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Factors Affecting the Persistence of Cholera Epidemics in Bibémi (North Cameroon)

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ABSTRACT

The recurrent cholera outbreaks in north Cameroon suggests the existence of hotspot cholera potential reservoirs including polluted surface waters and groundwater. This study investigated water sources, for contamination with Vibrio cholerae, to highlight their role in disease transmission in the cholera endemic areas of Bibémi (north Cameroon). Risk factors of cholera transmission among households were also assessed. The water quality of 15 water points (1 borehole, 8 wells and 6 surface water points) was assessed through commonly used microbiological tests. Also analysed were physicochemical parameters of the water. Results pointed out unsafe water sources (wells and streams) with total coliforms present in all water samples (13-168 CFU/100mL). However, borehole water was negative for total coliforms (0 CFU/100mL) and was qualified for all domestic uses. The results reported the presence of V. cholerae reservoirs along the mayo-Barka course, a stream which water points digged on the dried-up bed are used as drinking water sources in Bibémi. Wells and borehole were negative to V. cholerae. The physico-chemical characteristics of water varied with sampling points. The pH of the water was acidic for most water points; the lower value of temperature was 28.90 °C and the higher was 31.05 °C. The values of electrical conductivity, TDSs and salinity fluctuated from 136.2 to 1308.0 µS/cm, 68.1 to 652.0 mg/l and 67.8 to 650.0 ppm respectively in the water samples. The mayo-Barka presented the higher level of water mineralization. A survey carried out in the study area showed that the low level of education, poor hygiene, poor management of water sources and the scarcity of sanitation would contribute greatly the appearance and spread of cholera in Bibémi. Considering and improving these risk factors by health authorities would help reduce the incidence of cholera and improve the prevention strategies.

Keywords- *Vibrio cholerae*, Cholera, Epidemics, Water, Risk Factors.

I. INTRODUCTION

Cholera is one of the most common contagious diarrheal diseases in the world. It is caused by a specific pathogen, *Vibrio cholerae*. According to a report by the World Health Organization [1], 172 454 cholera cases and 1304 deaths were reported by 42 countries in 2015. Africa is the most affected continent with more than 90% of the globally reported cases. This situation is particularly critical in some countries in sub-Saharan Africa where cholera is endemic [2].

For more than two decades, cholera outbreaks have been recorded seasonally in different regions of Cameroon. According to the Cameroon Ministry of Public Health, the northern (North and Far North) regions are the most affected with almost 90% of reported cases. The epidemiological situation is particularly worrying in the North region, which records cholera epidemics each year since 1996 [3]. During the 2018 cholera outbreak in the Cameroon North region, Bibemi health district, with 212 cases and 9 deaths, was among the worst hit ones with Garoua I, Pitoa, and Golombe (unpublished data).

V. cholerae occurs in various aquatic environments [4]. Most strains of this species are found in the marine and estuarine environment. However, these bacteria can survive for a long time in fresh water in several forms: planktonic, fixed on other organisms or substrates, or in a viable but non-cultivable (VNC) state. However, VNC cells can actively restore their cultivability and infectivity in the aquatic environment when conditions become favorable or in the digestive tract of contaminated humans [5].

Guévart *et al.* [6] and Akoachere *et al.* [7] revealed the presence of *V. cholerae* in urban drinking water in Yaoundé and Douala. In the city of Douala, water has even been identified as the main vector for the spread of cholera. Nganou Donkeng *et al.* [8] isolated *V. cholerae* in the waters of lakes in the country's northern regions. The persistence of *V. cholerae* in such water in the absence of cholera confirms the survival and the growth of this organism in the natural environment. It is this survival of *V. cholerae* in the environment that would be responsible for the maintenance of cholera epidemics worldwide [9].

According to Kaas *et al.* [10], cholera epidemics are generally observed during the rainy season in the northern Cameroon, more precisely in the localities bordering Chad and Nigeria. Previous studies showed that the resurgence of outbreaks in Cameroon is linked to

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scarcity of potable water, insufficient access to sanitation, promiscuity and the practice of some funeral rites involving the manipulation of deaths [11]. These authors also noted shortcomings in strategies of cholera prevention implemented by the public authorities and the weakness of the epidemiological surveillance system. Indeed, the prevention of cholera epidemics is still difficult because the environmental reservoirs of *V. cholerae* are not identified. In addition, ecological niche of *V. cholerae* is unknown and the transmission factors of cholera are not under control. According to Ngwa *et al.* [12], a single 'one-size-fits-all' national approach to prevention and control of cholera might not be optimal. They further suggest the need to develop regionally or locally targeted prevention and mitigation strategies and plans.

This study aimed at detecting the aquatic reservoirs of *V. cholerae* and assessing the risk factors of cholera outbreaks in Bibémi.

II. MATERIAL AND METHODS

Study Site

The city of Bibémi (Latitude 09.30° North and Longitude 13.86° East) is in the Department of Bénoué, Region of North Cameroon (Figure 1). It gets an estimated population of around 9140 inhabitants. This localitybelong to a district that covers an area of 2,535 km² in the Cameroon Sudano-Sahelian zone [13].

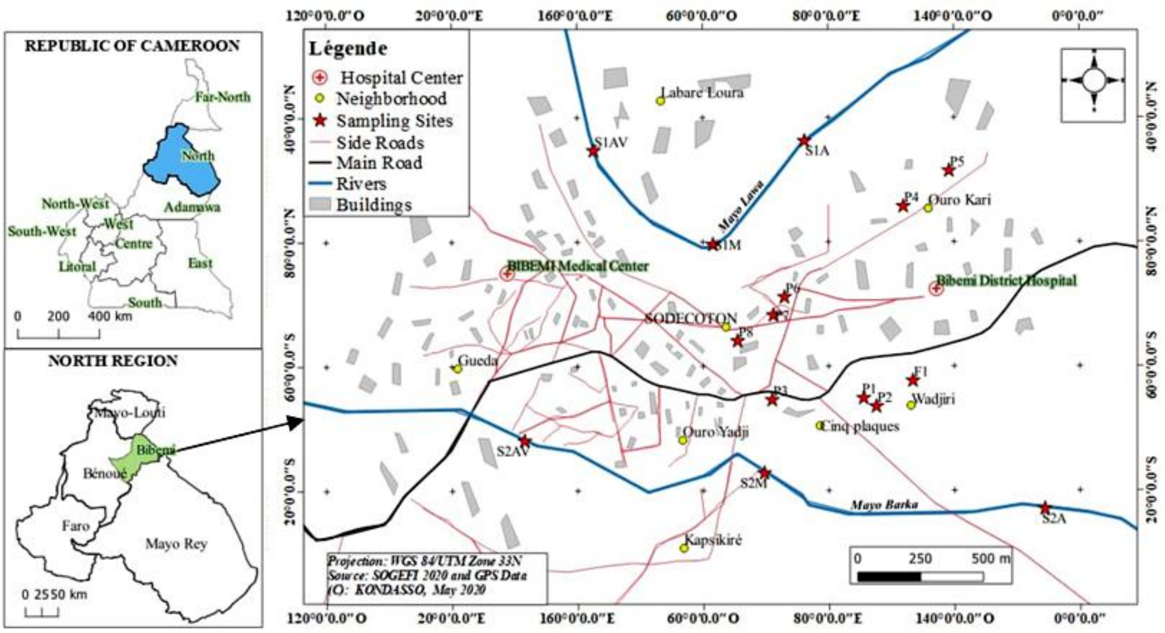

Figure 1: Map of Bibémi locality showing the sampled water points.

