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Physico-Chemical and Bacteriological Quality of Water from Boreholes in Otuoke Community, Bayelsa State, Nigeria

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Abstract

The concern over exposure to drinking contaminated water and the resultant adverse effect on human health has prompted several studies evaluating the quality of drinking water sources. This study was carried out to determine the bacteriological and Physico-chemical qualities of commercial borehole water within Otuoke community in Bayelsa state Nigeria. Ten (10) water samples were collected from the various locations designated as (A-J). The Physico-chemical parameters were determined by using the photometric technique through the Colour Q photometer and the bacteriological analysis was determined by using aerobic plate method. The Physico-chemical parameters of the water samples analysed were within the acceptable limit of WHO standard of drinking water quality except for Bromine and cyanuric acid which ranged from 1.6±0.1 to 2.7±0.1 and 2±1 to 9±1 mg/L respectively. The Result of total bacteria count obtained from the borehole water samples ranged from 1.1 x 10^5cfu/ml to 6.9 x 10^5cfu/ml and there was no detected growth for the faecal coliform count of most of the samples except for BHW-I and BHW-J which had 1.3 x 10^4 to 7.9 x 10^4cfu/ml respectively. Bacteria isolated and identified using conventional biochemical test include *E. coli* (17.9%), *Klebsiella spp.* (35.7%), *Salmonella spp* (25.0%), *Enterobacter aerogenes* (21.4%). The study therefore suggests that all the borehole water tested in Otuoke and environs are considered unsafe for consumption and therefore regular treatment before usage is recommended.

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Introduction

Water as an essential natural resource, is valuable for all living organisms from the simplest plant and microorganisms to the most complex living system [1]. Water is significant due to its unique physicochemical properties and is known to be the most abundant compound (70%) on earth [1-2]. Notwithstanding its relative abundance, good quality drinking water is not readily available particularly in many developing countries [2]. According to Adewale [3] about 1.2 billion people lack access to portable water globally and while in Nigerian only about 30% of the populace have access to clean drinking water. Access to safe drinking water is key to sustainable development, food production, poverty reduction and quality health [4]. The supply of safe drinking water to all has therefore engaged the attention of many individuals, groups, governmental organization and private organization [5]. In many developing countries including Nigeria, clean pipe borne water availability is limited and inadequate for the growing population. Thus, an increasing number of people in semi-urban areas in the country depend on dug wells and water vendors for water supply [6]. Due to the inability of government to meet the ever-increasing water demand, people resort to ground water sources such as shallow wells and boreholes as alternative water resources [7].

The non-availability of good quality drinking water has resulted into a number of health challenges as water is known to be a primary agent of some transmissible diseases. In developing countries of the world, 80% of all diseases and over 30% of deaths are related to drinking water [2,8]. Most drinking water sources are frequently contaminated with different pollutants like faeces, animal and plant wastes, makes such water unfit for drinking if not treated, untreated water harbours a variety of pathogens, which are manifested in diseases such as typhoid fever, amoebic dysentery, cholera and amongst others which has resulted in deterioration of health and in some cases death, [9]. Such polluted water also affects the chemistry of the water therefore making it unfit for drinking. The pollution of water by microorganism and other pollutants can only be detected by carrying out microbiological assessment and physicochemical analysis of such water. There is a worldwide concern relating to the effects of water-borne diseases as its morbidity and mortality are documented in many developing countries of the world [10].

Safe drinking water is essential to life and a satisfactory safe supply must be made available to consumers. Water is thus becoming a crucial factor for development and the quality of life in many countries. The water intended for human consumption must not contain pathogens or harmful chemicals. Therefore, it has necessitated the studying of bacteriological and physicochemical quality of drinking water in Otuoke community. It is on these basis that this research is conducted to determine the qualities of some commercial bore hole water source in Otuoke community using some water quality index (WQI).

Materials and Methods

Study Area

The study was carried out in Yenagoa the state capital of Bayelsa State in the Niger Delta region of Nigeria with latitude 4°56′1²N and longitude 6°17′6²E.

Sampling

Water samples from Ten (10) commercial boreholes water designated as A-J were collected in Otuoke community randomly using sterile containers and stored in ice box and transported to the laboratory for bacteriological and Physicochemical analysis within one hour. Water (250ml) samples were collected in triplicate from each sampling site as prescribed by APHA [11].

