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Quality of Water from Hand-Dug Wells in Nembe Town, Bayelsa State, Nigeria

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ABSTRACT: *This study examined the quality of water supply from hand-dug wells in Nembe town, Bayelsa State using sample survey design. Data was obtained from primary sources. To assess if the quality of groundwater supplied in Nembe town is safe for domestic and drinking purposes, the physico-chemical and microbial status of the groundwater were studied. Nembe town was stratified into ten neighbourhoods and a total of ten (10) hand dug well water samples was randomly collected from each of the sampled ten neighbourhoods and analyzed for twenty-one (21) paramaters in the month of November 2019. These samples were sent to the laboratory for physico-chemical and microbial analysis. The results of the study revealed that physico-chemical paramaters such as Total Dissolved Solids (TDS), Total Suspended Solids(TSS), Sulphate (So_4^{-2}), Bicarbonate (HCo_3^{-}), Calcium (Ca), Sodium (Na), Manganese (Mn), Electrical Conductivity (EC), Iron (Fe), Chloride (CL), Nitrate (NO), Salinity, Total Alkalinity (TA) and Magnesium (Mg) are all within the permissible level of WHO and NESREA drinking water standards. Groundwater in the area have turbidity and potassium levels higher than the WHO and NESREA maximum permissible limits for drinking water standard. All the sampled hand dug wells have pH value within the permissible limit of drinking water except one which had pH value of 6.48 and considered too acidic for human consumption. Based on hardness, 70% of the groundwater samples are slightly hard water to hard water in nature. The result of the microbial analysis showed the presence of total coliforms, Total bacteria counts and fungi in all the hand dug wells. The ANOVA statistical tool was employed in testing the stated hypothesis and the results show that there is no significant spatial variation in the physico-chemical properties of water in the study area and that there is a significant spatial variation in the microbial properties of water in the study area. The result of the study was conclusive evidence that all the hand dug wells studied are not safe for domestic purpose especially for drinking as they were affected by some physico-chemical and biological parameters. Hence the affected wells call for periodic monitoring and treatment to improve the quality of the water.*

KEYWORDS: hand dug-wells, water, quality, pollution.

INTRODUCTION

Water is the most unique molecular compound ever known in life. It exists in the solid, liquid and gaseous states. Water in its liquid state is what makes life possible on earth because all living organisms are composed of cells that contain at least sixty percent (60%) water (Enger and Smith, 2010). Water represent unique and significant feature in any settlement; for drinking, sanitation, washing, planting, recreation, industrial process amongst others. (Aderogba, 2005). Water is very important for the socio-economic survival of the human race, irrespective of the sources; its availability and quantity often affect or determine the type of use. Thus, water use (demand) is a function of availability (supply).

For water to be adequately utilized, it has to be reasonably free from contaminants. Otherwise, such waters could pose serious health and environmental risks to living organisms that depend on them. Potable water is a fresh water body that is unpolluted, suitable for drinking, odourless and tasteless (Enger and Smith, 2010). Such water boils at 100^{o}C, freezes at O^{o}C, is neutral to litmus and has an atmospheric pressure of 760mm Hg (Kolo, 2007). Water could be cultivated in various forms; it could be tapped from underground aquifers via wells or boreholes. It could be harvested as rain water (precipitation) from the atmosphere. This is the practice in most communities, while others fetch from surface water sources like rivers, streams, ponds, oases, seas or even oceans.

The problem of global water supply and sanitation is neither with the quantity of water on earth nor with the physical challenges of our various environments. Rather, it is all about water quality and accessibility to all categories of people; as well as the technology at the disposal of the countries (Nwaogazie, 2006). In developing countries of the world, people are still grappling with the problem of water supply. The provision of clean drinking water and discharge of adequately treated waste water is a fundamental requirement for human life. The lack of access to clean water supply is a serious health concern. According to reports worldwide, over a million deaths per year have been attributed to unsafe water, with close to 90% of these deaths occurring in children under five years of age (Akpor and Muchie, 2011). Globally, problems related to the management of water supply and distribution exists. This is partly due to extensive industrialization; increased population density and high rates of urbanization.

A proactive recipe to addressing the water situation in Nigeria is by conducting freshwater inventory of the country's water resources. Relying on the 1995 study report of the Assisted Water Resources master plan for Nigeria, the Federal Ministry of Water Resources (FMWR, 2011) postulated that, Nigeria has huge water resources potentials estimated at 267 billion cubic meters of ground water. Yet, the current water supply service coverage in the country is still very low, about 58% (i.e about 87 million people have access to safe water supply) while percentage of people with access to sanitation is just 32% (about 54million people) Again that about half of Nigerian populations (i.e. over 70 million people) do not have access to potable water supply. This represents about 6% of the world's population who do not have access to safe water supply

(FMWR 2011). The 2013 update of the water situation by the Federal Ministry of Water Resources (FMWR) argued that improved water supply now stands at 49.9% for the rural and 69.3% for the urban regions and a National average of 54.3%. Whether these figures contradict themselves and are misleading or not, the truth remains that access to safe water supply and basic sanitation is grossly inadequate in Nigeria.

The rural areas are often neglected in terms of social services. Access to safe water is also very appalling with majority of the rural poor having no choice to make rather than to rely upon unprotected wells, surface streams/rivers and swamps/ponds. These sources are often very vulnerable to pollution. Except in some rare cases where boreholes are provided by some individual philanthropists, NGOs and by community efforts, access to safe water supply in these areas is still low. These poor sources of water supply are often the avenues through which many disease vectors are spread across space; with the victims mostly children and the less priviledged (WOP, 2009; WHO-UNICEF, 2006). The lack of safe drinking water in any location can spell doom. Hence, proper planning on the provision of basic amenities especially potable water at the rural regions is paramount in our quests for development, making the study of water quantity and quality in our communities' expedient.

