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Research Paper

Faecal Contamination of Well Water in Garoua (Cameroon): Importance of Household Storage and Sanitary Hygiene

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Abstract - *A study was carried out in the Garoua region (Cameroon, Central Africa) in order to assess the faecal contamination of well water and stored well water samples in relation with sanitary hygiene. Data were collected from wells and household -stored well water. A survey had been conducted at same period to assess hygienic behaviors of the population using well water. Bacteriological analyses were performed using Membrane Filtration and Plate Count techniques. It was noted that the abundance of Heterotrophic Aerobic and Mesophilic Bacteria (HAMB) ranged from 1.2×10^3 to 7.3×10^4 CFU·mL^{-1}. The number of faecal coliforms varied from 1.3×10^2 to 7.0×10^3 CFU·100 mL^{-1} in sampled wells water. For staphylococci, abundances varied between 5.0×10^1 and 2.1×10^3 CFU.100 mL^{-1} in well water samples. The lower abundance of Enterobacteriaceae was 1.5×10^3 and the higher $2.2\text{x}10^4$ CFU.100 mL^{-1} in well water samples. The pH values of well waters were between 4.4 and 8.1. For the well water samples, the values of electrical conductivity (EC) were between 81.5 and 2180.0 µS·cm^{-1}. The concentrations of TDS fluctuated between 60.1 to 1530.0 mg·L^{-1} in water samples. The salinity of water ranged from 42.3 to 1100.0 ppm. Variations in bacterial abundances were significantly in the opposite direction of electrical conductivity, salinity and TDS concentrations ($p<0.05$ and $p<0.01$). However, there was no significant correlation between staphylococci abundances and salinity / TDS concentrations ($p>0.05$). During water storage, there was increase in bacterial abundance due to storage conditions, physicochemical properties of water and poor hygiene. The results highlight the need of well water treatment and safe storage as well as sanitary hygiene improvement to reduce waterborne diseases in the region.*

Keywords: bacterial contamination, hygiene,storage, well water etc.

Introduction

Safe drinking water is essential for human life maintenance. Unsafe water is responsible for many waterborne diseases. The sanitary risks in mean and long terms are related to physicochemical characteristics of water whereas in the short term it is related to the microbiological quality of water [1]. Waterborne diseases are among the major causes of mortality in developing countries. Diarrheal diseases represent 4.2% of the global burden of diseases [2]. Published data on the burden of diseases in Cameroon shows that diarrheal diseases (commonly due to fecal contamination of water) cause 15% to 20% of all deaths in the country, annually [3].

Many studies in south-Cameroon revealed significant bacteriological contamination of underground water consumed by poor communities. This water often contains pathogenic microorganisms and bacterial indicators of fecal water contamination. According to [4,5], bacterial distribution in underground water undergoes spatio-temporal fluctuations and it is influenced by physico-chemical and meteorological factors. The chemical characteristics of the environment, such as pH, ionic strength, mineral elements and the nature of solid particles play a major role in bacterial distributions. This role may vary with bacterial species [6,7].

According to [5], underground water of the South region of Cameroon is acidic, soft, slightly bicarbonate with a low to average level of mineralization. It harbors great faecal bacterial communities. The underground water quality at the point-of-use has also been assessed to better determine health risks observed in this part of Cameroon. The abundance of heterotrophic, aerobic and mesophilic bacteria increased considerably at the end of 144 hours of underground water storage at home conditions in Yaoundé [8-9].

Waterborne diseases occur every year in rural and urban areas in north-regions of Cameroon. Diarrheal diseases due to *Escherichia coli*, *Salmonella* and *Shigella* are almost endemic in this region. Epidemiological data show the highest incidence (25.3% of prevalence) of gastroenteritis in the northern region of Cameroon [3]. In addition, during the rainy season of the year 2010, there was an epidemic of cholera in this part of the country. The traditional latrine practices and the lack of waste water treatment by these communities may constitute the major factors of contamination of wells. Consequently spreading and transmission of waterborne diseases should therefore be due to the concentration of people in anarchic urbanization, poor hygiene, poverty and the lack of safe drinking water [10]. [3] Indicated that diarrheal diseases prevalence lowers with drinking water quality.