Physico Chemical Water Analysis

The physiochemical parameters were determined as previously described [11]. Parameters include temperature, dissolved oxygen, hardness, pH, turbidity, free chlorine, total chlorine, alkalinity, cyanide sulphide, total dissolved solid (TDS), conductivity, iron, copper were carried out.

Determination of the pH of Water Sample

This is to ensure that the pH of the water sample is within the acceptable limits 6.5-8.5. The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a ColorQ photometer. The meter was

turned on, the button was press to "Blank". The cuvette was removed and 5 drops of Wide Range P^H Reagent was added to the same cuvette, capped and inverted 3 times to mix. The cuvette was inserted into the photometer and the button was pressed to "pH". The pH value was recorded and the cuvette was removed.

Determination of Free Chlorine

This test is to quantify the amount of free chlorine present in a given water sample. The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a ColorQ photometer. The meter was turned on, the button was pressed to "Blank" and the cuvette was removed. A clean cuvette was filled with the water sample to the 5mL line. One tablet of DPD 1 was added, the cuvette was capped, shaken for ten seconds and inverted slowly 5 times. The cuvette was inserted into the photometer, the button was pressed to go to "FCL" free chlorine, the reading was recorded in ppm and the cuvette was removed.

Determination of Total Chlorine

This test is to determine the amount of total chlorine in water sample. The cap of the reacted FCL cuvette was removed, 1 tablet of DPD 3 was added. The cuvette was capped, shaken for ten seconds and inverted slowly. The cuvette was inserted into the photometer and the button was pressed to go to tCL" Total Chlorine. The readings were recorded in ppm and the cuvette was removed.

Determination of Hardness

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a colorQ photometer. The meter was turned on, the button was pressed to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5mL line with the water sample. 5 drops of Hardness 1 Buffer and Hardness 2 Indicator was added to the cuvette and capped. The cuvette was inverted 3 times to mix and inserted into the photometer. The button was pressed to read "Hd", the readings were recorded in gpg and the cuvette was removed.

Determination of Iron

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a colorQ photometer. The meter was turned on, the button was pressed to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5mL line with the water sample. One Iron Tablet was added to the cuvette and crushed with a tablet crusher. The cuvette was capped, inverted 3 times and inserted into the photometer. The button was pressed to go to "Ir" Iron, the readings were recorded in ppm and the cuvette was removed.

Determination of Copper

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a colorQ photometer. The meter was turned on, the button was pressed to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5ml line with the water sample. One Copper Tablet was added and crushed with a tablet crusher. The cuvette was capped, inverted 3 times to mix and inserted into the photometer. The button was pressed to go to "Cu" copper, the readings were recorded in ppm and the cuvette was removed.

Determination of Alkalinity

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a colorQ photometer. The meter was turned on, the button was press to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5mL line with the water sample. Five drops of Alkalinity Reagent was added. The cuvette was capped, inverted 3 times to mix and inserted into the photometer. The button was pressed to go to Alk" alkalinity. The readings were recorded in ppm and the cuvette was removed.

Determination of Cyanide

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and the cuvette was inserted into a colorQ photometer. The meter was turned on, the button was press to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5mL line with the water sample. One

tablet of Cyanuric Acid was added and crushed with tablet crusher. The cuvette was capped, inverted 3 times to mix, allowed to stand for 2 minutes and inserted into the photometer. The button was pressed to go to "Cyanuric acid", the readings were recorded in ppm and the cuvette was removed.

Determination of Sulphide

The sample bottle was filled with the water sample, a 5mL cuvette was filled with the water sample and a cuvette was inserted into a colorQ photometer. The meter was turned on, the button was pressed to "Blank" and the cuvette was removed. A clean cuvette was filled to the 5mL line with the water sample. 5 drops of Sulphide Reagent A and 3 drops of Sulphide Reagent B were added. The cuvette was capped, inverted 3 times and inserted into the photometer. The button was pressed to go to "SuL" Sulphide, the readings were recorded in ppm and the cuvette was removed.

