}	0	0	0	0	0
●S_{12}	2400	4	0	0	0
●S_{13}	1800	15	3	3	0

● = Private borehole
* = Public borehole

The parameters were the indicators of faecal pollution of water (total coliform bacteria, *Esxherichia coli, Streptococcus faecalis and Clostridium perfringens)* and total viable bacteria. The total viable count ranged from $1.6x10^3$ to $5.5x10^3$ cfu/ml in the private borehole, while $9x10^1$ was recorded for the public borehole water samples. Total coliform count on the private borehole water samples ranged from $4x10^0$ to $3.4x10^1$ cfu/100ml whereas there was no growth in the public source. The range of *Escherichia coli* was found to be $1x10^0$ to $4x10^0$ in the private source, while that of the public was zero. *Streptococcus faecalis* and *Clostridium perfingens* ranged from $1x10^0$ to $3x10^0$ cfu/100ml to $2x10^0$ cfu/100ml respectively in the private borehole water supply, whereas zero count was recorded for the public borehole water samples.

The frequency of occurrence of organisms in each borehole water supply source is represented in Figure 2.

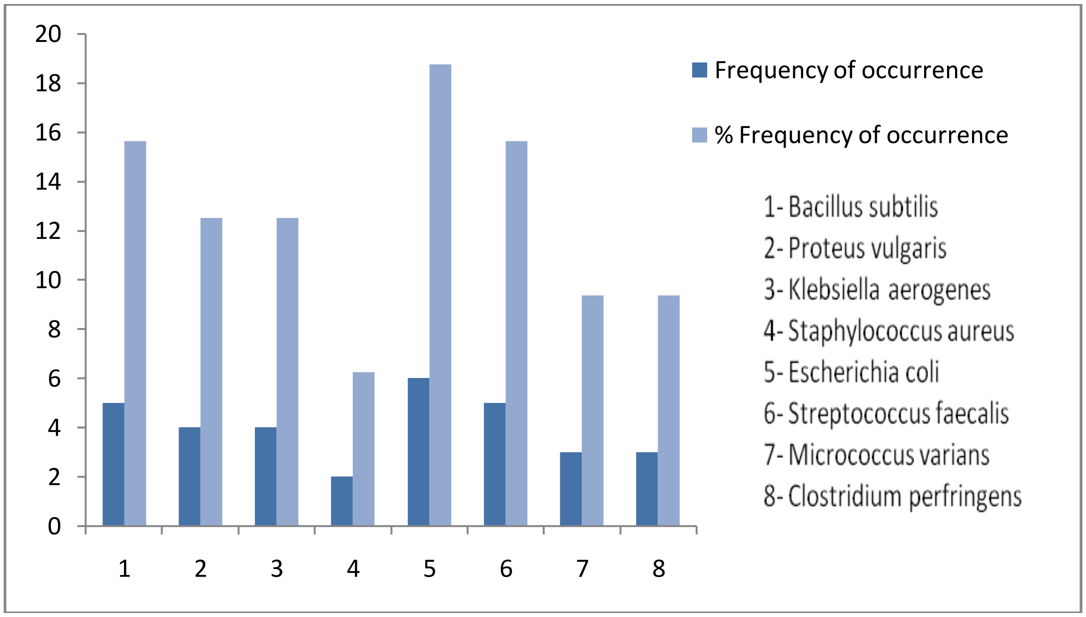

Fig. 2: Frequency of occurrence of organisms in each borehole water supply

Figure 3: represents the frequency and percentage frequency of occurrence of organisms in the two sources of borehole water supplies in the study area.