Nembe Town where this study is located is the headquarters of Nembe Local Government Area of Bayelsa State. It is well endowed with lots of water resources. However, much of this water is not safe and not readily available for use by the people. Safe water supply is very vital for the general welfare of the citizens hence, it is important for all governments to redouble their efforts in ensuring that safe water is available and accessible to the people. It is on this premise that this current study dwells.

The Nembe community has made efforts to provide and/or access potable water for domestic consumption to its inhabitants, Nevertheless the problem of water shortage has continued both in quantity and quality. This has caused the inhabitants to resort to the use of hand-dug wells as an alternative source of water supply. Suffice it to say, these wells are dug and utilized in areas of questionable hygiene due to the impact of substances such as physical, chemical (both inorganic and organic) and biological contaminants which cause taste, colour, odour and cloudy appearance (turbidity) and hardness, corrosiveness, staining and frothing. The residents of the community claim that limited access to or the poor water supply, unhygienic and unsanitary nature of the water from the hand-dug well is or suspected to cause the prevalence of waterborne diseases in the study area with far reaching health consequences. The aim of this study was to examine the quality of water supply from hand-dug wells in the Nembe town.

To achieve the aim of the study, the following are the specific objectives:

1. to assess the physico-chemical characteristics of water from hand-dug wells in the study area.
2. to assess the microbial characteristics of water from hand-dug wells in Nembe town.
3. to provide baseline information for future water quality monitoring in the area

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The Study Area

Nembe is a Local Government Area of Bayelsa State. Its headquarters are in the town of Nembe in the east of the area between Latitude 4^o30^1N and 4^o32^1N and Longitude 6^o23^1E and 6^o25^1E. The area covered is 760 kilometer square. It shares boundary with the following communities; Biokponga in the north, Agbakakiri in the West, Sangapiri in the north east and Butuboko in the south.

Geologically, the study area as well as the entire Bayelsa State, is located within the lower delta plain believed to have formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The major geological characteristic of the study area is sedimentary alluvium. The region exhibits a large amount of biological diversity. It is a low lying relief area. Its surface geology consists of fluvial sediments (Akpokodje, 1987).

The mangrove swamps are low lying, generally at less than above 5m above sea level, drained and crisscrossed by tidal creeks that divide the swamps into somewhat quasi-rectangular blocks. Within each block, elevation increases gradually away from the demarcating creeks towards the center of the block; the land in this central area is drier and supports vegetation that is different from the mangroves that line creek banks. The topography of the area is essentially flat, sloping very gently seawards. The area is low lying and is drained and crisscrossed by network of distributaries (Oyegun, 1999).

Nembe has basically two major climates normally referred to as wet and dry seasons which are characteristics of the sub-equatorial climate of the Niger Delta. The wet season is characterized by heavy precipitation. This season with its heavy down pours and long lasting drizzles, begins in the month of march and frizzles out in the month of November, Although, occasional sunshine could be experienced in some days during this season. The weather is generally dull and wet (Oyegun, 1999; Chima et al, 2007).

The dry season is characterized by abundant sunshine and could be very hot especially towards the mid-day. The season commences in the month of November and ends in the month of March except for occasional rainfall and towards the middle of the season which is cold, dry and dusty due to the influence of North East trade winds (Harmattan). The weather is generally hot. Due to the climate, tropical forest which appears very green during the wet season shed its leaves during the dry season thereby exposing the land (Digha, 2021a and Digha, 2021b).

The area is flat, nowhere is more than a few feet above sea level. Nembe is characterized by mangrove forest type of vegetation. It consists almost entirely of the red mangrove tree with its characteristic stilt of prop roots. The trees grow tallest along creek edges where fresh mud is deposited. In the old growth back swamp areas, trees are very stunted; especially in areas not receiving nourishing waters from the ocean or the Niger flood. The back swamp may have other smaller mangrove species, such as the white mangrove and the black mangrove (Nyananyo, 1999).

The area has the mangrove swamp alluvial soils. Some of the soil consists of mud mixed with decayed organic matter. The mangrove swamp alluvial soils are brownish on the surface, sometimes with an unpleasant and offensive odour. The soils of the swamps are rich in organic matter in the top layer, but contain too much salt especially in the dry season. The soils are all of fluviatile origin, except for coastal barrier islands that consists of marine sand overlain with an organic surface layer. The continuous movement of the delta's creeks has resulted in a mosaic of soil types. Remnants of old levees consist mostly of water permeable sand and loam (Okonny et al, 1999). The people of Nembe are made up of teachers, ministry workers, oil company workers, traders, fishermen and farmers.

The area covered is 760 kilometer square. According to the 2006 National population census, Nembe Local Government Area has a population of about 130, 931 people and Nembe town itself has about 23, 295 people.

