IOSR Journal Of Pharmacy
(e)-ISSN: 2250-3013, (p)-ISSN: 2319-4219
Volume 14, Issue 3 Series. I (March 2024), PP. 01-16
www.iosrphr.org

Effects of Households' Practices of Disinfection and Microbial Analysis of Boreholes and Wells in the Tiko Municipality

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Received 22 February 2024; Accepted 04 March 2024

ABSTRACT

Background: The quality of drinking water is a major concern in low resource settings like Cameroon where water- borne diseases occur frequently. Access to potable water in both rural and urban areas in the country is a challenge. Populations are therefore compelled to seek for alternative sources of water such as boreholes and wells (hand dug) as is the case in the Tiko Municipality, which are prone to contamination.

Objective: This study was aimed at assessing households' practices of disinfection and microbial analysis of borehole and well water sources in the Tiko Municipality. Materials and methods: An observational cross-sectional study was conducted in the Tiko Health District to assess the practices of disinfection of 482 households managing boreholes and wells, using questionnaires. The physical and chemical quality of water of the latter was equally evaluated using a checklist and LAQUA twin spectrophotometer respectively. The microbial analysis of water was carried out using culture and Analytical Profile Index (API).

Results: Of the 482 borehole/well owners and consumers, 242(50.2%) households treat/disinfect boreholes and wells to make them safe for consumption. Most inhabitants 136(28.2%) used Aqua tabs for disinfecting the water. The culture of 20 selected water resulted in 8(40.0%) *Clostridium perfringens,* 5(25.0%) *Escherichia coli,* 3(15.0%) *Salmonella typhi,* 3(15.0%) *Salmonella paratyphi* and 1(5.0%) *Staphylococcus aureus* growth.

Conclusion: There is poor bacteriological quality of the water sources (boreholes and wells) used by the inhabitants of the Tiko Municipality. An efficient and well maintained distribution system coupled with good hygienic practices would ensure that water is safe at the point of collection and before consumption.

I. INTRODUCTION

Water is a transparent, odorless, tasteless liquid made up of hydrogen and oxygen with main sources being rainwater, groundwater (wells, boreholes, and springs) and surface water (rivers, lakes, streams, and oceans) [1]. These sources vary with respect to their microbiological quality [2]. Surface waters are usually treated water distributed to communities but are the most vulnerable water to contaminants from runoff, wastewater discharges and airborne contaminant, [3]. Microbiologically contaminated drinking water can transmit diseases such as diarrhea, cholera, dysentery, typhoid and polio and is estimated to cause 485 000 diarrheal death each year [5]. The quality of drinking water is a major concern in low resource settings like Cameroon where epidemics of water-borne diseases occurs yearly [6, 7]. Within the context in Cameroon, access to water through taps is a luxury in which only a few (32%) inhabitants can afford. The populations salvage their need for drinking water from the natural springs, boreholes, wells and other alternative water sources in their communities [8]. Parameters such as appearance, taste, odor, and color amongst others are of primordial importance and are recommended for minimum monitoring of community water supplies. These parameters equally establish the hygienic state of water and the risk of water borne infections [9]. Contamination of portable water sources poses a public health risk and increases the cost of drinking water treatment [10].

In low and middle income nations, 58% of all diarrheal disease-related deaths are caused by inadequate access to safe water, poor hygiene, and unimproved sanitation conditions [11]. In Cameroon; waterborne diseases due to bacteria are common. Diarrheal diseases were estimated to cause 15 to 20% of deaths annually [12]. Morbidity and mortality rates of waterborne diseases are the second and third leading reported weekly epidemiological disease under surveillance in Fako Division, South West Region of Cameroon [12]. This study aimed at evaluating households' practices of disinfection and microbial analysis of borehole and well water sources in the Tiko Municipality.

II. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in the Tiko Health District, Fako division of the South West Region of Cameroon. Tiko town is a semi-urban settlement with a surface area of 4840 Km^2 and a population size of 134,649distributed in eight health areas, Mutengene, Mudeka, Misselele, Mondoni, Likomba, Holtforth, Kange and Tiko town. The population density of Tiko is 241 inhabitants/Km^2, with a population growth of 2.9% [52]. Tiko is located 10 meters above sea level between longitudes 9°15′E and 9°30′E, latitudes 3°57′N and 4°12′N with a relative humility of 83.1% and average rain fall of 4,524 mm. This area has a coastal equatorial climate with daily temperatures ranging from 28°C - 33°C. Inhabitants of the Tiko Health District make use boreholes and well water for drinking and domestic purposes [53].

2.2 Study Setting

The study was both community and laboratory-based case study carried out in the Tiko Municipality. Soil types include the sandy alluvial and volcanic with high agricultural potentials. The Tiko municipality is interspersed with water courses including rivers Mungo and Ombe, and Ndongo and Benyo streams which empty into the Atlantic Ocean [53]. The predominant livelihoods of people living in the communities are trading, farming and fishing [53].