The Sudano-Sahelian climate is characterized by a long dry season from October to April and a short rainy season from May to September. Average annual rainfall is 956 mm in 54 days of precipitation.

Temperatures are high with an average level of 31°C. The minimum temperature varies between 15 and 27°C, in January, and maximum reaches 42 to 45°C, in April. However, large irregularities can be observed from one year to another and even from one month to another due to climate change [13].

The presence of clay or clay-sandy soils in Bibémi makes the area particularly swampy and floodable [13]. The relief of the locality is characterized by a flat ground. It is interspersed with numerous valleys that converge to form small streams that join the Mayo-Kebi.

The hydrographic network of the city of Bibémi consists of three seasonal streams called "mayo": the mayo-Lawa, the mayo-Barka, the mayo-Lombo which only flow in the rainy season and often experience flooding.

Seeking for Potential Water Reservoirs of Vibrio Cholerae

Water Sampling Sites

Preliminary investigations in the study area have shown that wells and surface water due to their vulnerability to organic and faecal pollution are more exposed to bacterial contamination than boreholes. To increase the possibilities of detecting potential reservoirs of *V. cholerae* in the study area, 15 water points (1 borehole, 8 wells and 6 surface water points) were chosen for this study. The position of potential sources of pollution, the use of water primarily for drinking purpose and the presence of cholera cases in the neighborhood during the most recent epidemics guided the choice of the studied water points. The water points were distributed in the neighborhoods known as Wadjiri, 5 Plaques, Ouro-kari, Chantier, Sodecoton. Codes have been assigned to wells (P1, P2, P3, P4, P5, P6, P7, P8), to water points digged in dried up streams (S1. A, S1.M, S1. Av S2. A, S2.M , S2. Av) and borehole (F). Figure 1 shows the location of these sampling points on the map of the city of Bibémi.

Collection of Water Samples

The water samples were collected monthly during the dry season, from December to April. Indeed, the dry season is a period of the year marked by the absence of precipitation and the drying up of most water points. Depending on the availability of water sources, people collect drinking water from boreholes, wells or dig for water in a dried up stream bed. It was therefore interesting to verify the presence, in a viable and cultivable form, of *V. cholerae* in these aquatic environments, essential sources of drinking water at this period of the year, preceding the regular cholera season.

The samples were collected from the selected surface waters (streams) and groundwater sources (wells, and boreholes). At each sampling point, two water samples were collected, one in a sterile glass bottle and the other in a polyethylene bottle. The sample in sterile glass bottle was used for isolation of *V. cholerae* and bacteriological water quality analysis and the other, in the polyethylene bottle, for physico-chemical analysis [14]. Before taking sample from boreholes, water was flushed for 5 min and then the mouth of the hand pipe was sterilized with a spirit of lamp flame and then cooled by running water. Samples from wells and streams were collected as done by population to fill the sampling bottles. Indeed, a bucket is cleaned, then rinsed three times with water to be sampled. Finally, the water from the sampling site is drawn to fill the sterile bottles.

Isolation and Identification of V. cholerae

The isolation and identification of *V. cholerae* used multi-stage approach [15]. For each sampling site, 200 mL of water sample in sterile bottle was filtered through a sterile 47 mm, 0.22 µm-pore-diameter, gridded membrane filter, under partial vacuum. The used filter was then removed with sterile forceps and transferred to 10 mL of Alkaline Peptone water pH 8.4, for enrichment at 37°C for 24h. After incubation, a loop full of enrichment culture was picked just beneath the surface of broth and streaked onto thiosulfate citrate bile salt sucrose (TCBS) agar (Liofilchem s.r.I. Bacteriology Products, Italy) plates and incubated at 37°C for 18–24 hours. Presumptive colonies (yellow, measuring 2-4 mm) were sub cultured on brain heart agar to obtain pure cultures. The Gram negative, curved and motile rods from brain heart agar that are oxidase positive were subjected to further biochemical characterization using the API 20E kit (Bio Merieux SA, France) to identify *V. cholerae*. The affinity of *V. cholerae* for NaCl (growth at concentrations between 0 and 6%) was checked to confirm this biochemical identification.

Assessing Risk Factors of Contamination of Water Points and Cholera Transmission

Physico-Chemical Analyses of Water Samples

The seasonality of cholera outbreaks has been attributed to changing environmental factors. Water temperature, pH, salinity and nutrient concentration are among the environmental factors shown by field studies to influence the occurrence of *V. cholerae* in water sources [16]. The assessed physico-chemical parameters of water quality in this study were: temperature, total dissolved solids, pH, electrical conductivity and salinity. These parameters were determined in situ immediately after the samples were collected. They were measured with the use of pH/Conductivity / TDS / Salinity / Temperature Meter Extech EC500.

Isolation and Enumeration of Coliforms

Membrane filtration was used to enumerate qualitative microbial indicators [total coliforms (TCs)] according to the standard methods (American Public Health Association, 2012). For each well, raw/diluted 100 mL water sample was filtered through a sterile 47mm, 0.45µm-pore-diameter, gridded membrane filter, under partial vacuum. Funnel was rinsed with three 30ml portion of sterile dilution water. Filter was removed with sterile forceps and placed on agar in 55 × 9mm petri dish (Gosselin a Corning Brand, France). The m-Endo LES (Difco Laboratories, Detroit, MI, USA) agar was used for the enumeration of TCs, after 24h incubation at 37° C. The typical coliform colony on m-Endo has a pink to dark-red colour with a metallic surface sheen. The resulting metallic green sheen colony forming units (CFU) were subsequently identified according to Holt *et al*. [17].

Coliforms were isolated and counted in each sample to assess the pollution of water by organic and faecal matter to deduce its potential impact on the presence of *V. cholerae* in the water sources.

Sociodemographic and Health Surveys within Households

An investigation was carried out in Bibémi to determine the risk factors of water contamination and cholera transmission. For this purpose, a questionnaire was designed to collect data on household demographics, water sources, water management, environmental health, hygiene, sanitation, knowledge of waterborne diseases, etc. The questionnaire was written in French and the interview was conducted in French or Fulfulde, local language. A pre-survey phase on ten randomly chosen households per interviewer was conducted to assess our data collection technique and improve the survey questionnaire. The survey was conducted on 75 randomly selected households' female heads, after obtaining their consent.

Data Analysis

The collected data were analyzed using Rx64 3.4.1 software. Graphics were made to highlight the characteristics of the analyzed water samples. Multivariate analyses (Multiple correspondence analysis,

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Principal component analysis and Multifactorial analysis) were performed using the R software via the Rcmdr and FactoMiner packages to determine the potential link between variables.

III. RESULTS

Detection of V. cholerae in Aquatic Ecosystems

Following various water sampling campaigns carried out in the city of Bibémi, *V. cholerae* was only isolated in surface waters (Mayo Barka). Thus, no strain of *V. cholerae* has been isolated from borehole and well water. The reservoirs of *V. cholerae* identified are on the bed of the Mayo Barka, upstream (S2A) and downstream (S2Av).