According to report of the Ministry of Public Health, this epidemic recorded about 9447 cases and 602 deaths. Unfortunately, north region with its safe drinking water made available only to urban residential areas lacks even the least basic data on drinking water quality and related sanitary risks, due to poverty, illiteracy and climate variation, despite its vulnerability. Thus, traditional water points (wells) are widely used by poor communities which only evaluate water quality by subjective criteria such as odor and color. Considering the epidemiological survey reporting many victims of waterborne diseases in the north-Cameroon in general and the Garoua region in particular, faecal contamination of well water and its relationships with environmental factors (sanitary hygiene and storage conditions) were assessed, aiming to contribute to the setting up of strategies to control well water pollution and improve the public health.

Material and Methods

Study site

The Garoua region is located at latitude 9°18' north and longitude 13°24' east. It is made up of heterogenic soils [11]. It is characterized by a tropical climate with a long dry season (October to April) and a short rainy season (May to September) [12]. Generally, rainfalls do not exceed 985 mm in the year. The temperature values show wide fluctuations (minimum value around 18°C in January and maximum value about 42°C in March) [12]. The map of the study site indicating various districts of Garoua region and sample sites is presented in Fig.1.

Behaviors of population of Garoua

A survey was conducted to assess hygienic behaviors of population using well water in Garoua. The residents selected for this survey were those who gave consents to participate after being informed about the purpose of the study. A well-structured questionnaire was designed to collect information on water utilization, water handling and storage. Allocation of questionnaire was based on the population of each area and 50 households per area were selected. A total of 600 households were selected. The selected families met predefined criteria, such as low family income, consumers of well water, had been defecating in open or unhygienic latrines, among others.

Water Sampling

Eight well water points were selected in the various areas of the Garoua region based on their spatial distribution and their relative importance to the population. Water samples were collected at each water point. Samples meant for the physico-chemical analysis were collected in cleaned plastic bottles while those for bacteriological analyses were collected in sterile glass bottles. Replicates of well water samples were also collected from different containers at the households' level to assess impact of storage (for 24 to 36 hours) conditions in each area during dry season (between October 2010 and April 2011). Since it was important to collect paired samples, testing the same water at storage and supply levels, if a storage sample could not be collected within 24 to 36 hours, no new sample was taken. All the samples were transported to the laboratory according to the procedure described by [13]. Except the can, all the containers used to store water have large opening and water is extracted by the scooping of water with a cup and cannot avoid hand entry. The can has a spout and a handle to facilitate pouring. Can, bucket and barrel are plastic made containers. Pot is constituted of clay. Bucket is the more mouthed container. Water from all types of containers was poured directly into the sample bottles without use of a funnel or other devices.

Bacteriological analysis

The water quality parameters determined include total bacteria count, faecal coliform, Enterobacteriacea and staphylococci counts. These analyses were performed using standard methods for water analysis [14]. The isolation of faecal coliforms (F.C.), Enterobacteriacea (Entero.) and staphylococci (Staph.) was carried out using the membrane filtration technique using the Endo, Hektoen and Chapman agar culture media respectively [15]. The spread plate technique was used for the isolation and enumeration of heterotrophic, aerobic and mesophilic bacteria (AMHB) by using the standard Agar medium [15]. Results were expressed as the number of colony forming units (CFU)/volume of water.

Physico-chemical analysis

The main physico-chemical parameters considered were temperature, total dissolved solids (TDS), pH, electrical conductivity (EC) and salinity. These parameters were chosen in accordance with their general importance on bacterial metabolism and the availability of our laboratory equipments. These analyses were made using the techniques described by [13].