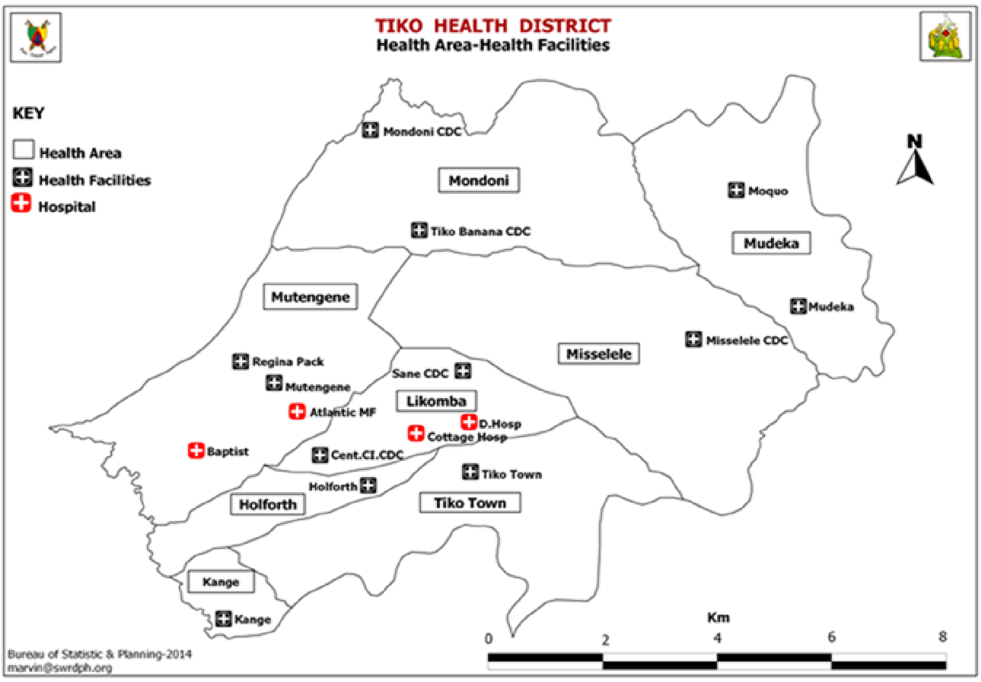

Figure 1: Map of Tiko Health District [54]

2.3 Study Design and Study Duration

It was an observational and cross-sectional study design involving both qualitative and quantitative data collection. This study took place for six months, from January, 2022 to July, 2022.

2.4 Target Population

The focus of this study was on the household inhabitants of the Tiko Municipality using boreholes and well water sources.

2.5 Inclusion / exclusion Criteria

Residents of households who make use of a borehole and/or well water around their vicinity and consented to participate were enrolled in the study and excluded non-consenting participants and households who were consuming tap water and other water sources for drinking.

2.6 Sample size Calculation

The sample size was calculated using the Cochrane formula. An estimated prevalence of 50% (which will result in the highest sample size)was used (we don't have much information on the subject to begin with, so we're going to assume that half of the households have knowledge on disinfection of water: this gives us maximum variability. So p = 0.5. Now let's say we want 95% confidence, and at least 5 percent plus or minus precision. A 95 % confidence level gives us Z values of 1.96, per the normal tables, so we get. From this prevalence, the sample was calculated using the formula below.

$$(n) = \left(\frac{Z^2 \times pq}{e^2}\right) \quad (n) = \left(\frac{(1.96)^2 \times 0.5(1-0.5)}{(0.05)^2}\right) = 385$$

n = sample size
Z = 1.96, critical Z-value at 95% confidence interval
P = 50% or 0.5
e^2 = 5% or 0.05, which is the level of precision
q = 1-p

2.7 Sampling Technique

A multi-stage sampling technique was used within the Tiko Municipality to obtain health areas from which the wells and boreholes were selected. These health areas are Mutengene, Mudeka, Misselele, Mondoni, Likomba, Holtforth, Kange and Tiko Town. Four health areas were selected by simple random sampling. Then selection of 49 quarters in different health areas was done using simple random sampling. In each quarter selected, a snowball technique was used to identify boreholes and wells and the users of these boreholes and wells were enrolled in the study by questionnaire administration.

2.8 Data Collection tool

Data was collected using a well-structured questionnaire and checklist for the organoleptic physico-chemical properties, knowledge and attitude of disinfection. Sterile collection containers were used to collect selected boreholes and well water samples and transported to the laboratory, for microbial analysis following standard operating procedures.

2.8.1 Pretesting of Questionnaire

Questionnaires for the study were pretested to assess the quality of information that was gotten and this was conducted at two quarters in Mudeka and Misselele after which the questionnaires were reorganised for proper administration.

2.8.2 Data collection

Questionnaires were used for data collection and were self-administered to participants with guidance from the researcher. An observational checklist was used to collect data on the physico-chemical characteristics of the boreholes and wells. Selected boreholes and wells especially those used publicly by households were collected in sterile leak proof containers using a transport medium was transported to the laboratory for physico-chemical properties and microbial analysis.

2.9 Data Management

Checklist and Questionnaire were checked for proper completion on collection from the participants. Questionnaires with >20% unanswered questions were rejected. Data was keyed into mobile application open data kit (ODK collect) specifically; Kobo collect version 2021.3.4 and later on Microsoft excel and then exported to Statistical Package for Social Sciences (SPSS) version 26 for analysis.

2.10 Statistical Analysis

Statistical package for Social sciences (SPSS) software version 26 was used to analyze the data. Descriptive variables were analyzed by calculating frequencies and multiple responds for some parameters. Scoring was done based on yes or no and also depending on other questions scoring was analyzed following 1 = good, 2 = acceptable, 3 = poor and 4 = don't know/not. Findings were presented in frequency tables and charts. The chi square test was used to investigate possible associations. A multivariate logistic regression model was used to identify factors independently associated with good knowledge and practice. P-values less than 0.05 was considered significant. Microbial analysis of selected boreholes/wells was analyzed using Microsoft Excel.