Physicochemical Characteristics of the Sampled Water

Temperature

Physico-chemical analyses of the water from Bibemi wells indicated water with temperatures showing little variation (28.90 to 29.90°C) (Figure 2). Similarly, in surface waters the temperature varied very little from one point to another (29.55 to 31.05°C). The minimum values were recorded at S1.A (29.55°C) at mayo-Lawa and at S2.A (30.30°C) in mayo-Barka. The average temperature of the borehole water was 31°C.

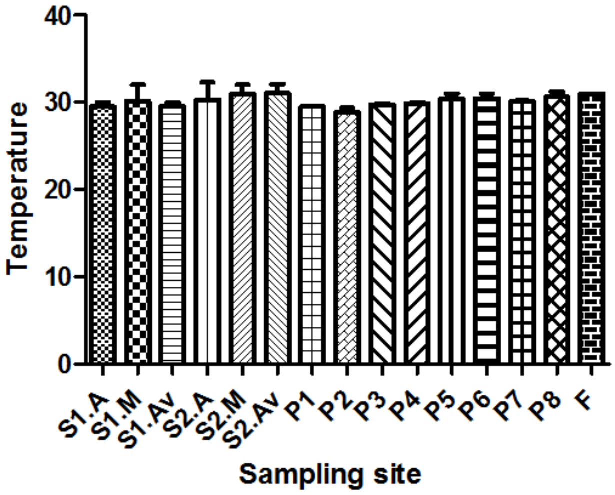

Figure 2: Variation of the temperature (mean ± standard deviation) of the waters in Bibémi according to the sampling points

The Potential of Hydrogen (pH)

The pH values recorded in well water varied between 4.97 (P6) and 7.98 (P3). The values recorded for surface waters varied between 5.86 (S1. Av) and 7.51 (S2. A). The average pH of the water in the borehole was 5.27 (Figure 3). The pH values of Bibémi waters in most of sampling points (P6, P4, F, S1. A, S1.M, S2. Av, P7, P8) indicated acidic water (pH below 7). Remaining water points (S2. A, S2.M, P1, P2, P3) however have basic waters (pH greater than 7 CU).

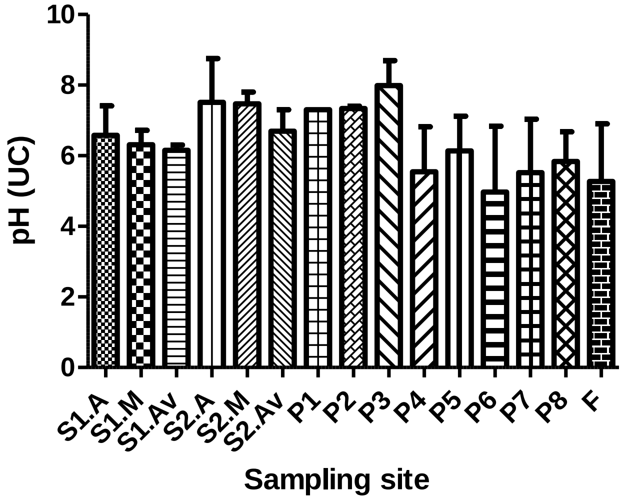

Figure 3: Variation in pH (mean ± standard deviation) of water samples in Bibémi according to sampling points

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Total Dissolved Solids (TDS)

The total dissolved solids (TDS) contents of the sampled waters presented minimum and maximum values of 68.10 mg/L (S1.M) and 652 mg/L (P8), respectively (Figure 4). For well water, TDS levels varied between 118.4 (P4) and 652 mg/L (P8). As for surface water, the highest value was recorded in point S1.Av (105.7 mg/L) and the lowest value in the S1.M site (68.10 mg/L). The average TDS content of the borehole water was 215.2 mg/L. Compared with mayo-Lawa, mayo-Barka presented relatively higher TDS content (321mg/L).

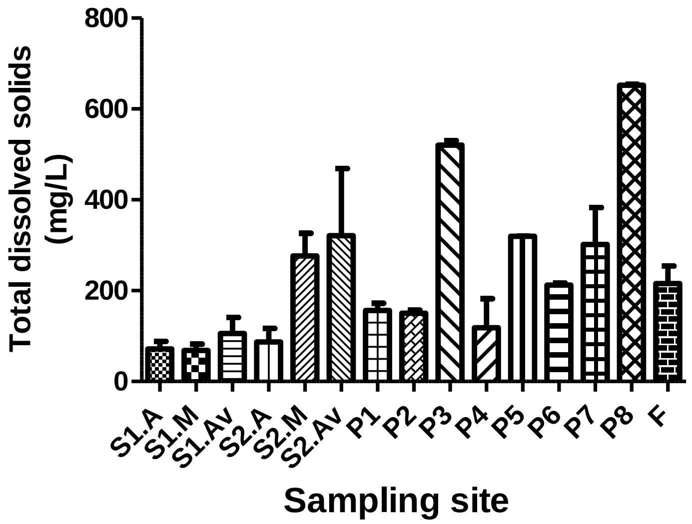

Figure 4: Variation in TDS contents of sampled Bibémi waters

Salinity

The salinity of the sampled waters varied greatly depending on the different sampling points. The minimum and maximum recorded values were respectively 67.75 ppm (S1.M) in the water of mayo-Lawa and 650 ppm in well water (P8) (Figure 5). The recorded salinity values for well water ranged from 99.1 ppm (P4) to 650 ppm (P8). An average salinity of 200 ppm was recorded for the borehole water (F). As in the case of TDS contents, the waters of mayo-Barka showed higher salinity values than those of mayo-Lawa.

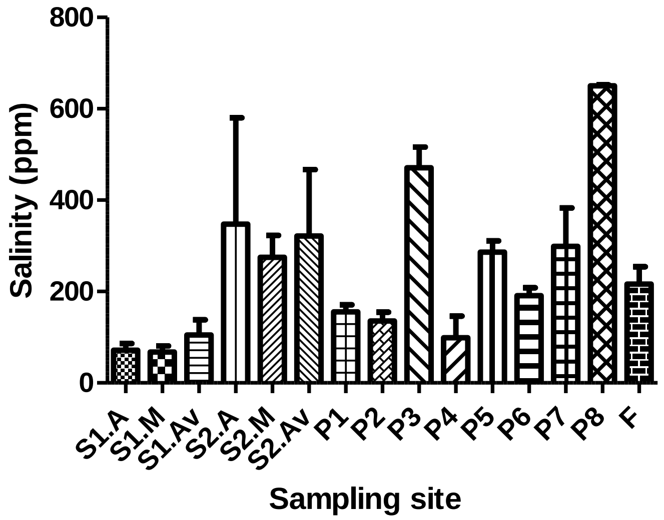

Figure 5: Variation in the salinity of Bibémi waters according to the sampling points

Electrical Conductivity

The electrical conductivity of the analyzed waters varied with sources. The maximum and minimum values were observed respectively at S1.M (136.2 µS/cm) and P8 (1308 µS/cm) sites. For well water, the highest value was recorded at point P8 (1308 µS/cm) and the lowest value at point P4 (238.5 µS/cm). The values of electrical conductivity of surface waters varied between

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136.15µS/cm (S1.M) and 217 µS/cm (S2.A). The average electrical conductivity of the borehole water (F) was 393µS/cm. These results (Figure 6) show that the sampling points of the surface water of mayo-Barka presented a high electrical conductivity compared to the water of mayo-Lawa. With respect to groundwater, wells P8 and P3 had the highest electrical conductivity values (1302µS/cm and 1045µS/cm, respectively).