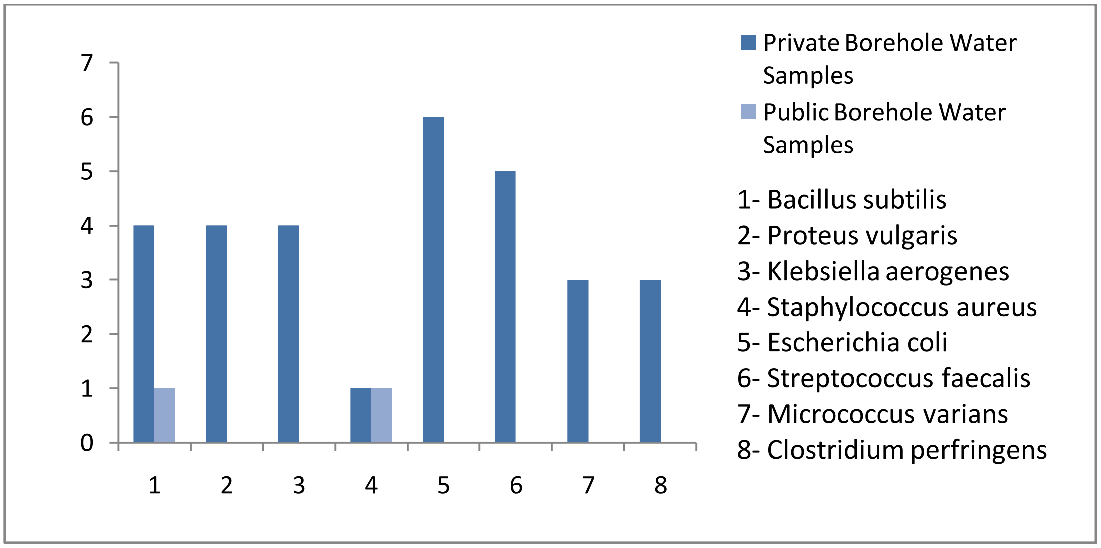

Fig. 3: Frequency and percentage frequency of occurrence of organisms in the two sources of borehole water supplies

3.3 Variance between the Qualities of Borehole Water Samples in the Study Area

The analytical data obtained were analyzed using one-way analysis of variance (ANOVA) employing the Statistical Package for Social Sciences (SPSS).

Table 4a: Summary of Analysis of Variance

Sample Locations	Count	Sum	Average	Variance
Sample Point 1	34	1935.971	56.94032353	4914.71486
Sample Point 2	34	3525.95	103.7044118	339279.2509
Sample Point 3	34	1784.883	52.49655882	74868.99116
Sample Point 4	34	206.201	6.064735294	291.1137066
Sample Point 5	34	3137.22	92.27117647	264017.9128
Sample Point 6	34	4552.971	133.9109118	568272.4749
Sample Point 7	34	3860.652	113.545882	401647.2265
Sample Point 8	34	427.041	12.36002941	1449.364718
Sample Point 9	34	1787.141	52.56297059	74855.792
Sample Point 10	34	5631.27	165.6255882	888473.9051
Sample Point 11	34	229.9	6.761764706	387.5042998
Sample Point 12	34	2520.891	74.14385294	168937.57
Sample Point 13	34	1942.62	57.13588235	94890.35268

Source: *Author's Analysis (2011)*

Table 4b: ANOVA Result

Source of Variation	SS	df	MS	F	P-value	F-crit
Between groups	988819.7242	12	82401.64368	0.97618816	0.97618816	1.774767771
Within groups	98085443.73	429	228637.398			
Total	99074263.45	441				

Source: *Author's Analysis (2011)*

The analysis of variance result is as presented in Table 4(b). From the Table, the sum of squares (SS) between groups is 988819.7242 while that of within groups is 98085443.73 totaling 99074263.45. The mean square (MS) between groups is 82401.64368 while that of within groups is 228637.398. The F-crit (critical value) is 1.774767771 and the F (Fisher's ratio) is 0.3604317 for degree of freedom of 12. The ANOVA result shows that there is no significant difference in the quality of water samples across the sample locations (S_1 to S_{13}) in the study area.

3.4 Testing Of Hypothesis

The t-test was used to test the formulated hypothesis employing a software based approach (SPSS). The physicochemical analysis results of private and public borehole water samples in the study area (Table 1) and the physicochemical analysis results (Table 2) were used to compute the t-test. The summary of the t-test is as presented in Table 5.

Table 5: t-test result (two sample assuming equal variances)

	Variable 1	Variable 2
Mean	3067.9569	287.714
Variance	1750287.314	14699.42035
Observations	10	
Pooled variance	1434725.878	
Hypothesized Mean Difference	0	
df	11	
t Stat	3.526039926	
P(T<=t) one-tail	0.002373885	
t Critical one-tail	1.795884814	
P(T<=t) two-tail	0.004747771	
t Critical two-tail	2.200985159	

Source: *Author's Analysis (2011)*

The mean value for variable 1 and 2 are 3067.9569 and 287.714 respectively, while variance of 1750287.314 and 14699.42035 for variable 1 and 2 respectively. From Table 5, the critical values (t-critical) one tail is 1.795884814, while the statistical value t-state) is 526039926 for df (degree of freedom) of 11. The t-test shows that there is significant difference between the quality of the public and private borehole water supply sources in the study area. The null hypothesis (Ho) which states that there is no significant difference between the quality of public and private borehole water supplies is therefore rejected and the alternative hypothesis (H_1) is accepted.

4.0 Discussion of Results

This sub-title covers discussions on the physicochemical and bacteriological analysis results of the private and public borehole water samples and implications of the findings in water supply.