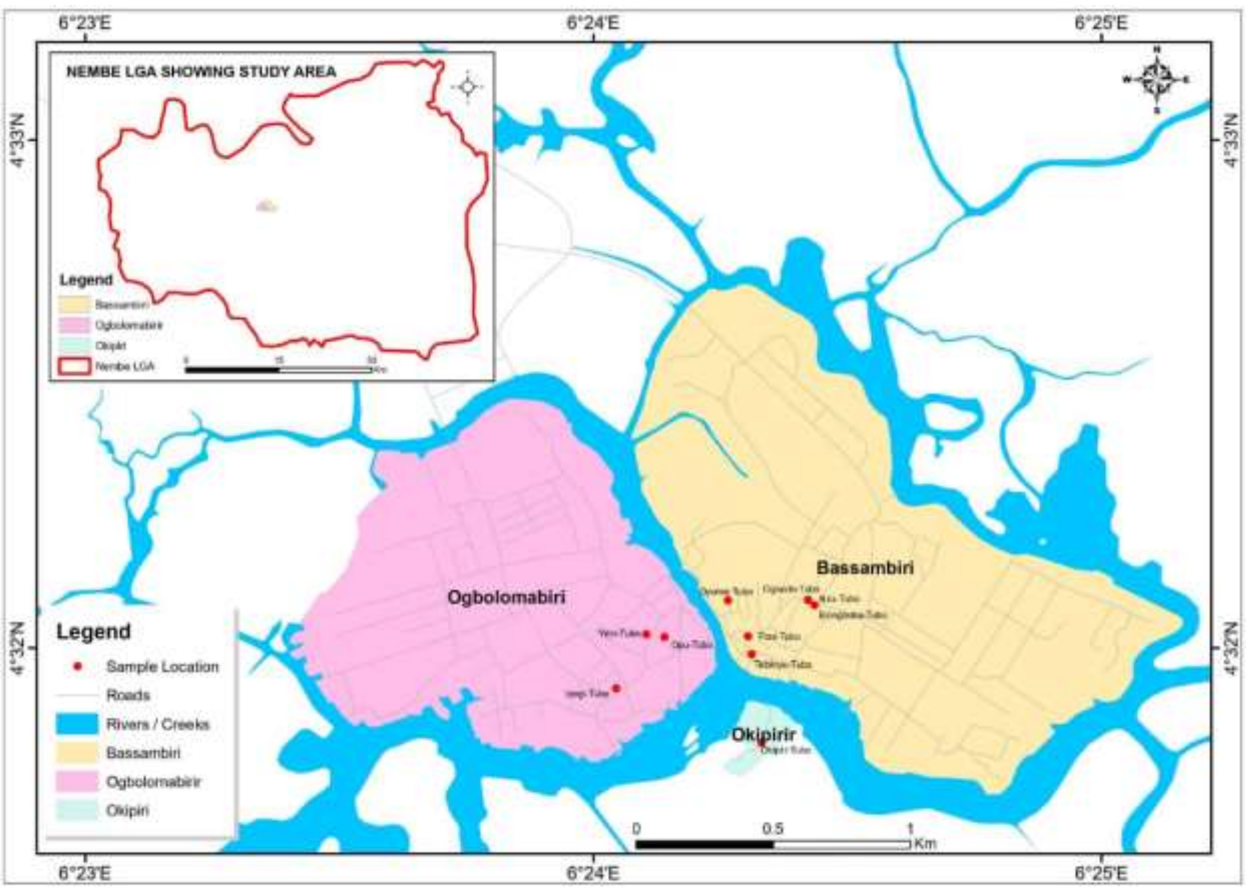

Figure 1: Map of Nembe Showing the study location on sampling area.

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MATERIALS AND METHODS

The water samples were collected at designated points adequately distributed throughout Nembe town. The stratified random sampling technique was employed in this work. Nembe town was stratified into ten neighborhoods namely; Ogbo-polo, Oyoma-Polo, Igbobele-Polo, Okipiri, Ilulu-Polo, Sikaka-Polo, Poni-Polo, Amassara-Polo, Agbutubu-Polo and Isokiri-Polo. The simple random technique was then adopted using the table of random numbers to collect a total of ten [10] hand-dug well water samples from each of the sampled ten neighbourhoods. The hand-dug wells in each neighbourhood was listed and then assigned with numbers. Then the researcher uses the table of random numbers to select a sample of ten [10] hand-dug wells which represented the sample size (See table 1).

Table 1: Sample locations of hand dug wells in Nembe town.

S/N	Sample description	Sample location	Latitudes	Longitudes
1	Ogbodo – Tubo	Ogbo - Polo	$4^{o}\ 32^{I}\ 5.68^{II}$ N	$6^{o}\ 24^{I}\ 25.32^{II}$ E
2	Oyoma – Tubo	Oyoma – Polo	$4^{o}\ 32^{I}\ 5.63^{II}$ N	$6^{o}\ 24^{I}\ 15.87^{II}$ E
3	Biongboba – Tubo	Igbobele – Polo	$4^{o}\ 32^{I}\ 07^{II}$ N	$6^{o}\ 24^{I}\ 26.11^{II}$ E
4	Okipiri – Tubo	Okipiri	$4^{o}\ 31^{I}\ 48.78^{II}$ N	$6^{o}\ 24^{I}\ 19.81^{II}$ E
5	Ilulu – Tubo	Ilulu - Polo	$4^{o}\ 32^{I}\ 5.68^{II}$ N	$6^{o}\ 24^{I}\ 25.32^{II}$ E
6	Teibinyu – Tubo	Sikaka - Polo	$4^{o}\ 31^{I}\ 59.26^{II}$ N	$6^{o}\ 24^{I}\ 18.66^{II}$ E
7	Opu – Tubo	Agbutubu – Polo	$4^{o}\ 32^{I}\ 1.31^{II}$ N	$6^{o}\ 24^{I}\ 8.38^{II}$ E
8	Poni – Tubo	Poni – Polo	$4^{o}\ 32^{I}\ 1.40^{II}$ N	$6^{o}\ 24^{I}\ 18.22^{II}$ E
9	Yinn – Tubo	Amassara - Polo	$4^{o}\ 32^{I}\ 1.62^{II}$ N	$6^{o}\ 24^{I}\ 6.21^{II}$ E
10	Ipogi - Tubo	Isokiri – Polo	$4^{o}\ 31^{I}\ 55.22^{II}$ N	$6^{o}\ 24^{I}\ 2.67^{II}$ E

The ten water samples were collected for laboratory analysis, samples were collected based on the water quality of the sample investigated and laboratory analysis was carried out to check the water quality in accordance with APHA (1998). The status of the existing water quality was compared with the standards of the World Health Organization (WHO, 2004) and National Environmental Standards and Regulations Enforcement Agency (NESREA; 2009].