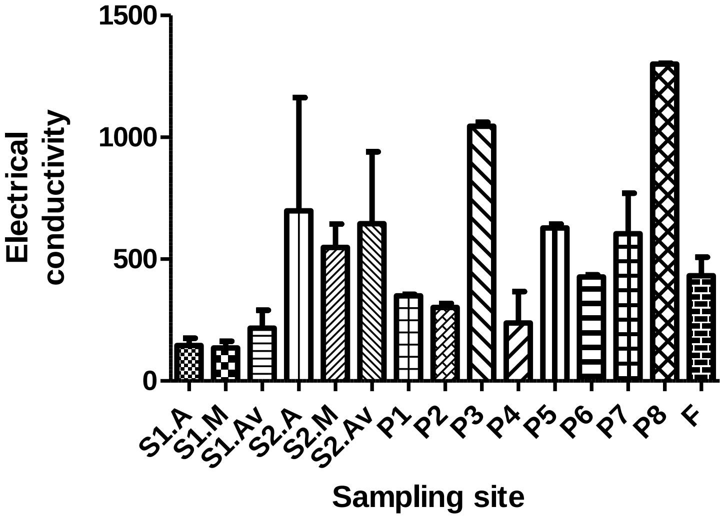

Figure 6: Variation of the electrical conductivity of Bibémi waters according to the sampling points.

Bacteriological Quality of the Water Sources

The total coliform count (TC) is used as an indicator of both faecal and organic pollution of the water. The abundance of coliforms in the analyzed water samples ranged from 0 CFU/100 mL (F) to 168 CFU/100 mL (S1.M) (Figure 7). For well water, the maximum value was recorded in well P1 (116 CFU/100 mL) and the minimum value in well P5 (13 CFU/100 mL). As for surface water, the abundance of TC fluctuated between 25 CFU/100 mL (S2.A) and 168 CFU/100 mL (S1.M). A TC abundance gradient was observed (downstream to upstream) for surface waters (mayo-Barka, mayo-Lawa) with relatively higher values for mayo-Lawa waters.

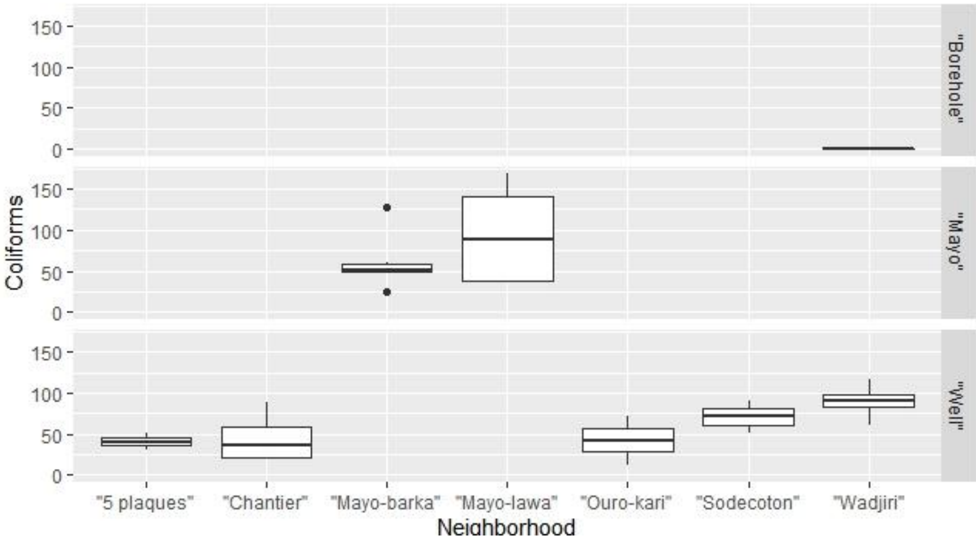

Figure 7: Variation in the abundance of total coliforms in Bibemi waters according to the sampling points.

Correlation between the Physico-Chemical and Bacteriological Parameters

The correlation between the different physico-chemical and bacteriological parameters was established by the principal components analysis. It was observed a statistically significant and positive correlation ($P < 0.05$) between temperature and pH on the one hand and between salinity, electrical conductivity and Total Dissolved Solids (TDS) on the other hand (Figure 8). The pH is opposed to the parameters linked to the

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mineralization of water (TDS, salinity, electrical conductivity) along axis 1 (Dim 1). While the total coliforms are opposed to all the physico-chemical parameters of water along axis 2 (Dim 2).

The first correlation group established between temperature and pH forms the first component of the correlation axis. The pH and the temperature move in the same direction. In addition, the increase in pH is consistent with an increase in the abundance of total coliforms in the medium. The pH and the temperature are the parameters which seem more linked to the development of coliforms in the analyzed waters.

The second correlation group, established between salinity, conductivity and TDS, forms the second component of the correlation axis. These three parameters indicate the levels of solutes in the water.

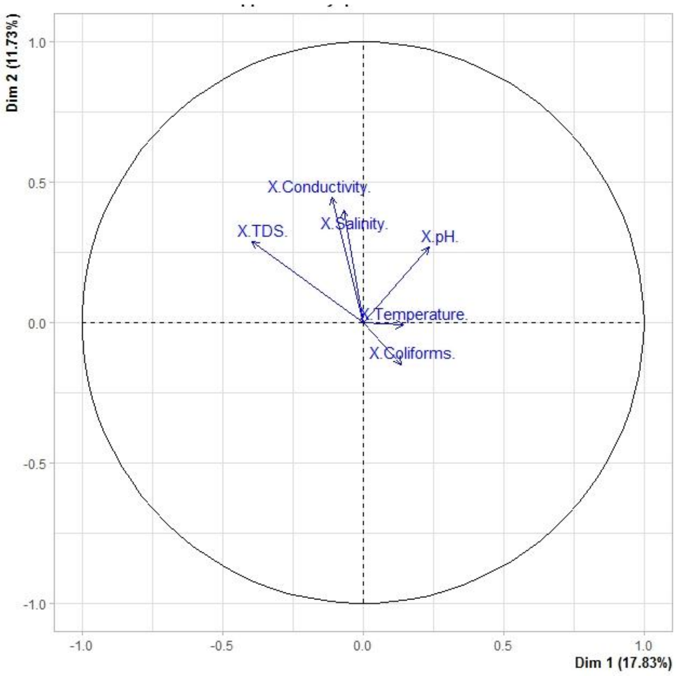

Figure 8: Correlation circle of the principal component analysis of the physico-chemical and bacteriological parameters of water.

Risk Factors for Contamination of Water Points and Transmission of Cholera

Sociodemographic Characteristics of the Study Population

The socio-demographic data of the households (Table 1) indicate that the average number of individuals in the households of Bibémi was 7.69 ± 4.09. Women represent 53% of the population and men 47%. The majority (60%) of the population of Bibémi are between 0 and 18 years of age. Children aged 0 to 5 alone represented 22% of the population (Table 1). 44% of the surveyed household female heads are illiterate, 41% have studied at primary level and 15% have completed secondary school. None of them, however, had a university education (Table 1).