(i) Physicochemical Quality of the Samples

There was no much considerable variation in the physicochemical parameters of the samples across the 13 sampling points. For example physical parameter like the colour remained constantly at 5.00HU.

Udom *et al*, (2002) obtained similar values (5.00 – 15.00HU) in their work and they recommended that the colour of the sample was within the acceptable limit of the World Health Organisation (WHO) standard for drinking water. The turbidity results obtained were in the range of 0.67 to 0.96 NTU for private and 0.32 to 0.41 NTU for the public borehole water samples. The same range of result (0.08 to 0.58 NTU) was obtained by Okonko et al., (2006) in their studies of borehole water and other samples used for domestic purposes in Lagos, Nigeria.

The values of electrical conductivity obtained from the private borehole water samples ranged from 18.13 to 38.62 µs/cm while that of the public ranged from 89.18 to 103.00µs/cm. These values were below the recommended WHO standard of 1000 µs/cm and was better health wise. Mishra and Bhatt (2007) obtained electrical conductivity range of 20.50 to 45.50 µs/cm in their studies of borehole water in Anand District of India. Lehloesa and Muyima (2002) had comparable values of 18.80 to 60. 00µs/cm in their study of underground water in the Victoria District of South Africa. Other physical parameters like the appearance, temperature, taste and odour were within the approved standards.

The pH range of water samples form the private borehole was 5.28 to 5.61 against the WHO standard range of 6.50 to 8.50 whereas that of the public was 6.88 to 7.56. This pH range (6.88 to 7.56) might have been achieved through certain form of water treatment (pH correction) by the Akwa Ibom State Water Company which is the donour agency. The low pH range of water samples from the private borehole may be injurious to health if consumed.

The range of dissolved oxygen (DO) value obtained for private borehole water samples was 1.20 to 1.50mg/l, while that of the public was 1.50 to 1.90mg/l. Itah and Akpan (2005) obtained values of 0.01 to 2.00mg/l in a similar study of borehole water samples from Eastern Obolo Local Government Area of Akwa Ibom State. This range was regarded as being acceptable even though they were lower than the recommended value of 6.00mg/l by the International Standards.

The Biochemical Oxygen Demand $(BOD)_5$ range of 1.07 to 1.28mg/l was recorded for private borehole water samples, while 0.30 to 0.72 mg/l was recorded for the public and were quite lower than the WHO recommended standard of 10mg/l, but acceptable. Ogan (1988) reported a range of 0.15 to 6.92mg/l in the river of Port Harcourt which were surface water, while Ekeh and Sikoki (2003) obtained the range of 1.32 to 6.80mg/l from the Calabar River. Itah and Akpan (2005) also obtained a range of 0.16 to 3.40mg/l from a similar study of borehole water samples from the oil impacted community in Eastern Obolo of Akwa Ibom State. The average alkalinity values of 1.36 and 1.00mg/l were recorded for the private and public borehole water samples in the study area respectively. These values were below the highest desirable level of 200mg/l recommended by the WHO and were accepted.

The concentration of chloride in the private borehole water samples ranged from 9.17 to 8.97mg/l while that of the public ranged from 7.53 to 8.70mg/l. Mishra and Bhatt (2007) obtained higher values of 17.50 to 22.20mg/l in their studies of borehole water from Anand District of India and were still within the WHO recommended standards of 250mg/l. Values of other inorganic anions like nitrate, phosphate, nitrite and fluoride in the two sources of borehole water supplies in the study area were within the approved standards for drinking water.

The average level of sodium in the two sources of borehole water supplies was 2.86mg/l, while that of potassium was 0.63mg/l and were within the acceptable limits. Nkansah and Ephraim (2009) obtained value of 6.00 to 87.00 mg/l in their physicochemical studies on selected borehole water samples from Bosomtwi District of Ghana and were still below the European Union recommendation of 200mg/l. The concentration of other inorganic cations like calcium and magnesium were within the recommended level.

The value of copper in the private borehole water samples ranged from 0.02 to 0.18mg/l while that of the public ranged from 0.10 to 0.15mg/l. Itah and Akpan (2005) obtained a range of 0.01 to 1.00mg/l which where in accordance with the maximum acceptable limit of 1.00mg/l. The average level of zinc in the private and public borehole water samples were 0.043 and 0.10mg/l respectively. Itah and Akpan (2005) recorded zinc values of 0.01 to 0.05mg/l in borehole water samples from Eastern Obolo Local Government Area of Akwa Ibom State. These values were within the WHO standard of 0.10mg/l.