2.11 Ethical considerations

Ethical clearance was obtained from the Institutional Review Board [Reference;1662-02] of the Faculty of Health Sciences of the University of Buea. Administrative authorization to carry out research was obtained from the Head of Department of Public Health and Hygiene. Administrative clearance was obtained from the

Regional Delegate of Public Health and Tiko District Health Service, the Tiko council followed by the Sub Divisional Officer to the various chiefs of health area and quarter heads for their approval and finally verbal consent was obtained from boreholes/wells owners for this study to be carried out.

III. RESULTS

3.2 Distribution of socio-demographic characteristics

3.2.1 Characteristics by respondents and health area

In this study, respondents were 82/482 borehole and well owners who responded with 17% and 400/482 consumers with 83%.The study which took place in four health areas namely Holtforth, Likomba, Mutengene and Tiko Town, and Holtforth registered the highest participants thus 220/482 (45.6%) and lowest from Likomba and Mutengene with 43/482 (8.9 %) participants for each (Table 1).

Table 1: Demographic characteristics of Borehole and well water owners and consumers following Health areas

Variable		Frequency (n)	Percent (%)
Respondent	Borehole/well owners	82	17
	Borehole/well consumers	400	83
	Total	**482**	**100**
Health area	HoltfortHoltforth	220	45.6
	Likomba	43	8.9
	Mutengene	43	8.9
	Tiko Town	176	36.6
	Total	**482**	**100**

3.2.2 Demographic characteristics of study participants

Of the 482 respondents, majority females respondents [287/482(59.5%)].The Age group of respondents ranges from ≤ 20 to >50 years with highest participants 20 – 30 years [223/482 (46.3%)] and the lowest number of participants aged > 50 with 23(4.8%). Single participants were [247/482 (51.2%)] which rated the highest and 16 (3.3%) were divorced. Two hundred and sixty-five (265) participants who had children responded with a yes giving 55% and [217/482(45.0%)] had no child. Most households were crowded with 4-6 inhabitants per household with [202/482(41.9%)] households and households with >6 inhabitants being [86/482 (17.8%)]. Participants who attended secondary school made the highest with [264/482 (54.8%)] while those who did not go to school at all were 5(1.0%). Participants who were employed were the highest with 353/482 (73.2%) and those who were unemployed were 129/482 (26.8%). Most participants were Christians, 450/482 (93.4%) and other religion had 2/482(0.4%).Majority 162/482 (33.6%) of the participants received a monthly salary ranging from 50000 – 100000FCFA and participants who received > 200000FCFA were 24/482 (5.0%) the lowest population (Table 2).

Table 2: Demographic characteristics of study participants

Variable	Categories	Frequency (n)	Percent (%)
Sex	Female	287	59.5
	Male	195	40.5
	Total	**482**	**100**
Age group(years)	≤ 20	40	8.3
	21– 30	223	46.3
	31 – 40	132	27.4
	41 – 50	64	13.3
	> 50	23	4.7
	Total	**482**	**100**

	Divorced	16	3.3
	Married	200	41.5
Marital status	Single	247	51.2
	Widow(er)	19	4.0
	Total	**482**	**100**
	NO	217	45.0
Have children	YES	265	55.0
	Total	**482**	**100**
	1 –3	194	40.2
	4 –6	202	42.0
	> 6	86	17.8
	Total	**482**	**100**
	None Education	5	1.0
	Primary	49	10.2
Education level	Secondary	264	54.8
	University	164	34.0
	Total	**482**	**100**
	Employed	353	73.2
Employment	Unemployed	129	26.8
	Total	**482**	**100**
	Christian	450	93.4
Religion	Islam	30	6.2
	Others(pagan)	2	0.4
	Total	**482**	**100**
	None	85	17.6
	< 50000	133	27.6
Monthly income (FCFA)	51000 - 100000	162	33.6
	110000 - 200000	78	16.2
	> 210000	24	5.0
	Total	**482**	**100**

3.3 Practice towards frequency of usage of Boreholes and wells

The household participants who made use of the boreholes and well water for two days and more were [137/482(28.4%)] and those who use it immediately they fetch, that is directly from the source without storing were [3/482(0.6%)] (Figure 2)

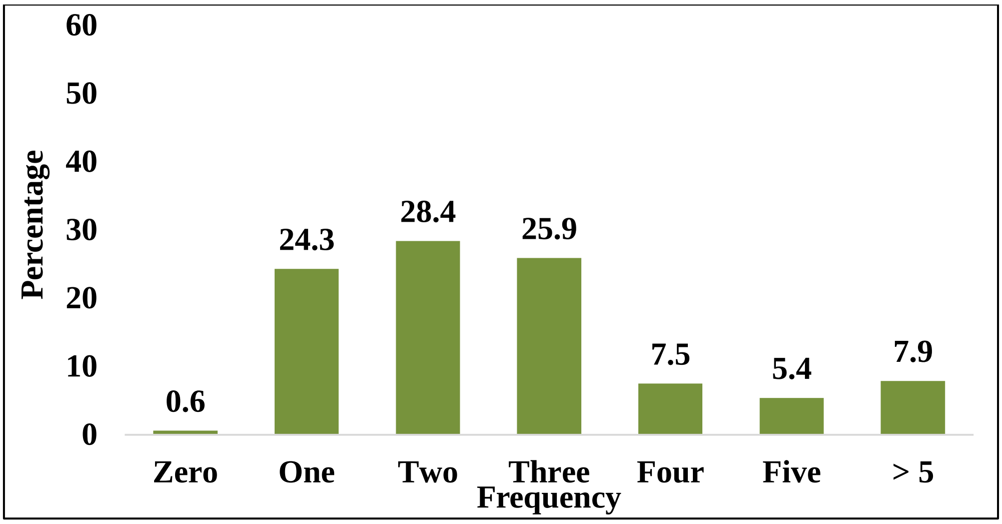

Figure 2: Frequency in days of usage of boreholes and wells water in Tiko municipality