Table 1: Summary of the household demographics

Demographics	**Number of people (and percentage)**
People in household Gender	
Male	271 (47%)
Female	304 (53%)
Age group	
Children<5 years	105 (18%)
Children (6-10 years)	118 (21%)
Children (11-18 years)	127 (22%)
Adult (>18 years)	225 (39%)

Education level of female head of household	
University	0 (0%)
Secondary school	11 (15%)
Primary school	31 (41%)
None	33 (44%)

Hygiene and Sanitation

The collected data on sanitation and personal hygiene in the households of Bibémi are shown in Table 2. Regarding the personal hygiene of the population in Bibémi, 100% of the respondents claimed to wash their hands before eating, 99% after being to toilet, 87% after cleaning their babies' buttock; but only 32% of this population wash their hands before food preparation. In addition, the survey found that only 31% of the respondents use water + soap to wash their hands and the remaining 69% use only water. In terms of sanitation, most of the respondents (92%) have traditional toilets; while 8% of them defecate in the open field. In 51% of households, it was reported that 6-10 persons use the same latrines. When the toilets are unavailable, 48% of their users use neighbors' toilets, 25% said they can wait, 16% have several latrines that can serve as alternatives and 11% defecate in the open field. Poor waste water management was also observed in the study site (Table 2) with septic tank available in only 5% of the study households.

Table 2: Summary of waste management and sanitation in Bibémi

Variables	Number (and percentage) of people
Type of toilet used	
Traditional	69 (92%)
None	6 (8%)
Number of people using the toilet	
1 to 5	21 (30%)
6 to 10	42 (59%)
>10	8 (11%)
Action when toilet is not available	
Relieve himself at the vicinity of the house	8 (11%)
use neighbour's toilet facilities	36 (48%)
wait for availability	19 (25%)
use another toilet	12 (16%)
How is water including waste from flush toilets disposed of?	
Poured into a septic tank	4 (5%)
Poured outside of the yard	63 (81%)
Poured into the yard	11 (14%)
Occasions of hand washing	
Before eating	75 (100%)
Before food preparation	24 (32%)
After being to toilet	74(99%)
After waking up	73 (97%)
After cleaning baby's buttock	65 (87%)
Do you use soap to wash hands?	
Yes	23(31%)
No	52(69%)

Sources and Management of Drinking Water

The Table 3 shows that a high number of households (96%) do not pay for water and 4% of the population get their water from paid sources (boreholes). The sources of drinking water used in Bibémi households include wells (35%), streams or mayo (61%) and boreholes (4%). It was noted that most of the drinking water points are located near the homes with distances varying from 0 to 100 m for 30% of households, from 100 to 500 m for 63% of households. Only 7% of households get their drinking water from sources located above 500m. Both morning and evening are the periods where the water sources are most visited (Table 3). Thus, only 7% of households visit water points at other times of the day. These results also show that each water point supplies more than 50 households. Taps are unavailable and water is mainly (96%) collected from the sources by deeping into it with a container. Observations made during the field investigations showed that there is practically no committee set up by the population for the management of water sources.

Storage of water in containers at home for various durations was observed in all the surveyed households. Thus, only 2% of households store water for a few hours, 46% of the population store water for a day, 48% for a duration of 2 days and 4% for a duration greater than or equal to 3 days. Results indicate that in most (80%) of households, water storage containers are cleaned without the use of disinfectant before to be filled with water, while 19% of households use soap and 1% use bleach as disinfectants. Women (53%) and children (46%) are in charge of water collection for the household.

Table 3: Summary of the water sources in Bibémi

Water use characteristics	Number of people (and percentage)
Water source	
Stream	46 (61%)
Well	26 (35%)
Borehole	3 (4%)
Source distance from household (m)	
0-100	23 (30%)
100-500	47 (63%)
>500	5 (7%)
Method used to fetch water from the source	
Deeping into it with a container	72 (96%)
hand pump	3 (4%)
Do you pay water	
Yes	3 (4%)
No	72 (96%)
Who fetch the water for the household	
Female adults	69 (53%)
Children	58 (46%)
Male adults	2 (1%)
Both	0 (0%)
Congestion period	
Morning	7 (9%)
Morning-Evening	37 (51%)
Evening	24 (33%)
Never	5 (7%)
Water storage duration	
Few hours	1 (2%)
1 day	31(46%)
2 days	32 (48%)
≥3 days	3(4%)

Knowledge and Prevalence of Waterborne Diseases

Waterborne diseases are recurrent in households in the city of Bibémi, with a prevalence of 57% for the six months preceding the study. Among these are cholera (9%), typhoid (8%), diarrhea (40%). According to the surveyed population, these diseases are caused by the

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consumption of poor quality water, food, teething and witchcraft.

Relationship between Observations Made on Water Points and Environmental Variables

Multiple correspondence analysis (MCA) made it possible to determine the link between the various observations made on water points (Figure 9) to identify the environmental variables that explain water contamination by *V. cholerae*. According to dimension 1, surface water (S2. A) of mayo-Barka is too far from habitats, marked by the presence of algae, this source is for domestic use. The other surface waters (S2. Av, S1. A, S2.M, S1.M) are close to habitats and are exposed to human and animal pollution. These waters are for household and drinking use. The different mayo-Barka sampling points (S2. A, S2.M and S2. Av) revealed the presence of *V. cholerae*. Dimension 2 shows that the groundwater, notably the wells (P1 and P3) of 5 Plaques, P5 of Ourokari, P7 and P8 of Chantier, P6 of Sodecoton and P2 of Wadjiri are very close to the dwellings. These water points face human pollution. On the opposite side we have the borehole which is very far from the dwellings and which is characterized by the absence of a nearby source of fecal pollution.

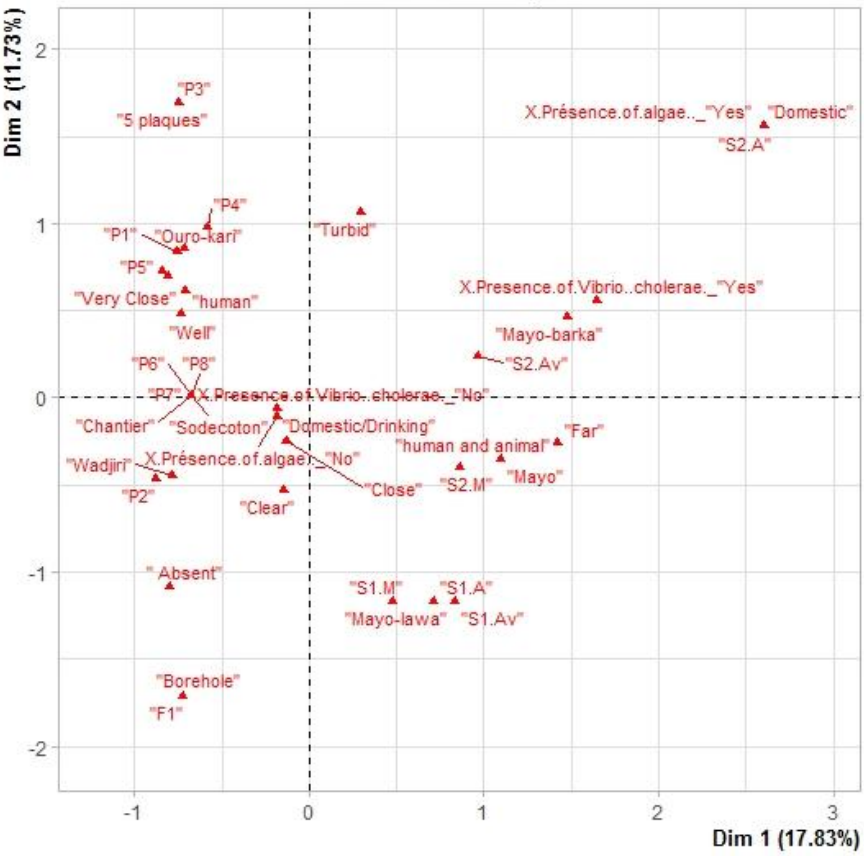

Figure 9: Graph of the Multiple Correspondence Analysis (MCA) of the different sampling points