The G.P.S was used to measure the co-ordinates of sampling stations. The groundwater samples were collected manually from ten (10) hand dug wells which are used for domestic purposes. A clean rope was tied to a small bucket which was washed with detergent and rinsed properly before fetching the well water. The water was then turned into ten (10) 2litre plastic containers that have been sterilized to avoid contamination by any physical, chemical or microbial means after thorough washing and rinsing with the respective water samples. As soon as each of the 75cl plastic containers was filled to the brim to avoid air bubbles, the cap was used to seal it firmly, the bottle labeled and kept in a cooler box containing ice, before being sent to the laboratory for analysis. The water samples were collected and analyzed in December 2019 in a once-off sampling exercise.

The water samples were collected between 6am and 7am at all locations on same day. The water quality parameters selected for the study were pH, salinity, Electrical conductivity, Turbidity, TDS, TSS, NO_3^-, SO_4^{-2}, TA (Total alkalinity), TH (total hardness), Ca, Mg. Na, K, Fe, Mn, Total coliform (T.col), Total Heterotrophic Bacteria (THB) and fungi.

The collection, transportation, preservation and analyses of water sample were carried out as prescribed in the standard methods for water examination (APHA, 1985) and interpreted based on the World Health Organisation Standard for Drinking Water Quality and the Nigerian Drinking Water Quality Standard. The concentrations of the physico-chemical and bacteriological constituents as they affect the quality of drinking water were used to determine the level of groundwater pollution in the study area.

For parameters like PH, temperature, turbidity, total dissolved solids, electrical conductivity, turbidity calibrated meters were used in the analyses. For other parameters like alkalinity, chloride as iron, chromium, cadmium, copper, zinc was analysed using atomic absorption spectrophotometric techniques. While total and faecal coliform were determined using multiple fermentation and most probable number (MPN) techniques using media such as nutrient agar and macConky agar. As noted earlier, water samples were collected from the various sources and taken to the laboratory for the various analyses. These include specifically, the two main quality test for drinking water – physico-chemical and bacteriological components, which was compared with the standards of the World Health Organization (WHO, 2004) and National Environmental Standards and Regulations Enforcement Agency [NESREA 2009]. Water samples were analyzed at Niger Delta University (NDU) chemistry and biology laboratories, Amassoma, Bayelsa State. Inferential statistics was employed to test the hypothesis. The one – way Analysis of Variance (ANOVA) was used to analyse the two hypotheses.

RESULTS AND DISCUSSION

The sample locations of the hand-dug wells were obtained by the researcher with the aid of the GPS (see appendix 1). Table 1 below is a summary of results for the eighteen (18) physico-chemical parameters studied for groundwater at Nembe town.

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Table 2 Summary of Physico-Chemical and Microbial Parameters
From 10 Sampled hand dug wells in the study area.

S/N	Parameters Physical	Range	Mean	WHO Standard	NESREA Standard
1.	pH	6.48-7.14	6.888	7.0-8.5	6.5-8.5
2.	Salinity (mg/l)	0.05-0.43	0.201	400	-
3.	Conductivity(/cm)	132.0-750	403.84	1000	-
4.	Turbidity (NTU)	12.80-36.50	24.035	5	5
5.	TDS (mg/l)	66.0-375	197.1	500	1200
6.	TSS (mg/l)	1.876-3.57	2.6769	-	30
7.	NO_3^- (mg/l)	2.187-6.560	3.6021	45	10
8	CL^- (mg/l)	10.0-59.0	30.0	-	10
9.	SO_4^{2-} (mg/l)	4.40-29.50	14.42	0.05	250
10.	HCO_3 (mg/l)	1.50-4.30	2.59	1000	-
11.	Total Alkalinity (mg/l)	14.0-46.0	27.8	500	-
12.	Total Hardness (mg/l)	52.0-272.0	155.1	500	-
13.	Ca. (mg/l)	10.36-46.20	26.204	75-200	-
14.	Mg (mg/l)	2.54-10.79	5.978	30-150	-
15.	Na (mg/l)	3.83-22.80	11.955	200	-
16.	K (mg/l)	1.32-8.24	3.866	2	-
17.	Fe (mg/l)	0.02-0.06	0.029	0.1-1	0.03
18.	Mn (mg/l)	0.01-0.03	0.016	0.05-0.5	0.05
19.	Total coliform (mpn/100ml)	0.09-111.0	15.209	0	0
20.	Total Heterotrophic Bacteria (mpn/100ml	0.09-115.0	24.378	0	0

- means not determined (nd)

pH of Sampled Well Water**:** The hydrogen ion concentration (pH) is an important factor in water analysis, since it enters into the calculation of acidity, alkalinity and the processes like coagulation, disinfection and corrosion control. The pH of water indicates the form in which the carbon dioxide is present. A change of pH from 6 to 7 indicates that there is a tenfold decrease in the hydrogen ions concentration. In a similar fashion, a change of pH 7 to 8 indicates a tenfold increase in hydroxyl ions. In nine of the sampling locations of the study area, the pH values of groundwater varied from 6.78 to 7.14 [table 2], which is reported as alkaline in nature and also within the permissible limits of drinking water (WHO 1984; 2004, NESREA 2009). One of the sampling locations pH value was 6.48 which is below the permissible limits of drinking water. pH values less than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis.