3.3.1 Practice on household water treatment/disinfection

Of the 482 borehole and well owners and consumers, whose households treat/disinfect borehole and well to make it safe for consumption were [242/482 (49.8%)] inhabitants while those who do not disinfect before consumption were [240/482 (50.2%)] inhabitants. Household inhabitants who attested that they have never disinfect water to make it safer drinking were [244/482 (50.6%)] inhabitants and those who had never disinfected water to make it safer for drinking were [238/482 (49.4%)] inhabitants. Also most inhabitants used different procedures for disinfecting the water, most of them that is [136/482(56.2%)] used Aqua tabs to disinfect water meanwhile those who did not know the disinfection procedure were just [1/482 (0.4%)]. More so inhabitants who treated/disinfected their water following the disinfection procedures as per the time of this study for the same day of the study were [26/482 (5.4%)] and those who did not know the last time their household disinfected water were [240/482 (49.8%)]. Those who said the disinfection procedure was difficult were [52/482 (10.8%)] and those who said they do not know if the disinfection procedure was difficult were [240/482 (49.8%)]. Most households had a duration of their last treatment less than 7 days giving [206/482(85.1%) inhabitants and greater and equal to 7 days had [36/482(14.9%)]. Furthermore, the expenditure for water disinfection per month in households were [240/482 (49.8%)] households who did not know the approximate money used and [80/482 (16.6%)] households spend nothing for water disinfection (Table 3).

Table 3: Household water treatment practices by borehole and well owners and consumers

Variable	Category	Frequency(n)	Percent (%)
Household treatment or disinfection of borehole and wells	NO	240	49.8
	YES	242	50.2
	Total	**482**	**100**
Household ever treated or disinfect borehole or well to make it safer for drinking	NO	238	49.4
	YES	244	50.6
	Total	**482**	**100**
Water treatment method	Boil the water	16	6.6
	Add bleach/chlorine	26	10.8
	Sieve it through cloth	13	5.4
	Water filtration	9	3.7
	Let it stand and settle	11	4.5
	Aqua tabs	136	56.2
	Don't know	1	0.4
	Other(refrigerator)	30	12.4
	Total	**242**	**100**
Last time your household	Don't know	240	49.8

treated the water using this method	Less than one week ago	91	19.0
	Less than one month ago	39	8.1
	More than one month ago	39	8.1
	Today	26	5.4
	Yesterday	47	9.6
	Total	**482**	**100**
Is the procedure you use for disinfecting the borehole or well difficult	Don't know	240	49.8
	NO	190	39.4
	YES	52	10.8
	Total	**482**	**100**
Duration since last treatment or disinfection procedure	< 7 days	206	85.1
	≥7 days	36	14.9
	Total	**242**	**100**
Money spend on the water treatment per month	Nothing	80	16.6
	SPECIFY AMOUNT	162	33.6
	Don't know	240	49.8
	Total	**482**	**100**
Amount spent for water treatment (FCFA)	Nothing	80	16.6
	100 – 1000	67	13.9
	1100-5000	67	13.9
	> 5000	28	5.8
	Don't know	240	49.8
	Total	**482**	**100.0**

3.3.2 Water treatment/disinfection methods practiced by borehole and well owners and consumers

Borehole and well owners used many different other methods for disinfecting the borehole and well water giving a percentage of [125/482(25.9%)] while those who did not know the methods of disinfection were [4/482 (0.9%)]; on the one hand, most of the borehole and well water consumers used addition of bleach/chlorine with [138/482(28.7%)] and borehole and well water consumers who used aqua tabs were [24/482(4.9%)], those who let it stand and settle were [24/482(4.9%)] and those who sieve it through clean clothes were [24/482(4.9%)] been the lowest percentages of disinfection (Figure 3).

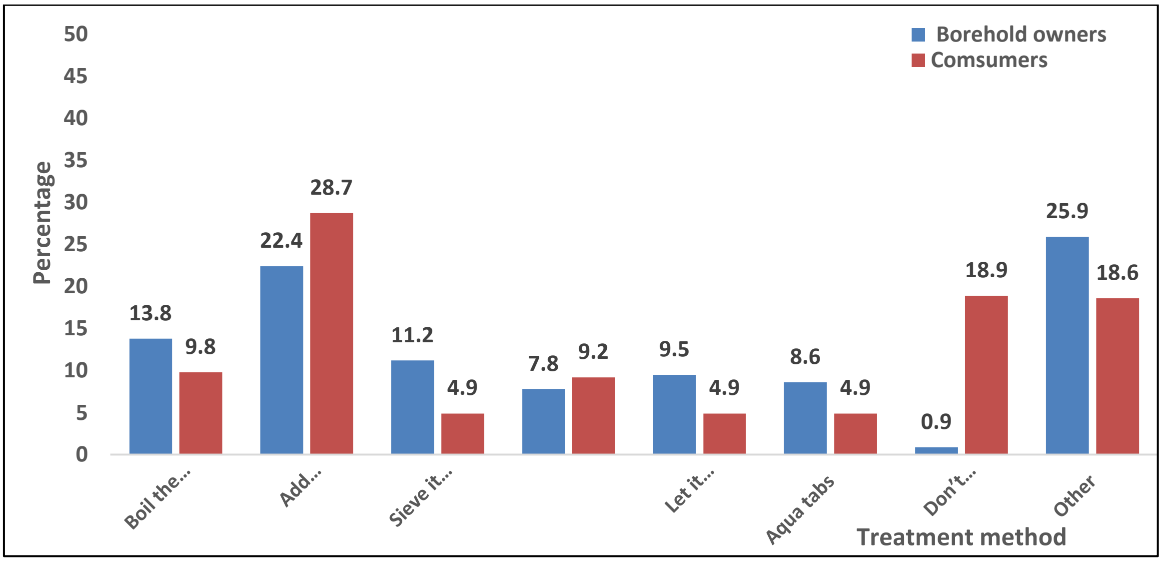

Figure 3: Water treatment methods practiced by borehole and well owners and consumers