Determination of Total Dissolved Solids (TDS)

The total dissolved solid was determined using a conductivity meter, the programme menu of the conductivity /TBS meter was switched to total dissolved solid, the meter was immersed into the sample up to the maximum immersion level without touching the bottom of the beaker. The results of the total dissolved solid were displayed and recorded [11].

Bacteriological Analysis

Culture Media, Preparations and Incubation

The total heterotrophic bacteria (THB) and total coliform were analysed using standard plate count as described by [12]. Nutrient Agar, and MacConkey agar was used for the enumeration of THB and coliforms respectively.

The microbial inoculation and density enumeration of the water samples was carried out using total aerobic count as described by several authors [11-13]. The method of Angaye and colleagues [14] was adopted with slight modification. The media used for the investigation were Nutrient Agar for Total Heterotrophic Bacteria (THB) at 35^{O}C for 24 hours, MacConkey Agar for Enterobacteriaceae at 37^{o}C for 24 - 48 hours [15]. All media were weighed according to manufacturer instruction and allowed to cool at room temperature 37±2^{O}C. before dispensing to Petri dishes.

Confirmation and Identification of Isolates from Pure Cultures

The pure cultures were again inoculated into MacConkey Agar, *Salmonella Shigella* agar and Eosin methylene blue agar for the purpose of obtaining purer isolates which were initially stored in agar slant. The confirmation was carried out by transferring from the slants that were presumptive of the respective bacteria cells. The biochemical identification of bacteria isolates was carried out which includes; gram reaction, motility, indole, catalase, coagulase, oxidase, urease and citrate as well as the use of specialized media. Also, morphologically identification was based on shape, colour, texture, margin, and elevation. The emerging characteristics were compared with already established taxa from Bergey's Manual of Determinative Bacteriology, and the scheme of [16-17]. The formation of black centred colonies in *Salmonella-Shigella* agar incubated at 37^{O}C for 24 hours indicates the presence of *Salmonellae* species. [16]. Eosin Methylene Blue (EMB) Agar incubated at 37^{o} C for 24 - 48 hours; *Enterobacter species* forms large greenish metallic sheen as opposed to small greenish metallic sheen of *E. coli*. [18].

Statistical Analysis

SPSS software version 24 was used to carry out the statistical analysis. The data were expressed as Mean ± standard error. A one-way analysis of variance was used to determine significance difference (P=0.05), and mean separation was performed with Tukey's Post Hoc test.

Results/Discussion

Bacteriological Analysis

In this study, analysis of the THB count in the water samples revealed the presence of heterotrophic bacteria in all the water sources (Table 1). The WHO standard for heterotrophic bacteria in potable water states that the total heterotrophic bacteria count should not be more than 100 cfu/ml [19]. The presence of bacteria counts exceeding the WHO limits indicated that the water samples contain bacteria that makes the water unsafe for drinking and for domestic purposes. The Heterotrophic Bacteria count from this study exceeded WHO limits. The result from this study agrees

Table 1: Total Heterotrophic Bacteria and Total Coliform obtained from water samples

Sample Codes	Heterotrophic Bacterial count (x 10^5 cfu/ml)	Coliform count (x 10^5 cfu/ml)
A	0.9 ± 0.57	0.6 ± 0.33
B	0.6 ± 0.57	0.4 ± 1.5
C	1.0 ± 1.2	0.6 ± 0.33
D	0.7 ± 0.88	0.6 ± 0.33
E	1.2 ± 1.3	0.5 ± 0.8
F	1.0 ± 0.33	0.7 ± 0.66
G	0.7 ± 0.57	0.3 ± 0.66
H	0.8 ± 0.57	0.4 ± 0.88
I	0.7 ± 0.88	0.5 ± 0.33
J	0.9 ± 0.57	0.6 ± 0.57

Table 2: Incidence of enteric bacterial pathogens in the water samples No. (%) of Enteric Bacterial pathogens isolated