Salinity of Sampled Well Water: Salinity is the total concentration of all dissolved salts in water. The salinity values ranged from 0.05 to 0.43mg/l [table 2]. The permissible limit for salinity is

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400mg/l. The results indicated that all the samples of the study area are all below the acceptable level of 400mg/l set by the World Health Organization (WHO). High salinity in water makes it unsuitable for drinking and other usages such as agriculture and industry. High salinity may be caused by natural sources such as the geological structure of soil or by man-made pollutants. The low salinity values may be due to the rains that makes the water brackish unlike the peak of the dry season when the salinity level will be higher.

Electrical Conductivity of Sampled Well Water: Electrical conductivity is a measure of the salt content of water in the form of ions. Conductivity was highest at Sikaka-polo neighborhood with 750٢slcm and lowest at Amassara-polo neighbourhood with 132.0٢slcm [table 2]. The maximum permissible limit of 1000 ٢slcm wasn't met by all values under study. Higher values for conductivity at Sikaka-polo, Poni-polo and Igbobele-polo neighbourhoods could be attributed to dissolved salts and organic materials present as natural resources.

Turbidity of Sampled Well Water: Turbidity values of sampled water were found to range from 12.80 to 36.50 NTU (Table 2). The lowest value of 12.80 NTU was recorded at Amassara-polo neighbourhood while the highest value of 36.50 NTU was recorded at Poni-polo neighbourhood. These values show that all the ten sampled hand dug wells have unsatisfactory turdidity concentrations as they are higher than WHO 5 NTU threshold for potable water supply. The probable reason for the high turbidity values is the high water table. This makes the water in the affected neighbourhoods to be unsafe for human consumption without proper treatment because high turbidity is known to interfere with disinfection and facilitate microbial growth [Ohwo, 2014]. Total Dissolved Solids (TDS) of Sampled Well Water: Drinking water quality is affected by the presence of soluble salts. The total dissolved solids (TDS) up to 500 to 1200mg/l is permitted for drinking as well as other domestic purposes as per the WHO and NESREA standards. TDS also affect the strength and durability of concrete and palatability of food cooked. The TDS concentration in the study area ranged from 66.0 to 375mg/l [table 2]. These values show that all the ten sampled hand dug wells are below the acceptable level of 500g/l set by the World Health Organization (WHO). Since all values were below the acceptable limit they are all safe for drinking on the basis of TDS as supported by Bruvold and Ongerth (1969) as cited in Amukali O (2012) that waters within the limits obtained shere are highly palatable. Total Suspended Solids (TSS) of Sampled Well Water: Total Suspended solid is a measure of the portions of solids that are retained on a filter of standard specified size (generally 2.04) under specific conditions (Bhatia, 2010). The TSS values range from 1.876 to 3.57mg/l, with the lowest value of 1.876mg/l recorded at Ogbo-polo neighbourhood, while the highest value of 3.57mg/l was recorded at Sikaka-polo neighbourhood [table 2]. These values show that all the ten sample hand dug wells are below the maximum permissible limits of 30mg/l set by NESREA Standard

Nitrate (No_3) of Sampled Well Water: In groundwater's, most of the Nitrogen is found in the form of Nitrates. The determination of nitrate is important particularly in drinking water as its presence above 45mg/l has adverse effects on health. When water with high nitrogen concentration is used for drinking, it causes disease like methaemoglobinaenia. The NO_3^- concentration in the study area

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range from 2.187 to 6.560mg/l, with the lowest value of 2.187mg/l recorded at Agbutubu-polo neighbourhood, while the highest value of 6.560mg/l was recorded at Oyoma-polo neighbourhood [table 2]. These values show that all the ten sampled hand dug wells are below the WHO 45mg/l threshold for potable water supply. Low nitrogen concentration in ground waters in the study area means that plants and animals that depend on nitrogen would be suffering from nitrogen-deficiency diseases. Vegetative growth of plants would be grossly affected if ground water were to be used for watering plants within the studied area.

Chloride (Cl^-) of Sampled Well Water: Chloride occurs in all natural water in widely varying concentrations. The origin of chloride in surface and groundwater may be from diverse sources such as weathering and leaching of sedimentary rocks and soils, domestic and industrial waste discharge etc. Excessive chloride in potable water is not particularly harmful and the criteria set for this anion are based primarily on palatability and its potentially high corrosiveness. The concentration of chloride in the study area range from 10.0 to 59.0mg/l [table 2], with the lowest value of 10.0mg/l recorded at Amassara-polo neighbourhood, while the highest value of 59.0mg/l was recorded at igbobele-polo neighbourhood. All values recorded in this study were below the maximum permissible limit of 250mg/l for drinking water (NESERA 2009). The very low value of chloride in groundwater could be attributed to increased neutralization reactions by dissolved alkaline hydroxyl containing agents. Such water could have a tendency of not being able to effectively prevent the proliferation of pathogens owing to the very low level of chlorides in groundwater.