3.3.3 Practice of water treatment/disinfection technique by household inhabitants

There was an overall good [280/482(58.0%)] practice for water disinfection technique done by household inhabitants and an overall poor [202/482(42.0%)] practice for water disinfection procedure. Here there were six (6) parameters talking about the practice of water disinfection, when a participant has four and above correct responses following the practice of water disinfection was rated good while those who had poor knowledge had ≤ 3 correct responses. (Figure 4).

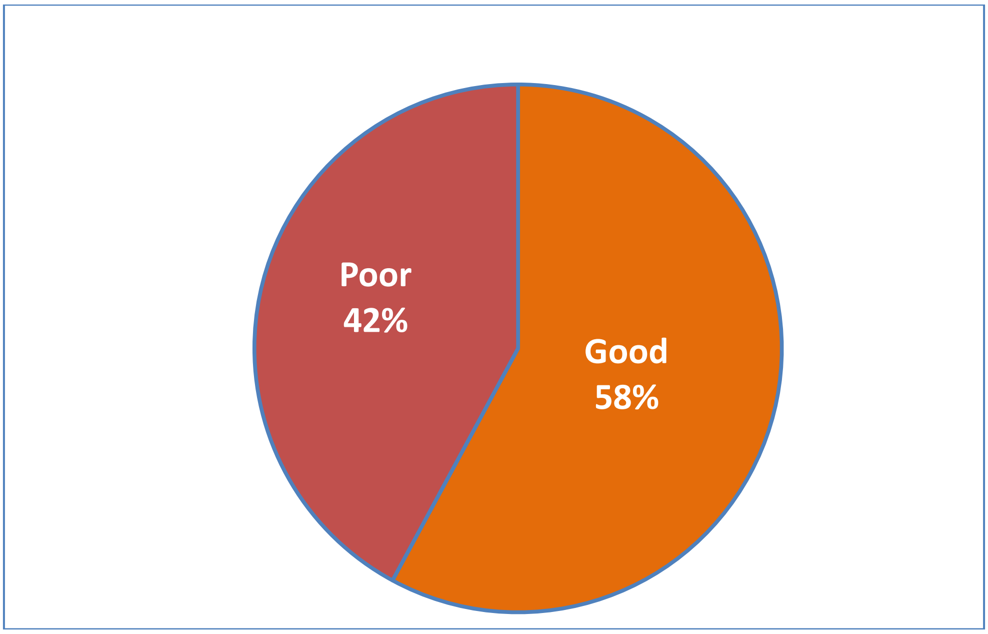

Figure 4: Practice of water disinfection

3.4 Association between practice and demographic characteristics

The association between the practice and demographic characteristics was done using the Pearson's chi square test. There was a significant association between borehole ownership and practice of disinfection (Table 4).

Table 4: Association between practice and demographic characteristics

Variables	**Categories**	**Practice**				**Chi-square**	**p-value**
		Good	**%**	**Poor**	**%**		
Respondents	Borehole and well owners	33	6.9	49	10.2	12.6	**0.0**
	Consumers	246	51.0	154	32.0		
	Total	**279**	**57.9**	**203**	**42.1**		
Health area	Holtforth	134	27.8	86	17.8	3.3	0.5
	Likomba	27	5.6	16	3.3		
	Mutengene	22	4.6	21	4.4		
	Tiko Town	96	19.9	80	16.6		
	Total	**279**	**57.9**	**203**	**42.1**		
Age group(years)	< 20	24	5.0	16	3.3	3.9	0.4
	20 - 30	132	27.4	91	18.9		
	31 – 40	75	15.6	57	11.8		
	41 – 50	39	8.1	25	5.2		
	> 50	9	1.9	14	2.9		
	Total	**279**	**57.9**	**203**	**42.1**		
Sex	Female	170	35.3	117	24.3	0.5	0.5
	Male	109	22.6	86	17.8		
	Total	**279**	**57.9**	**203**	**42.1**		

Marital status	Divorced	13	2.7	3	0.6	6.1	0.1
	Married	106	22.0	94	19.5		
	Single	149	30.9	98	20.3		
	Widow(er)	11	2.28	8	1.7		
	Total	**279**	**57.9**	**203**	**42.1**		
Household size (inhabitants)	1 - 3	117	24.3	77	16.0	5.5	0.1
	4 - 6	122	25.3	80	16.6		
	> 6	40	8.3	46	9.5		
	Total	**279**	**57.9**	**203**	**42.1**		
Employment	Employed	203	42.1	150	31.1	0.1	0.8
	Unemployed	76	15.8	53	11.0		
	Total	**279**	**57.9**	**203**	**42.1**		
Monthly income (FCFA)	None	41	8.5	44	9.1	7.1	0.1
	< 50000	83	17.2	50	10.4		
	50000 – 100000	101	21.0	61	12.7		
	110000 – 200000	40	8.3	38	7.8		
	> 200000	14	2.9	10	2.1		
	Total	**279**	**57.9**	**203**	**42.1**		