Sample Codes	Sample size	*E. coli*	*Salmonella* spp	*Klebsiella pneu-moniae*	*Enterobacter aerogenes*	Total
A	3	2(33.3%)	1(16.7%)	3(50.0%)	0(0.0%)	6
B	3	1(20.0%)	0(0.0%)	2(40.0%)	2(40.0%)	5
C	3	3(38.5%)	2(25.0%)	2(25.0%)	1(12.5%)	8
D	3	0(0.0%)	2(66.7%)	1(33.3%)	0(0.0%)	3
E	3	2(28.6%)	2(28.6%)	3(42.8%)	0(0.0%)	7
F	3	1(20.0%)	2(40.0%)	0(0.0%)	2(40.0%)	5
G	3	0(0.0%)	3(50.0%)	0(0.0%)	3(50.0%)	6
H	3	0(0.0%)	0(0.0%)	4(80.0%)	1(20.0%)	5
I	3	1(16.7%)	1(16.7%)	2(33.3%)	2(33.3%)	6
J	3	0(0%)	1(20.0) %	3(60.0%)	1(20.0%)	5
TOTAL	30	10(17.9%)	14(25.0%)	20(35.7%)	12(21.4%)	56

with agrees with earlier findings [20]. The high values obtained could be due to poor environmental conditions and the presence of stagnant water around the borehole which provide an excellent breeding ground for bacteria. The total coliform count in Table 4.1 above ranged from 0.3 ± 0.66 to 0.7 ± 0.66 x 10^5 cfu/ml. This is unacceptable because WHO standard of potable water states that no coliform should be present in any drinking water. There was significant difference ($p<0.05$, 0.0001) among the water samples with respect to heterotrophic bacterial counts and coliform counts.

Table 2 shows the presence of these bacteria cells (S*almonella spp, Escherichia coli, Enterobacter aerogenes* and *Klebsiella pneumoniae*) the presence of this pathogens suggests faecal contamination and this agrees with findings of Zige and collaborators [21]. The presence of these bacteria maybe as a result of leakages of pipes thus allowing seepages of microbial contaminants into the borehole. Table 4.2 also shows that *E. coli* was identified in all locations except location D, G H and J while *Salmonella* is B and H, *Klebsiella* is F and G, *Eneterobacter* A, D and E. on the other hand in Location A 50% of isolates identified were *Klebsiella* followed by E coli which was 33%, site B *Klebsiella* and Enterobacter were 40%, site C has the highest percentage for *E coli*, Site D was on *Salmonella* spp. Likewise other pathogenic bacteria were present in samples. The presence of *Salmonella* spp corresponds with reports of high *Salmonella* endemicity in coastal area [22] While *E. coli* a causative agent of diarrhoea indicating faecal contamination found in the water samples is as a resulted of poor hygienic practice [21]. However, the presence of these pathogens poses a significant threat to the community as water is a major source of reservoir and transmission of faecooral pathogens [22]. The potential risk associated with the presence of these pathogen present could be diarrhoea, enteric fever, pneumonia, osteomyelitis, endocarditis amongst others.

Table 3 shows the result of the physico-chemical analysis carried out on the different water sample. The pH value of all the borehole water samples ranged between pH 6.2±0.15 to 7.1±0.1 with all the samples tending towards neutral (pH 7) though pH has no direct effect on human its indirect actions cannot be over emphasized [4]. BHW-I with the pH 7.0 was the most significant and significantly different from the other water samples. The pH values obtained for all the water samples are almost within the permissible limit of WHO [19] which is 6.5 to 8.5 and the range obtained are similar to previously reported values in the Niger Delta region of Nigeria according to [23] and the significant difference ($p<0.05$) was high among these different boreholes. While the TDS values of all sampled borehole water ranged from 2±1 to 14±1 with the highest at BHW-F at 14mg/l and the lowest at BHW-B, BHW- H, BHW- J at 2mg/L not exceeding the NAFDAC standard and WHO standard value of 300mg/l. The significant difference of these different boreholes was high with $p<0.05$. The TDS represents all inorganic matter in the water and the constituent include magnesium, sodium, and hydrogen carbonate etc. The low TDS in the sampled water in these areas are associated with natural source, sewage, industrial wastewater as well as urban run-off and chemical used in the treatment process as well as the aquifers and their remoteness from the influence of any saline intrusion. These low TDS values was in accordance with [24] who conducted a research on borehole water samples in Yenagoa. Fe value in the borehole water samples ranged from 0.1±0.1mg/L to 0.2±0.1mg/L with no detection in BHW-E, BHW-F, BHW-I, and BHW-J and the significant difference between the different borehole ($p>0.05$) was low. The less concentration of Fe in this iron rich region may be attributed to the rigorous treatment process carried out in these boreholes to remove the high concentration of iron which may be responsible for the observed brownish colouration of the water when pumped directly from the ground. Notwithstanding the values reported were in contrast with those reported by [25] but similar to that recorded in a study conducted in Yenagoa [26]. Based on this, the Fe concentration in all the ten-sampled borehole water were within permissible range of WHO limit of 0.3mg/L. The hardness of the borehole water samples ranged from 5±1 to 29±1mg/L with the significant difference of $p<0.05$ high. The highest was observed in BHW-B and the least in BHW-J with hardness which was extremely low. The value of hardness of these water samples were generally lower than the WHO standard and it could be attributed to the leaching of hardness by magnesium