Sulphate (So_4^{-2}) of Sampled Well Water: The observed level of bicarbonate (So_4^-) in the study area range from 4.40 to 29.50mg/l, with the lowest value of 4.40mg/l recorded at Amassara-polo neighbourhood, while the highest value of 29.50mg/l was recorded at Igbobele-polo neighbourhood [table 2]. All the values observed for the 10 sampled hand dug wells are within the maximum permitted level stipulated by WHO and NESREA. Bicarbonate (HCo_3^-) of Sampled Well Water: The observed level of bicarbonate (HCo_3^-) in the study area range from 1.50 to 4.30mg/l, with the lowest value of 1.50mg/l recorded at Amassara-polo neighbourhood, while the highest value of 4.30mg/l was recorded was at Sikaka-polo neighbourhood [table 2]. All the values observed for the 10 sampled hand dug wells are below the maximum permissible level of 1000mg/l by the WHO standard. The bicarbonate concentration can be said to be free and safe for use as house hold level.

Total Alkalinity (TA) of Sampled Well Water: Alkalinity is a measure of ability to neutralize acids. Excess alkalinity gives bitter taste to water and reacts with cations forming precipitates, which can damage the pipes, Valves, etc. However, some alkalinity is required for drinking water to neutralize acids, such as lactic acid and citric acid produced in the human body. Minimum and maximum alkalinity values in the study area range from 14.0 to 46.0mg/l. The lowest value of 14.0mg/l was recorded at Okipiri and Amassara-polo neighbourhoods, while the highest value of 46.0mg/l was recorded at Poni-polo neighbourhood [table 2]. All values recorded in this study were below the acceptable limit of 500mg/l for drinking water.

Total Hardness as ($CaCO_3$) of Sampled Well Water: Hardness is the chemical property of water, which prevents the formation of lather with soap, caused mainly by the multivalent metallic cations like calcium, magnesium, iron and strontium. Total Hardness (TH) for the samples ranged from 52.0 to 272.0mg/l [table 2], with the lowest value of 52.0mg/l recorded at Ogbo-polo neighbourhood, while the highest value of 272.0mg/l was recorded at Sikaka-polo neighbourhood.

These values show that all the ten sampled hand dug wells were below the WHO 500mg/l threshold for potable water supply (see table 3).

The Water hardness classification according to WHO, 2004 follows this criterion.
Table 3 Water Hardness classification

	$CaCO_3$/L
Soft	0 - 50mg
Moderate soft	50 - 100mg
Slightly Hard	100 - 150mg
Moderate Hard	150 - 200mg
Hard	200 - 300mg
Very Hard	Over 300mg

Source: WHO 2004 Classification

From the WHO 2004 classification, 3 of the sampled hand dug wells have moderate soft water which is suitable for domestic use, 3 of the samples have slightly hard water, 1 of the sampled hand dug well have moderate hard water and the remaining 3 sampled hand dug wells have hard water. Hardness in groundwater is normally considered as an aesthetic water quality factor, it does not pose a health risk but higher concentration in water however creates consumer problems that ranged from wastage of soap and interferes with every cleaning task from laundry to household washing. Calcium (Ca) of Sampled Well Water: Calcium is the major constituent of most of the igneous, sedimentary and metamorphic rocks. The values of calcium concentration in the water samples range from 10.36 to 46.20mg/l with the lowest value measured at Amassara-polo neighbourhood, while the highest value was measured at point-polo neighbourhood (table 2). The maximum permissible limit for calcium in drinking water 75-200mgll (WHO 1984; 2004) was not exceeded by any of the sampled hand dug wells.

Magnesium (Mg) of Sampled Well Water**:** The concentration of magnesium of the water samples ranged from 2.54 to 10.79mg/l, with the lowest value measured at Amassara-polo neighbourhood, while the highest value was measured at Igbobele-polo neighbourhood (Table 2). All values recorded in this study were below the maximum permissible limit of 150mg/l for drinking water (WHO, 2004). Higher values of Magnesium could be attributed to rock weathering which could disintegrate chemical substances like magnesium into surface water bodies from where they percolate into ground waters. Hypomagnesaemia could result from consistent dependence on usage of water source as in this case where the magnesium levels were very low.

Sodium (Na) of Sampled Well Water: The concentration of sodium of the water samples ranged from 3.83 to 22.80mg/l, with the lowest value measured at Amassara-polo neighbourhood, while the highest value was measured at Igbobele-polo neighbourhood (Table 2). All values recorded in this study were below the maximum permissible limit of 200mg/l for drinking water (WHO 1984; 2004). At these levels, sodium does not pose any health or environmental threat to the environmental or organisms that depend on the studied area's ground water source. Potassium (K) of Sampled Well Water: Potassium values of sampled water were found to range from 1.32 to 8.24mg/l (Table 2). The lowest value of 1.32mg/l was recorded in Ilulu-polo neighbourhood, while the highest value of 8.24mg/l was recorded at Sikaka-polo neighbourhood. Six of the sampled hand dug wells exceeded the maximum limit set by WHO (2004) range between 1-2mg/l while the remaining four sampled hand dug well did not exceed the maximum limit.

Iron (Fe) of Sampled Well Water: The values of iron concentrations in the water samples range from 0.02 to 0.06mg/l [table 2], with the lowest value measured in six neighbourhoods, while the highest value was measured at Amassara-polo neighbourhood. The concentration limits of iron in drinking water range between 0.1 (acceptable level) and 1.0mg/l (permissible level) (WHO; 2004). All the values recorded in this study were within the permissible level. High Iron concentration affects the taste of water, has adverse effects on domestic uses and promotes growth of iron bacteria. Measure should be taken before consumption by installation of iron removing plants. Manganese (Mn) of Sampled Well Water: The concentration of manganese of the water samples ranged from 0.01 to 0.03mg/l [table 2]. The permissible limit for Mn is 0.05mg/l (WHO 1984; 2004, NESREA 2009). The results indicated that all the samples of the study area is within the permissible limit. Manganese concentration in the water samples was satisfactory, as they were within the respective WHO thresholds for drinking water.