3.5 Organoleptic and physico-chemical quality of borehole and well water sources

3.5.1 Water quality of boreholes and wells

With respect to the organoleptic and physico-chemical quality of boreholes and wells, parameters like clarity, colour, smell, taste, healthiness, stability of water flow and convenience to fetch water were assessed. The analysis reveals that a minimum percentage 6/482(1.2%) of participants don't know about the clarity and colour of drinking water while of the 482 participants who attested that the water quality was good for all parameters had[329/482(68.3%)] for clarity, and [286/482(59.5%)] for colour, and[281/482(58.3%)] for smell, [269/482(55.8%)] for taste and healthiness, [268/482(55.6%)] for stability and[264/482(54.8%)] for convenience (figure 5).

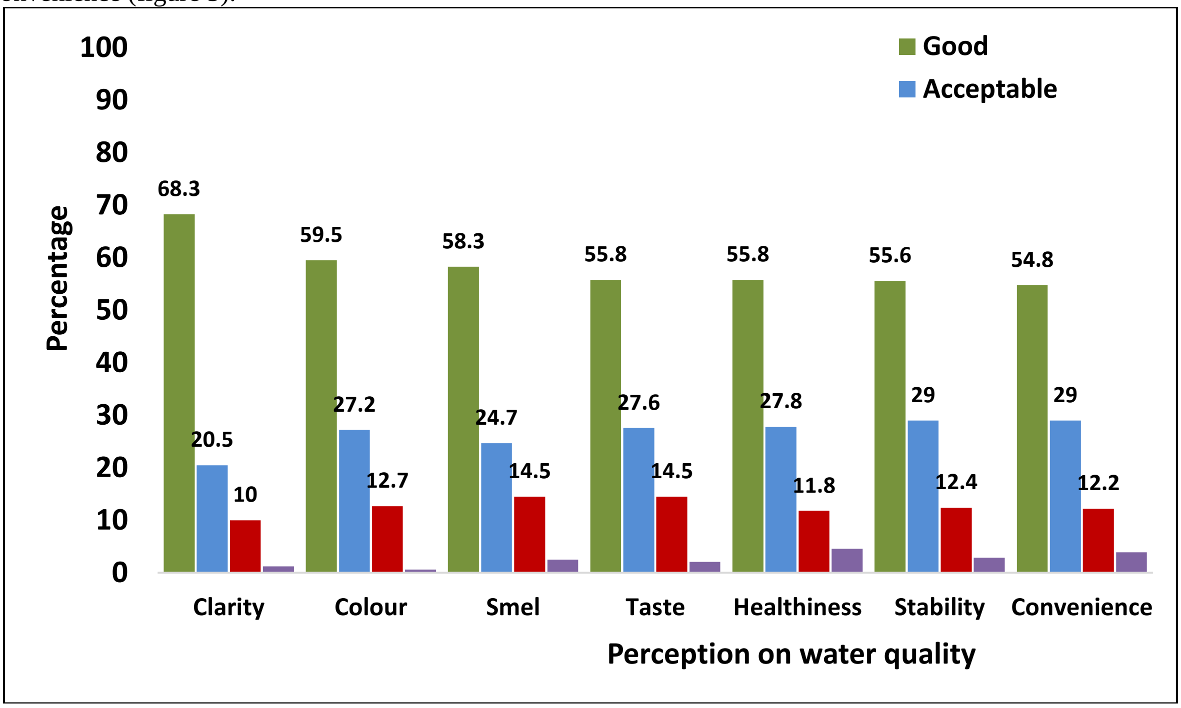

Figure 5: Participants' perception of the quality of water in the Tiko Municipality

3.6 Mineral analysis of selected boreholes and wells

Based on the concentration of the mineral samples determined from the different water sources, the mean and standard deviation of the various minerals were Calcium (14.7 ± 2.9), Magnesium (2.0±0.5), Potassium (3.5±0.2) and Chlorine (1.2±0.1) as presented on table 5 below.

Table 5: Measurements of minerals from the different water sources

		Calcium	Magnesium	Potassium	Chlorine
No	**Valid**	20	20	20	20
Mean		14.7	2.0	3.5	1.2
Median		13.8	2.0	3.6	1.2
Mode		13.2	2.0	3.6	1.1
Std. Deviation		2.9	0.5	0.2	0.1
Variance		8.2	0.2	0.1	0.0
Range		9.2	1.9	0.9	0.3

3.7 Isolation of bacteria from the borehole and wells

The culture of 20selected water sources resulted in 13(65.0%) growth for several bacteria. With 8(40.0%) *Clostridium perfringens* being the highest that is having 5(25.0%) growth for wells and 3(15.0%) for boreholes, 5(25.0%) *Escherichia coli* that is 4(20%) for wells and 1(5%) for borehole bacteria growth, 3(15.0%) *Salmonella typhi* that is 2(10%) growth for well and 1(5%) for boreholes, 3(15.0%) *Salmonella paratyphi* 1(5%) growth for wells and 2(10%) for boreholes and 1(5.0%) *Staphylococcus aureus* growth for a well only (Figure 6).