Table 3: Showing the Mean and Range of the different physico-chemical parameters of the water samples

Samples	TCL	FCL	Br	PH	ALK	HD	CU	CYA	FE	TDS	SUL
BHW-A	1.24±0.01	1.24±0.15	2.6±0.1	6.6±0.1	72±1	5±1	0.2±0.1	8±1	5±1	4±1	4±1
BHW-B	0.82±0.01	0.71±0.01	1.36±0.15	6.5±0.15	49±1	29±1	0.3±0.1	4±1	0.1±0.1	2±1	6±1
BHW-C	1.35±0.01	1.29±0.01	2.7±0.1	6.3±0.15	30±1	17±1	0.2±0.1	9±0.1	0.1±0.1	4±1	6±1
BHW-D	1.07±0.01	0.98±0.01	2.1±0.1	6.2±0.15	36±1.5	25±1	0.4±0.1	ND	0.1±0.1	5±0.5	81
BHW-E	0.98±0.01	0.94±0.01	1.8±0.1	6.5±0.1	33±1	LOW	0.5±0.1	16±1	0±0	6±1	8±1
BHW-F	1.15±0.01	0.9±0.01	1.76±0.15	6.5±0.1	86±1	24±1	0.2±0.1	5±1	0±0	14±1	13±1
BHW-G	1.27±0.01	1.2±0.01	2.4±0.1	6.6±0.1	60±1	24.6±1	NIL	8±1	0.2±0.1	4±1	27±1
BHW-H	1.19±0.01	1.19±0.01	2.4±0.1	6.3±0.15	28±1	17±1	0.2±0.1	NIL	0.1±0.1	2±1	13±1
BHW-I	1.03±0.01	0.84±0.01	1.6±0.1	7.1±0.1	91.0±1.5	7±1	0.2±0.1	3±1	0±0	5±1	4±1
BHW-J	0.93±0.01	0.93±0.01	1.8±0.1	6.8±0.1	30±1	LOW	NIL	2±1	NIL	2±1	4±1
WHO Limit	$\geq$ 0.5mg/l	$\leq$ 250mg/l	0mg/L	6.5-8.5	120mg/l	200-600mg/l	1.0mg/L	0-0.2mg/L	0.3mg/L	259-500mg/L	500mg/L

KEY: BHW-A-Borehole water A, BHW-B- Borehole water B, BHW-C-Borehole water C, BHW-D- Borehole water D, BHW-E- Borehole water E, BHW-F- Borehole water F, BHW-G-Borehole water G, BHW-H- Borehole water H, BHW-I-Borehole water I, BHW-J-Borehole water J, TCL-Total chlorine, FCL-Free chloride, Br-bromine, PH-Hydrogen potential, ALK-Alkaline, HD-Hardness, CU-cupper, CYA-Cyanide, FE-iron, TDS-Total Dissolved Solid, SUL-Sulphide

and calcium and this low hardness of borehole water was also reported [26] in research carried out in the Niger Delta region.

Total chlorine is the remaining chlorine concentration after chlorine demand and is not available for disinfection. The range for total chlorine was from 0.82±0.01 to 1.35±0.01mg/L with the significant difference ($p<0.05$) between these boreholes high the suitable concentration of total chlorine adopted by [19] is 5mg/L but with regards to all the samples analysed, the total chlorine concentration was within permissible range of WHO standard. However, the effect of heavily chlorinated water can lead to increased risk OF cancer as well as asthma and dermatitis and can also lead to bleeding gums [27].