Microbial characteristics of the water used in the study area

Total Coliform Counts in Sampled Well Water: Coliform colonies were detected in all the water samples (Table 2). The values recorded in this study ranged from 0.09 to 111.0 cfu/100ml. The highest coliform count 111 cfu/100ml was recorded in Oyoma-polo neighbourhood. These values show that all the ten sampled hand dug wells were above the maximum permissible limit of Ocfu/ml (WHO, 2004, NESREA 2009) of drinking water sample, thus making the water very unsafe for drinking.

Total Heterotrophic Bacteria of Sampled Well Water: The values for total bacteria count recorded in this study range from 0.09 to 115.0 cfu/100ml [table 2]. The highest bacteria count 115.0 cfu/100ml was recorded in Oyoma-polo neighbourhood. These values show that all the ten sample hand dug wells were above the maximum permissible limit of Ocfu/ml (WHO; 2004, NESREA 2009) of drinking water sample, thus making the water very unsafe for drinking.

Total Fungi of Sampled Well Water**:** The results of the test for fungi in all water samples showed a positive result, indicating the presence of fungi in the water samples. 6 of the hand dug wells had the presence of spore fungi (S.F), two (2) had the presence of both spore fungi and filamentous fungi and two [2] had the presence of filamentous fungi [appendix 4].

Hypothesis 1: There is no significant spatial variation in the physico- chemical properties of water from hand-dug wells in the study area.
This hypothesis was analyzed using the one-way analysis of variance. The stated hypothesis seeks to establish whether or not, there is any spatial variation in the physico-chemical properties of water in the study area.

Table 4 Summary of ANOVA computation for Ho_1

Source of Variance	Sum of Squares	DF	Variance Estimate	Fcal	F critical	Decision
Between samples	125471.49	9	13941.28			
Within Samples	2360535.31	170	13885.5	1.00	1.88	Accepted
Total	2486006.8	179				

Table 4 above show statistically that there is no significant spatial variation (i.e $H0_1$ is accepted) since calculated value 1.0 is less than F-critical table value 1.88. This implies that there is no significant spatial variation in the physico-chemical properties of water from hand-dug wells in the study area. Hence the hypothesis was retained at 0.05 level of significant.

Hypothesis 2: There is no significant spatial variation in the microbial properties of water from hand-dug wells quality in Nembe town.
This hypothesis was analyzed using the one-way analysis of variance. The stated hypothesis seeks to establish whether or not, there is any spatial variation in the microbial properties of hand-dug wells in the study area.

Table 5 Summary of ANOVA computation for Ho_2

Source of Variance	Sum of Squares	DF	Variance Estimate	Fcal	F critical	Decision
Between samples	20618.43	9	2290.94			
Within Samples	799.38	10	79.94	28.66	3.02	Reject
Total	21417.81	19				

Table 5 above show statistically that there is a significant spatial variation in the microbial properties (i.e Ho_2 is rejected) since calculated value 28.66 is greater than F critical table value

3.02. This implies that there is a significant spatial variation in the microbial properties of water from hand-dug wells in the study area. Hence, the hypothesis was not retained at 0.05 level of significant.

SUMMARY OF FINDINGS

Based on the analyses and investigations of the study, the main findings are summarized as follows;

1. There is no significant spatial variation in the physico-chemical properties of water from hand-dug wells in the study area.
2. There is significant spatial variation in the microbial properties of water from hand-dug wells in the study area.
3. Majority of the hand- dug wells are either unprotected or semi-protected.
4. All of the hand-dug well waters are contaminated with microbial parameters.
5. Groundwater in the area have turbidity and potassium levels higher than the WHO and NESREA maximum permissible limit for drinking water standards
6. Physico-chemical parameters such as TDS, TSS, SO_4^{-2}, HCO_3^-, Ca, Na, Mn, Ec, Fe, Cl, N, salinity, TA and Mg are all within the permissible levels of WHO and NESREA drinking water standards.
7. All the sampled hand- dug wells have pH values within the permissible limits of drinking water except one which had pH value of 6.48 and considered too acidic for human consumption.
8. Based on hardness, three of the groundwater samples have moderate soft water which is suitable for domestic use while the seven groundwater samples are slightly hard water to hard water in nature.

It is important to note here that some of the findings of this study are in line with earlier studies. It was noted that turbidity ranges were within 12.80 to 36.50 NTU, which is higher than the WHO and NESREA drinking water standards, this could be as result of high water table. This is in line with studies carried out in Yenagoa which shows that turbidity values of sampled borehole water were found to range from 20.70 to 41.20 NTU, these values were higher than WHO limit for potable water supply (Ohwo, and Abotutu, 2014). This is contrary to studies carried out by Oghenekaro, (2014) in Ogwashi-uku, Delta state on water supply challenges which shows that turbidity ranges were within 1.0-4.49 NTU which falls within the WHO and Nigerian Standard, this could be as a result of low depth (140m-200m) for borehole samples.

pH values range were within 6.48 to 7.14 which is within the permissible limits of drinking water except one hand dug well which had pH value of 6.48 which is below the permissible limits. This is in contrast with that of Egbai, Adaikpoh and Aigbogun (2013) on Water Quality Assessment of Groundwater in Okwuagbe community of Delta State, Nigeria where the pH values for hand dug wells range within 5.36 to 5.94. Similar study carried out by Ohwo and Abotutu, (2014) in Yenagoa reveals that sampled borehole had ph values ranging from 6.30-6.90.