Relationship between Risk Factors of Water Contamination and Cholera Transmission

Unlike MCA, which focuses on individual variables, Multiple Factor Analysis (MFA) compares groups of defined variables on the same set of individuals. The variables were therefore grouped into the classes: Demographic data, Water sources, transport and storage of water, water-borne diseases, sanitation, hygiene and observations made by the interviewers during the survey. This method has the advantage of extending to both quantitative and qualitative variables.

The groups of variables corresponding to the highest contributions relating to the construction of the first factorial axis are: sanitation, observations of the interviewers and hygiene (Figure 10). The first factorial axis represents the contribution of sanitation, hygiene and the observations of the interviewers in the definition of strategies to fight against cholera. The success of such strategies requires awareness raising on the respect of hygiene measures, sanitation and the improvement of the living environment reported by the interviewers. The second axis is naturally interpreted as being the axis of water management and demographic data. Indeed, the strongest contribution relative to this second axis refers to the variables of this group, which of course reflects a fundamental condition in the success of the fight against cholera.

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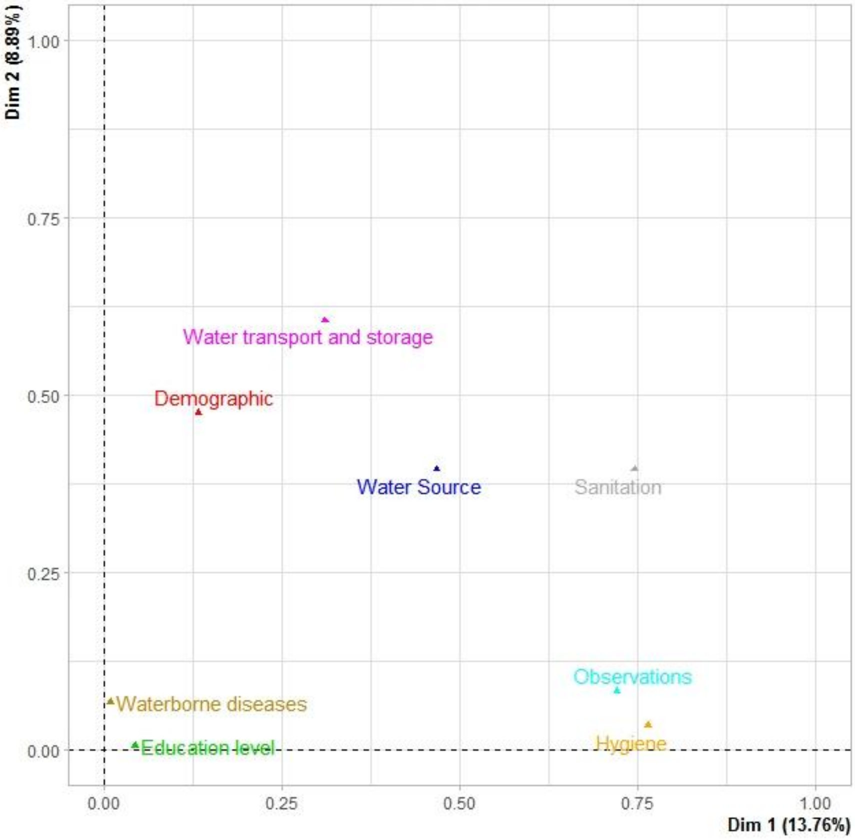

Figure 10: Grouping of cholera risk factors in Bibémi

IV. DISCUSSION

Water Reservoirs of V. cholerae

V. cholerae has been isolated in the waters of mayo-Barka from upstream to downstream. However, this bacterium was not isolated from the waters of mayo-Lawa and from the groundwater of the same city. The detection of these reservoirs of *V. cholerae* would represent a substantial contribution to the epidemiology of cholera in the region of North Cameroon. According to Nganou Donkeng *et al*. [8], the presence of *Vibrio* species in the lakes of North Cameroon is the result of contamination of the water. The contamination of surface water by *V. cholerae* could be explained by faecal pollution from the watershed [18]. The absence of *V. cholerae* at the other sampling sites could be explained by the changes in environmental conditions, in other words *V. cholerae* would be found in a VNC form and in association with other aquatic organisms [5]. This result corroborates the findings of Djaouda *et al*. [19]. However, borehole water trapped in the depths, cut off from any obvious interaction with the external environment, is less favorable to microbial contamination. The absence of *V. cholerae* in borehole water could be explained by the absence of faecal contamination.

Physico-chemical Characteristics of the Studied Hydrosystems

Water temperatures close to 30°C with slight variations were noted in the mayo, wells and boreholes. The water temperature values recorded for all the studied hydrosystems are above the 25°C limit prescribed in the WHO standards for drinking water. The relatively higher water temperature could be explained by the combination of several factors such as, the sampling period, the season, the sunshine and the depth of the water [19]. These high values favors the microbial development in the aquatic ecosystem.

The water pH at the different sampling points varied from acidic to basic. The slightly acidic nature of the water at some sampling points is linked to the geological nature of the aquifer [19]. Water sources which presented basic water pH were close to human habitation and therefore more exposed to anthropogenic activities. The work of Bakouan *et al*. [18] pointed out that pollution around the water source causes a change in the pH and the action of microorganisms in the water. The water pH in the mayo-Barka was between 7 and 9.5, values for which the increase in the number of *V. cholerae* is optimal [20].

Most of the TDS levels at the sampling points were below 500 mg/L, which complies with the standards recommended by the WHO [21] for drinking water. The

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P3 and P8 sites, however, presented values greater than 500 mg/L. Studies by Djaouda *et al*. [22] revealed that the high TDS levels in open wells are due to the presence of dissolved matter from decomposing organic matter. These high values in these sampling points would come from the impact of human activities, rainwater can cause an excess of minerals by bringing degradable organic matter to these sites. The high values of TDS recorded in surface waters, and even more in mayo-Barka compared to mayo-Lawa, could be explained by strong anthropic activity, the presence of animal faeces, the vegetation around the site.