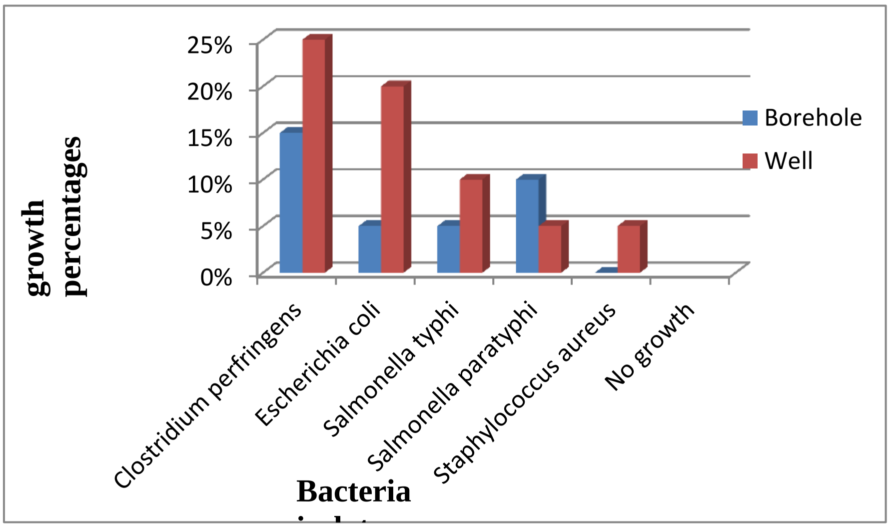

Figure 6: Number and types of bacteria isolated from the boreholes and well water

IV. DISCUSSION

Participants main source of drinking water were boreholes with a percentage of 44.2%; showing that most of the household make use of boreholes as their primary source of drinking water and mostly those who used it for two days had the highest frequency with 28.4%. Household inhabitants who mostly go to fetch water and understand the procedure of fetching water are the sons, representing the highest number of household with 31.1%.The age group with highest participants were 20 – 30 years (46.3%). Most (41.9%) households were crowded with 4 - 6 inhabitants. These are in line with findings from Muhammad and collaborators (2017) [63] who said that about 35% of the world rural population are children aged below 5 years and majority of the population are youths aged above 20 years. The young population is presumed to be more cautious with regard to water safety, uses and water borne diseases. Another study from Jeffrey and colleagues (2006) [64] also stated that households with more residents use more water. Women and children dominate the African population, defining their role in carrying water over long distances from the sources to the households by Mallick and co-workers (2015) [65]. Findings showed 25.9% participants used various methods, 28.7% addition of bleach/chlorine, 4.9% aqua tabs, 4.9% those who let it settle and 9% sieve it through clean clothes for disinfecting water while 0.9% did not know the methods of disinfection.This agrees with a study carried out by Pradhan and collaborators (2018) [66], about 27.0% had knowledge about chlorination and 22.4% membrane filter. However, around 21% of the participant had no knowledge about any of the above mentioned methods for household treatment methods. Also, another study by WHO, (2016) [32] says storage of water may be regarded as a form of treatment. *Schistosoma mansoni* cercariae are normally unable to survive 48 hours of storage and the number of faecal *Escherichia coli* will be considerably reduced when the raw water is subjected to storages.

In the present study regarding practice of water disinfection methods, 58.0% of households' practices good water disinfection technique and 42.0% practice poor water disinfection procedure. This is in accordance with a study carried out by Kuberan and colleagues (2015)[67] were 45.0% of the participants were not following any methods of water treatment and among them half of the participants felt water was already clean and did not require any additional treatment. In another study, nearly a quarter of households used no method of drinking water disinfection, 82.0% reported using of a cloth filter and 33.3% reported boiling the water. Use of aqua tabs and liquid chlorine for drinking water purification was not frequent [68]. However, families with lower instruction participate in more water protection practices and utilize less water than advanced educated families. The unit water consumption by the educated families are always higher [69]. However, they are more concerned about the safe utilization of the water resources in the area. Improvement in the literacy levels goes a long way to facilitate diversification of water handling practices geared towards achievement of Sustainable Development Goals [69].

Based on the Organoleptic and physico-chemical quality of borehole and well water sources, this study shows a minimum percentage (1.2%) of participants don't know about the clarity and colour of drinking water while participants who attested that the water quality was good for all parameters had 68.3% for clarity, 59.5% for colour, 58.3% for smell, 55.8% for taste and healthiness, 55.6% for stability and 54.8% for convenience. This is higher than the findings of Muhammad and collaborators (2017)[63] who reported that environmental change is probably going to additionally compound existing stressors on water supplies. Meeting this test will require sourcing selective water supplies and expanding the efficiency of existing water supplies [70]. Piped, protected and unprotected well as well as hand pump among other water sources are used for drinking purposes irrespective of their safety for human health.