Conductivity values range were 132.0-750.0۲s/cm which is contrary to Oghenekaro's (2014) studies in Ogwashi-Uku, Delta State were the conductivity values ranged within 8.27-18.0۲s/cm which showed the water is slightly impaired. Adebola, Adedayo and Abiola (2013) study on pollution studies on Groundwater contamination: Water quality of Abeokuta, Ogun State had EC value range from 657 to 8134۲slcm which is below WHO highest desirable level of 900۲slcm
TDS, TSS and Mn values are all below the WHO and NESREA standards. Similar studies carried out by Ohwo and Abotutu (2014) in Yenagoa and Oghenekaro (2014) in Ogwashi- Uku in Delta state also have these values below the WHO standards. The result of bacteriological analysis showed the presence of total coliforms, Total bacteria counts (TBC) and fungi in all the hand dug wells examined. This is contrary to the study carried out by Amukali, (2012) in Ndokwa-East local government area, Delta state on Assessment of water pollution where total coliform was absent in the groundwater samples tested. Similar study carried out by Tiimub and Adu-Gyamfi (2013) on potable Quality Determination of groundwater from point collection sources in the Asante Mampong Municipality of Ashanti Region in Ghana revealed the absence of E-coli bacteria and the presence of total colifrom. Oghenekaro (2014) study also revealed the absence of feacal coliform and presence of total heterotrophic bacteria THB and fungi in the water samples.

Water is very important to our body metabolic system for the general operations of the tissues, cells and organs. This is how safe water is vital in the economic development of societies. It is truism that health is wealth, and water is food. For the people of any society to remain healthy in order to make reasonable wealth, they must need to have safe and adequate supply of drinking water which is accessible to all irrespective of differences in socio-economic status and tribal, religious or ethnic inclination. If the rural socio-economic activities of the area must thrive, then the supply of adequate potable water is very crucial. Twenty-one (21) parameters were used to establish the exact current water quality status of hand dug wells in the month of November in Nembe town. All 21 parameters studied in this case were compared against maximum permissible limits laid down by WHO (2004) and NERSEA (2009). Numerical values of concentrations that were below a standard specified limit were considered to be safe and unpolluted, those above the limits were considered unsafe and polluted.

Water samples from all the hand-dug wells showed that turbidity content are very high, beyond the maximum permissible limits as recommended by WHO and NESREA standards; six of the sample hand dug wells have potassium values higher than the permissible limits. All the sampled hand dug wells have pH values within the permissible limit of drinking water except one which had pH value of 6.48 at Amassara-polo neighborhood and considered too acidic for human consumption. Water samples from majority of the wells showed that the water is hard water in nature. There is no significant spatial variation in the physic-chemical properties of water from hand-dug wells in the study area.

Results from sample analysis of water from the hand dug wells showed that all of the wells are highly polluted with microbial contaminants (Total coliform, THB and fungi) and this could lead to a variety of diseases. Also there is significant spatial variation in the microbial properties of water from hand-dug wells in the study area. This is an indication that the hand dug wells within the studied area were affected by physico-chemical and biological parameters. Hence proper water treatment is necessary but this is lacking at the moment.

CONCLUSION

Safe and adequate water supply in any region is vital if that region wants to be relevant. Life on earth cannot be possible without adequate water supply. Safe, adequate and accessible water is a crucial social welfare matter. It is also used as a facility or index of measurement of the development in any region. The findings of this study have revealed that the hand dug wells in Nembe town is not fit for human consumption. It also revealed that there is no significant spatial variation in the physico-chemical properties of water from hand-dug wells in the study area and that there is a significant spatial variation in the microbial properties of water from hand-dug wells in the study area. Physico-chemical parameters such as potassium, total hardness and turbidity levels are higher than the WHO and NESREA maximum permissible limits for drinking water standards.

The study also detected the presence of microbial parameters in all the hand dug wells thus, making the water very unsafe for drinking. The presence of these microorganisms and coliform bacteria in drinking water is probably the result of poor environmental hygienic habits of the people, particularly in areas where wells have been exposed to sub-surface migration of contaminants as a result of leachates infiltration from the unprotected conditions prevailing around these major sources of drinking water. The indications are that, there would be likelihood outbreak of diarrhea and other water borne infections in the study area if, cleansing or adequate water improvement treatment measures are not put in place to address shortfalls with the biological aspects of the hand dug wells that the community patronizes on daily basis. The study therefore calls for urgent intervention for the protection of hand dug wells and implementation of drinking water treatment barriers ensuring the production of safe potable water in the study area.

Recommendations

Having investigated the quality of water supply from hand-dug wells in the study area, it is the researcher's sincere hope that the relevant government authorities, individuals, corporate bodies, multinationals and others interested in the welfare and progress of the rural dwellers, should help in the implementation of the following recommendations.

1. Due to the fact that some of the physico-chemical parameters are naturally occurring (e.g Turbidity, potassium, total hardness) with very high levels exceeding the recommended WHO and NESREA standards for drinking water, proper treatment of water before use should be carried out. This will help reduce the cases of abandonment of projects due to hardness of the water as in the case in some of the neighborhoods. On no account should the occurrence of microbial parameters be allowed. This is because of their potent danger. Hence, all microbial parameter measurements must always indicate absent or Zero (0) as recommended by WHO, USEPA and NESREA.

2. Regular cleaning and treatment of hand dug wells should be encouraged.
3. Reconstruction of traditional wells by protecting and fencing will greatly improve water quality and reduce the risk of accidents and waterborne diseases.
4. Raising the well head above the surrounding ground surface by the construction of a headwall prevents runoff water and split water from entering the well and reduces the chances of people or animals falling into the well.
5. Placing a cover slab made of wood or concrete on the well reduces the risk of foreign objects falling into the well and the addition of a lid further reduces the risk.

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