The average concentration of iron in the private borehole water samples was 0.05mg/l while that of the public was 0.04mg/l and were within the acceptable limits. The concentration of other heavy metals (lead, nickel, cadmium, chromium and manganese) was <0.01mg/l for the two sources of borehole water supplies and fell within the recommend standards.

(ii) Bacteriological Quality of the Samples

There was much considerable variation in the bacteriological quality of the samples across the 13 sampling points. The bacteriological quality of the samples was unsatisfactory except samples from the public boreholes that met the approved standards. The total viable count on the private borehole water samples ranged from 1.6×10^3 to 5.5×10^3 cfu/ml, whereas 9×10^1 cfu/ml was obtained from only one public borehole water sample (S_8) in Utit Uruan. Total coliform bacteria count ranged from 4×10^0 to 34×10^1 cfu/ml in private borehole water samples, while 0cfu/100ml was recorded for the public borehole water samples. Faccal coliform count (*Eschrichia coli*) ranged from 1×10^0 to 4×10^1cfu/100ml in private borehole water samples, whereas there was no growth of *E.coli* in the public source.

The presence of *E.coli* in some samples is of great concern and implies faecal contamination of such samples. This strongly suggests the possible presence of enteric pathogenic bacteria like *Salmonella typhi, Salmonella paratyphi, Vibrio cholera, Aeromonas hydrophila and Yesinia enterocolitica* (Itah, Etukudoh and Akpan, 1996) as well as other parasites. Zabbey (2009) detected faecal coliform contamination level of 15 to 25cfu/100ml in his study of borehole water samples from Ogale Nehia of River State.

Streptococcus faecalis was isolated from 5 private borehole water samples and ranged from 1×10^0 to 3×10^0cfu/100ml, while *Clostridium perfringens* ranged from 1×10^0cfu/100ml for the same private borehole source. None of these organisms was isolated from the public borehole water samples. The presence of *Streptococcus faecalis* (*Enterococcus faecalis*) in some samples implies faecal pollution dating to remote period. In the same manner, the presence of *Clostridium perfringens* (*Clostridium welchii*) is similarly an indication of pollution for a very remote period since *Clostridium* is a microaerophilic endospore forming bacteria that can survive adverse environmental conditions for a long period of time unlike the other organism like E.coli that are without spores.

The bacteriological results therefore agree with the reports by Itah and Akpan (2005) in their studies on potability of drinking water in an oil impacted community in Southern Nigeria and that of Adesiyun, Alayande and Adeleke (1999). According to the authors, the water samples were found to contain indictor organism most especially *Escherichia coli* and other coliform bacteria with several other heterotrophic bacteria which made them unfit for human consumption. The presence of *E.coli* in water meant for drinking is generally unaccepted.

Other organisms isolated in this study were *Klebsiella aerogenes, Staphyllococcus aureus, Proteus vulgaris, Bacillus subtilis* and *Micrococcus variance*. These organisms are pathogenic in nature and might have gained entrance into the supplies through various sources. Most sanitary pipelines are located in close proximity to water supply including borehole locations which traverse the septic tank absorption fields. Since the sewer and the cast pipes for the transportation of water are subject to leakages, sometimes accidental backflow or back seepage of polluted water from toilets and wash bowls may occur, resulting in the contamination of water supply pipes through leakages in supply line passing through the drain fields (Uriah and Esuagbe, 1990). The authors explained that faecal coliform bacteria might be introduce into the borehole in the same manner.

They also added that boreholes located near latrine (or soak away pits) may receive high load of enteric bacteria from the toilet through percolation to the borehole water level, thus faecally contaminating the drinking water sources.

Investigation in the area under study shows that there are many reported cases of enteric diseases like typhoid and paratyphoid fevers in the health centres. This may not be unconnected with the presence of the isolated organisms in the supplies which are detrimental to health as they are responsible for varieties of diseases. The complete absence of organisms in two public borehole water samples perhaps might be due to the fact that some forms of treatment (disinfection) was periodically applied to the supply by the donour agency (Akwa Ibom State Water Company). This could be evidenced by the presence of residual chlorine in the samples.

Conclusion

The physicochemical parameters of the selected private and public borehole water samples in the study area were within the acceptable limits by WHO and FMEnv. standards for drinking water except the pH value which was comparatively low in private borehole water samples. Although some of the chemical parameters fell below the approved standards, they were judged to be acceptable since they were not above the required maximum permissible limits which could have been more riskful and dangerous to health.

The bacteriological analysis results of the 10 selected private borehole water samples were not acceptable since they were all found to yield moderate to heavy growth of bacteria, thereby making them unfit for human consumption and other domestic purposes.

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