The salinity of the sampled waters showed a great variation depending on the different sampling points. The high salinity values recorded in wells P3 and P5 are linked to an interaction resulting from the contact between the waters and the rock which contains them [23]. However, the high value recorded in mayo-Barka would be linked to the nature of the soil and the abundance of anthropogenic activities around the site. Studies by Antarpreet *et al*. [24] found that when the salinity of fresh water increases, it promotes the growth of *V. cholerae.*

As in the case of salinity, the relatively high values of the electrical conductivity in sites P3 and P8 compared to the other wells could be explained by the presence of mineral contaminants resulting from the degradation of water quality [19]. Regarding the surface water, the high values recorded in mayo-Barka compared to mayo-Lawa would be associated to mineralization of organic matter of various origins [22]. According to Anwar *et al*. [20] an increase in the electrical conductivity of drinking water contaminated with *V. cholerae* is strongly correlated with an increased risk of cholera epidemics.

Bacteriological Quality of the Analyzed Water Samples

The low abundances of total coliforms in the borehole water (0UFC/100mL) and some wells could be explained by distant sources of pollution, the magnitude of which depends on the distance from the sampling site, the depth and the nature of host rocks [25]. The relatively high abundance of total coliforms in wells P1 and P2 would be due to the presence of faecal or organic wastes, the discharge of wastewater near sampling sites, proximity to latrines and topography of the soil [26]. The high abundance of total coliforms in the waters of mayo-Lawa would be linked to the dumping of household waste in this mayo.

Risk Factors of Water Contamination and Cholera Transmission

The high number of people (on average 7 per household) in the households would reflect the populous nature of the study area and the non-compliance with family planning standards. These results correspond to African families made up mainly of women and children. However, this mass of the population suffers from a lack of education with a limited level of education, most of them in primary school. Nsagha *et al*. [27] have shown that vulnerability to cholera is linked to the low level of education of the population and the high number of people per household is an important factor in the transmission of diseases.

According to the survey results, only 31% of respondents wash their hands with soap. In addition to the 8% of households that do not have latrines and whose inhabitants claimed to defecate open field, 11% also defecate at the vicinity of their homes when their latrines are unavailable. Only 5% of the surveyed households have septic tanks where domestic wastewater is discharged. Failure to comply with hygienic rules in households could increase the risk of cholera epidemics in the Bibémi locality. Open-field defecation could be the source of faecal contamination of water sources and one of the causes of the resurgence of cholera outbreaks in this area. This result confirms the observations of Ndié *et al*. [11] according to which the resurgence of cholera outbreaks in the North Cameroon region is linked to the poor access of populations to drinking water, the low use of latrines, promiscuity and some traditional practices.

The low proportion of the population to get access to paid improved water sources is explained by the poverty observed in some households and increases the risk of cholera epidemics. Indeed, the city of Bibémi is in one of the regions with a high level of poverty in Cameroon with dilapidated or non-existent infrastructures of drinking water production. Studies on the etiology of cholera in Africa have shown that populations affected by cholera are those who do not have enough water for drinking and household chores [28]. Thus, the crowding of the population on the same water point observed in this study would reflect an insufficiency of the water points of consumption in this locality. In addition, the absence of a water management committee would indicate poor local organization to deal with the shortage of drinking water. This should be a good indicator of a capacity for self-organization of the population if collective action is considered for improving access to sanitation and drinking water. Regarding the water storage method, many people store water for a long period (24 to 48 hours) in households. This habitude would be linked to the culture and the low availability of water resources which require making reserves. Not disinfecting water storage containers before filling them could favor the installation of certain microorganisms in biofilms on the container walls and increase the risk of transmission of water-borne diseases [19]. These results are consistent with those of the Bibémi township [13]. The borehole water is very little used by the population. This could be explained by the ease of access to water from the mayos and wells on the one hand, and the poverty that limits the installation of taps and boreholes in households, on the other hand. Most people collect water in the morning and in the evening to go about their daily activities (school, administrative work, trade, farming, field, etc.) and during rest hours (after classes or work). These times of the day would be most appropriate when considering an awareness campaign regarding the quality of drinking water sources in the city.

Inhabitants of Bibémi with their low level of education also have a precarious knowledge of water-borne diseases. Although they are warned that drinking poor quality water can cause waterborne illness, they neither know the quality of the water they consume nor the factors that could degrade its quality. According to ACF [29], the conditions and lifestyles of population associated with the problem of access to drinking water and non-compliance with hygiene rules significantly affect the onset of water-borne diseases in households [29].

V. CONCLUSION

The aim of this study was to identify the aquatic reservoirs of *V. cholerae* and the transmission factors of cholera to contribute to the strengthening of cholera surveillance strategies. The results of this study highlighted the presence of *V. cholerae* in surface waters, more precisely on the bed of mayo-Barka. This finding highlights the existence of a *V. cholerae* water reservoir in the town of Bibémi. The results of the household survey report that the rejection of human faeces near water points, the rejection in receiving environments of waste water without prior treatment, the non-respect of hygiene rules and the poor water storage conditions would have a major impact on the contamination of water points and the transmission of cholera. The results obtained during this study allow us to make some recommendations to reinforce cholera prevention and control strategies.

To public authorities, we recommend:

- Establishing a real policy aimed at extending the public distribution network of drinking water and boreholes in the neighborhoods of Bibémi;
- Ensuring the sanitation of the city of Bibémi by creating public latrines and setting up a system for collecting and treating household wastewater.

To the population, we recommend:

- Avoiding dumping human wastes into waterways;
- Treating well and borehole waters with chlorine before any household use and store it away from any source of secondary contamination.

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REFERENCES

[1] WHO (2017). Weekly epidemiological records. *WHO*, *92* (34), 477-500. Available at: https://www.who.int/wer/2017/wer9234/en/

[2] Assogba A. L. *et al.* (2012). L'initiative contre les maladies diarrhéiques et entériques en Afrique: une contribution à la lutte contre le choléra. *Médecine d'Afrique Noire, 5* (5), 251-257.

[3] Debes A. (2015). *Assessment of efficient and sustainable tools for cholera detection and intervention in low resource settings. PhD dissertation*, Johns Hopkins University, Baltimore, USA, pp. 167.

[4] Baron, S., Lesne, J., Moore, S., Rossignol, E., Rebaudet, S., Gazin, P., Barrais, R., Magloire, R., Boncy, J., & Piarroux, R. (2013). No Evidence of Significant Levels of Toxigenic V. cholerae O1 in the Haitian Aquatic Environment During the 2012 Rainy Season. *PLoS Currents*. https://doi.org/10.1371/currents.outbreaks.7735b392bdcb749baf5812d2096d331e

[5] Tshwane University of Technology South Africa, Momba, M., Azab El-Liethy, M., & Tshwane University of Technology South Africa. (2019). Vibrio cholerae and Cholera biotypes. In Michigan State University, J. Rose, B. Jiménez-Cisneros, & UNESCO - International Hydrological Programme (Eds.), *Global Water Pathogen Project*. Michigan State University. https://doi.org/10.14321/waterpathogens.28

[6] Guévart E. *et al.* (2006). Déterminants du choléra à Douala. *Médecine Tropicale*, *66*, 283-291. Avilable at: https://www.jle.com/fr/MedSanteTrop/2006/66.3/283-291%20D%C3%A9terminants%20du%20ch%20o%20l%20%C3%A9%20ra%20%C3%A0%20Douala%20(Guevart).pdf

[7] Akoachere, J.-F. T. K., Masalla, T. N., & Njom, H. A. (2013). Multi-drug resistant toxigenic Vibrio cholerae O1 is persistent in water sources in New Bell-Douala, Cameroon. *BMC Infectious Diseases*, *13*(1), 366. https://doi.org/10.1186/1471-2334-13-366