Free chlorine is the chlorine available for disinfection and for deactivating organisms. The concentration of free chlorine ranged from 0.71±0.01 to 1.2±0.01mg/L with a high significant difference ($p<0.05$) observed in the different borehole water analysed. [19] however the standard guideline value for free chlorine is given as 5mg/l and with due consideration to the permissible limit all the water sample analysed were below the standard given by WHO and is thus acceptable according to WHO standard.

The range for sulphide was from 4±1- 27±1mg/L and with significant difference ($p<0.05$) of these boreholes high. Seven of the sampled borehole point were within the permissible range [19] which is 10mg/L but BHW-G and BHW-H and BHW-I exceeded the permissible range.

The range of cyanuric acid of these borehole waters was from 2±1 to 9±0.1mg/L and a high significant difference ($p<0.05$) among the different boreholes was observed among the boreholes analysed. Both sodium dichlorocyanurate and sodium cyanurate which are sources of cyanuric acid have low acute oral toxicity and generally classified as essentially non-toxic. And the ranges obtained from the sampled borehole water all exceeded the permissible range of WHO limit of 0 – 0.2mg/L except in BHW-C and BHW-H in which cyanuric acid was not detected.

The copper range of the borehole water sampled were from 0.2±0.1 -0.5±0.1mg/L with copper not detected in BHW-G and BHW-J. The values obtained from the boreholes water were lower than WHO permissible range of 1.0mg/L and the significant difference ($p>0.05$) was low among the various boreholes obtained. high level of copper in water can be due to leaching of copper from plumbing pipes into water and as such ingestion of excess copper can cause stomach and intestinal disorder, liver and kidney damage as well as anaemia in high doses [28]. The values obtained were not within the WHO maximum permissible limit of 1.0mg/L but were also in accordance with those obtained by Itah and colleagues [15] in the same Niger Delta region.

Bromine is a bleach which is similar to chlorine as a disinfectant however it is more effective than that of the chloramines which is poisonous in fluid form and bromine vapour is destructive for the human skin, eyes and respirational tract, when bromine is used to disinfect water, bromines and hypobromous acid react with organic matter in the water to form brominated disinfection by products. These can be harmful to human health. The range of bromine in the sampled water was from 1.36±0.15 to 2.6±0.15 with a high significant difference ($p<0.05$). However according to the Environmental Protection Agency (EPA) it is not to be used in public drinking water supply treatment [19]. Large doses of bromide cause nausea and vomiting, abdominal pain, coma and paralysis.

Alkalinity is not a pollutant, it is a total measure of the substances in the water that have acid neutralizing ability and it protect against pH changes [29]. The alkalinity of the water sampled falls within the range of 30±1 to 91.0±1.5 mg/L And the highest was obtained in BHW-I (91mg/L) however, the alkalinity level of the sampled water were at a normal permissible range which WHO standard pegged at 1.0 to 100mg/L and these ranges were in consonance with earlier reports [29-30].

Conclusion/Recommendation

The necessity of breaking the chain of infection is crucial as it will control the spread of infectious disease thus understanding the reservoir of infection is important. Water as a major reservoir of infectious diseases and a basic need of all living system should be

carefully and well dispensed. Therefore, people should be educated on the health implication of drinking unsafe water by organizing workshop and seminars and other means of communication like newspaper, organizing public health education. Regulatory authorities should be formulated both locally and nationally. Agencies such as National Agency for Food and Drug Administration and Control (NAFDAC) should maximize their effort in monitoring the owners of these different boreholes to meet the standard for drinking water as it will help reduce the spread of infectious diseases, other cheap and affordable methods are applicable also in combatting infectious diseases spread especially education on storage, use of chlorine formulated commercial water protection products such as Water guard. The provision of potable water by the government through a central water treatment plant will also help curb the spread of water borne diseases. The geologist drilling boreholes have to be educated on the importance of ensuring that dump sites are not used for drilling of boreholes and also, the construction of pit latrines near water sources should be avoided.

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