Also these findings are in accordance with a study by WHO reporting that high water temperature may facilitate growth of microorganisms and can also impact undesirable taste and odour as well as the corrosive ability of the water, hence affecting water quality [71]. The higher temperatures observed in samples from Tiko might be attributed to the environmental temperature and other climatic conditions prevailing at the time of sampling given that Tiko normally records higher temperatures owing to its coastal Equatorial climate and sandy belts [72], Neba [73]. Hence, the water temperatures recorded here may only highlight environmental characteristics without any suggestion for adverse effects on human health. The pH values of all the samples ranged from 4.9 to 8.4and these could be classified as suitable for drinking purposes. The WHO Minimum pH value is 6.5. According to Sabrina and colleagues (2013) [74] at low pH, water can be corrosive and cause damage to equipment, since it can increase metal leaching from pipes and fixtures, such as copper and lead lined. Damaged metal pipes within the well due to acidic pH values can also lead to aesthetic problems, causing water to have a metallic or sour taste [74]. The concentration of total dissolved solids (TDS) is related to Electro Caution (EC) which increases as TDS increases. The inter-linkage between TDS and EC observed in this analysis is similar to the result of Shigut and co-workers (2016) [75] who carried out a separate assessment of borehole and spring water in Ethiopia and observed that TDS and EC of borehole water were inter-linked. Moreover, increase in TDS and EC increases the corrosive nature of water. Unusual taste, odour and feeling problems usually due to TDS and higher EC indicate the presence of dissolved minerals [76].Turbidity is one of the important physical parameters for water quality. It is indicative of the presence of suspended solids in water and causes the muddy or turbid appearance of the water body [77].This result goes to confirm the observations made during field work where most of the boreholes had turbid water. Turbidity of water can possibly be due to underground clay contamination, presence of inorganic particulate matter and non-soluble metal oxides The high turbidity observed in some boreholes in this study could result from corrosion due to the use of a hand pump which can further cause permeability of the hand pump such that soil particles seep into the water thereby causing high turbidity levels. Pure water is colorless [23].

Dissolved organic material from decaying vegetation (algae, and humus compounds) and certain inorganic matter for example increasing concentrations of dissolved (Fe and Mn) ions, measured in (ppm) causes color in water. The color is estimated by comparing sample color with a standard solution color (1.245 gm of chloro-platinium potassium added to 1.0 gm of crystalline cobalt chloride in one liter distilled water and quantitative determinations of odor have been developed based on the maximum degree of dilution that can be distinguished from odor-free water Pure water is odorless according to Soran and colleagues (2021) [23]. They continued saying that Temperature affects the geochemical and chemical reactions. It effects the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste, ideally, normal turbidity should be below 1 Nephelometric turbidity Unit NTU [23].

Based on bacteria isolated and identified from the various water sources in the Holtforth Layout Tiko included; (40.0%) *Clostridium perfringens*, (25.0%) *Escherichia coli*,(15.0%)*Salmonella typhi*, (15.0%)*Salmonella paratyphi* and(5.0%) *Staphylococcus aureus*. Growth was remarkable by giving up to 65.0%contaminated samples. A study conducted in Nigeria by Nwandor and collaborators (2015) [78] which gave 68.0% boreholes *with Streptococcus spp, E.coli, Pseudomonas spp, Enterobacter spp, Bacillus, Salmonella* and *Proteus spp* confirms this findings. The high number of bacteria isolated in the Tiko Municipality may be attributed to the climatic factor and geographic condition, and isolates recorded could be responsible for water borne diseases such as diarrhea and typhoid. This analysis are confirms with that of Bernette RW and collaborators (2010) [42] giving that the presence of *Staphylococcus aureus* maybe as a result of environmental contamination during culturing and poor sanitation conditions. The presence of faecal coliforms in a water sample indicates the possible presence of other pathogenic bacteria such as *Salmonella spp*, *Shigella spp*, pathogenic *E. coli*, *V. cholera*, *Klebsiella spp* and *Campylobacter spp* associated with waterborne diseases. Unfortunately faecal coliform bacteria exhibit species to species variations in their respective stability and resistance to disinfection processes; and do not distinguish between faeces of human and animals origin; also it have low survival rates and have been detected in water sources thought to be free of faecal pollution.

This study contrary to the study conducted in Douala, Cameroon by Tatah and collaborators (2013) [79], who isolated *S. aureus, E. coli, A hydrophila, C. freundii, P. aeruginosa, E. aerogenes, K. pneumonia, S. epidermidis, V. mimicus, Salmonella spp, V.fluvialis, V. vulnificus V. cholera.* The low number of bacteria isolated in Holtforth, Likomba, Mutengene and Tiko town may be attributed to the low population compare to Douala which is overcrowded. This could be attributed to the location of pit latrine close to the wells, and also as a result of defecating in water by animals or humans. It might also be from septic tanks near the water source and sewage leaking into the underground source. The presence of *Clostridium perfringens* in water could be as a result of defecation in water by mostly animals. In relation to distance of water source from latrines, 60% of water sources were found at a distance of less than 30 meters especially the well water sources which is below WHO recommendation for minimum distance that should exist between latrines and water source. Some (50%) of the well water sources were without covers. However, safe water is essential for good health, all effort must be taken to safeguard its quality at all stages of distribution.

4.2 CONCLUSION

Based on the findings from this study, the following conclusions are arrived at;

- Most households practice water disinfection techniques out of the numerous techniques but yet some consider water as clean and minimize a disinfection practice which leads to contaminations by microbes present in water.
- This study revealed organoleptic and physico-chemical quality of boreholes and well to be within range with a few slightly out of normal ranges.
- There was a poor bacteriological quality of the water sources (boreholes and wells) used by the inhabitants of the Holtforth, Likomba, Mutengene and Tiko Town Health areas. The water sources contained bacteriological indicators of pollution. The bacterial indicators present suggest inadequate hygiene and sanitation. Consequently they are not suitable for domestic activities and most importantly drinking and could be at the origin of water borne diseases outbreaks.

4.3 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made;

- There is a need for enforcement of public laws on setting and construction of pit latrines, and guidelines for well construction.
- An efficient and well maintained distribution system coupled with good hygiene practices would ensure that water will be safe at the point of collection and before consumption, health, hygiene and sanitation education which should emphasize on regularly adequate water disinfection.
- Water sources should be protected and local public health services and rural councils should establish local water management committees to help in monitoring and ensuring water sources do not represent a risk of waterborne disease outbreak.

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