[8] Donkeng. (2011). Characterization of the bacterial flora of tilapia (Oreochoromis niloticus) harvested from four lakes in the north of Cameroon. *African Journal of Biotechnology*, *10*(71), 16016- 16023. https://doi.org/10.5897/AJB10.1491

[9] Gwenzi, W., & Sanganyado, E. (2019). Recurrent Cholera Outbreaks in Sub-Saharan Africa: Moving beyond Epidemiology to Understand the Environmental Reservoirs and Drivers. *Challenges*, *10*(1), 1. https://doi.org/10.3390/challe10010001

[10] Gwenzi, W., & Sanganyado, E. (2019). Recurrent Cholera Outbreaks in Sub-Saharan Africa: Moving beyond Epidemiology to Understand the Environmental Reservoirs and Drivers. *Challenges*, *10*(1), 1. https://doi.org/10.3390/challe10010001

[11] Ndié, J., Bayoro, I., Takoukam, I., & Wina, P. (2016). Étude Des Aspects Épidémiologiques Du Choléra Dans Le District De Santé De Tcholliré (Nord-Cameroun). *European Scientific Journal, ESJ*, *12*(15), 278. https://doi.org/10.19044/esj.2016.v12n15p278

[12] Ngwa, M. C., Liang, S., Kracalik, I. T., Morris, L., Blackburn, J. K., Mbam, L. M., Ba Pouth, S. F. B.,

ISSN: 2349-8889
Volume-7, Issue-4 (July 2020)
https://doi.org/10.31033/ijrasb.7.4.9

Teboh, A., Yang, Y., Arabi, M., Sugimoto, J. D., & Morris, J. G. (2016). Cholera in Cameroon, 2000-2012: Spatial and Temporal Analysis at the Operational (Health District) and Sub Climate Levels. *PLOS Neglected Tropical Diseases*, *10*(11), e0005105. https://doi.org/10.1371/journal.pntd.0005105

[13] Commune de Bibémi (2014). Plan Communal de Développement de Bibémi. Available at: https://www.pndp.org

[14] APHA (2012). *Standard Methods for the Examination of Water and Wastewater (22nd edn).* American Public Health Association/American Water Works Association/Water Environment Federation: Washington, DC, USA.

[15] M S Islam, M K Hasan, M A Miah, M Yunus, K Zaman, and M J Albert. (1994). Isolation of Vibrio cholerae O139 synonym Bengal from the aquatic environment in Bangladesh: implications for disease transmission. *Appl Environ Microbiol*, *60*(5), 1684–1686.

[16] Louis, V. R., Russek-Cohen, E., Choopun, N., Rivera, I. N. G., Gangle, B., Jiang, S. C., Rubin, A., Patz, J. A., Huq, A., & Colwell, R. R. (2003). Predictability of Vibrio cholerae in Chesapeake Bay. *Applied and Environmental Microbiology*, *69*(5), 2773–2785. https://doi.org/10.1128/AEM.69.5.2773-2785.2003

[17] Holt JG. *et al*. (2000). *Bergey's Manual of Determinative Bacteriology (9th edn).* Lippincott Williams and Wilkins: Philadelphia.

[18] Corneille Bakouan, Boubié Guel, Anne-Lise Hantson. (2017). Caractérisation physico-chimique des eaux des forages des villages de Tanlili etLilgomdé dans la région Nord du Burkina Faso - Corrélation entreles paramètres physico-chimiques. *Afrique Science*, *13*(6), 325 - 337.

[19] Djaouda, M., Lecke, A., Maine, M. K., Wadoube, Z., Liang, S., Nola, M., & Njine, T. (2018). Assessment of bacteriological quality of groundwater from boreholes in Maroua (Far North Cameroon). *International Journal of Biological and Chemical Sciences*, *12*(2), 958. https://doi.org/10.4314/ijbcs.v12i2.26

[20] Huq, A., Sack, R. B., Nizam, A., Longini, I. M., Nair, G. B., Ali, A., Morris, J. G., Khan, M. N. H., Siddique, A. K., Yunus, M., Albert, M. J., Sack, D. A., & Colwell, R. R. (2005). Critical Factors Influencing the Occurrence of Vibrio cholerae in the Environment of Bangladesh. *Applied and Environmental Microbiology*, *71*(8), 4645–4654. https://doi.org/10.1128/AEM.71.8.4645-4654.2005

[21] WHO. (1996). *Total dissolved solids in drinking-water: background documents for development of WHO Guidelines for drinking-water quality*. WHO, Geneva.

[22] Djaouda, M., Njiné, T., Liang, S., Ebang Menye, D., Gaké, B., Zébazé Togouet, S. H., & Nola, M. (2014). Bacteriological Quality of Well Waters in Garoua, North Cameroon. *Water Quality, Exposure and Health*, *6*(4), 161–176. https://doi.org/10.1007/s12403-014-0120-z

[23] Monjerezi, M., & Ngongondo, C. (2012). Quality of Groundwater Resources in Chikhwawa, Lower Shire Valley, Malawi. *Water Quality, Exposure and Health*, *4*(1), 39–53. https://doi.org/10.1007/s12403-012-0064-0

[24] Huq, A., Hasan, N., Akanda, A., Whitcombe, E., Colwell, R., Haley, B., Alam, M., Jutla, A., & Sack, R. B. (2013). Environmental Factors Influencing Epidemic Cholera. *The American Journal of Tropical Medicine and Hygiene*, *89*(3), 597–607. https://doi.org/10.4269/ajtmh.12-0721

[25] Islam, M. S., Mahmud, Z. H., Islam, M. S., Saha, G. C., Zahid, A., Ali, A. Z., Hassan, M. Q., Islam, K., Jahan, H., Hossain, Y., Hasan, M. M., Cairncross, S., Carter, R., Luby, S. P., Cravioto, A., Endtz, H. Ph., Faruque, S. M., & Clemens, J. D. (2016). Safe distances between groundwater-based water wells and pit latrines at different hydrogeological conditions in the Ganges Atrai floodplains of Bangladesh. *Journal of Health, Population and Nutrition*, *35*(1), 26. https://doi.org/10.1186/s41043-016-0063-z

[26] Olatunde, S. K., & Ayandele, A. A. (2018). Microbiological and physico-chemical analyses of hand dug well-water near pit latrine in a rural Area of Western Nigeria. *African Journal of Environmental Science and Technology*, *12*(4), 132–140. https://doi.org/10.5897/AJEST2017.2463

[27] Nsagha, D. S., Atashili, J., Fon, P. N., Tanue, E. A., Ayima, C. W., & Kibu, O. D. (2015). Assessing the risk factors of cholera epidemic in the Buea Health District of Cameroon. *BMC Public Health*, *15*(1), 1128. https://doi.org/10.1186/s12889-015-2485-8

[28] Janny T. (2004). *Epidémies de choléra en Afrique: Analyse d'une étiologie multifactorielle, Mémoire de l'Ecole Nationale de la Santé publique (ENSP)*, Rennes, FRANCE, pp. 59.

[29] ACF. (2006). *Eau Assainissement Hygiène pour les populations à risque. (2ème edition)*. Hermann, PARIS, pp. 785.