Data analysis

The spatio-temporal variations of the values of analyzed parameters were illustrated by diagrams. The relationships among the parameters were assessed. The SPSS program (12.0) was used.

Results

Behaviors of population of Garoua

Residents of Garoua who use well water in the 600 households responded and cooperated during this study. The average age of the respondent was 34.51. Well water is largely consumed for drinking purpose in many areas without any treatment. Clay pots (454/600: 75.7%) were major storage methods compared with plastic buckets (82/600: 13.7%), bottles and metallic containers (64/600: 10.7%). Over 83% of the respondents knew about the risk of biological contamination of the drinking water. However, only 51% stated that use of the well water without any treatment should expose them to waterborne diseases. Although respondents stated that they knew about treatment of water prior to use, 63% reported that they do not use treatment.

The investigation of latrines types and their use by respondents show three situations: closed latrines ("salka") are considered in the study region as a sanitary latrine and is widely used (73%); open latrines (25%) usually provide little or no privacy - they are very smelly and unpleasant; the worst situation (2%) was that of residents who defecated in open fields.

Physico-chemical parameters

The maximum, average and minimum values of the physico-chemical factors in Table 1 show that the pH values of well waters were between 4.43 and 8.09. For the well water samples, the values of electrical conductivity (EC) were between 81.50 and 2180.00 $\mu S \cdot cm^{-1}$. The concentrations of TDS fluctuated between 60.10 to 1530.00 $mg \cdot L^{-1}$ in water samples. The salinity of water ranged from 42.30 to 1100.00 ppm. The values of standard deviation indicated high variation between salinity, TDS and conductivity of water samples.

The results of the physico-chemical analysis show that water samples range from acidic to basic with low to high mineralization. The TDS and salinity of water samples also varied with water source.

The wells from Roumdé Adjia area had the highest pH value, a relatively higher salinity, TDS and also the highest electrical conductivity (Fig.2) whereas Ngalbidjé's wells had the lowest values of EC, salinity, TDS, and pH. The average values of pH had been obtained in Base Aérienne's well water samples. Although water samples collected from different containers at households level did not have the same physico-chemical characteristics as the well they have been taking from, they followed the tendency of the parent points.

Bacterial abundances

Abundances of each bacterial group are presented in Table 2. They indicate clear evidence of faecal water Contamination. The concentrations of Enterobacteriaceae, faecal coliform, HAMB and staphylococci vary from one well to another, with the highest values recorded at Ngalbidjé's well for the HAMB and Enterobacteriaceae (clay pot), at Roumdé Adjia's well for the faecal coliforms (plastic bucket) and staphylococci (clay pot) (Table 2).

The abundance of HAMB in well water samples ranged from 1.2×10^3 to 7.3×10^4 $CFU \cdot mL^{-1}$ (Table 2) and 2.4×10^3 to 2.6×10^5 $CFU \cdot mL^{-1}$ in stored wells water (Table 2). The number of faecal coliforms varied from 1.3×10^2 to 7.0×10^3 $CFU \cdot 100\ mL^{-1}$ in sampled wells water and from 4.0×10^1 to 1.6×10^4 $CFU \cdot 100\ mL^{-1}$ in stored wells water (Table 2). For staphylococci, abundances varied between 0 and $3.4x10^3$ CFU.100 mL^{-1} in stored conditions while they ranged from 5.0×10^1 to $2.1x10^3$ CFU.100 mL^{-1} in well water samples. The lower abundance of Enterobacteriaceae was 6.2×10^1 and the higher $3.7x10^4$ CFU.100 mL^{-1} in stored well water samples whereas they were respectively 1.5×10^3 and $2.2x10^4$ CFU.100 mL^{-1} in well water samples.

The Spearman correlation test was done using the data obtained from 51 samples collected from well and stored well water. All statistically significant correlations obtained were negative.

The results also show that the degree and the nature of the relationship between the abundance of each group of bacteria and the evolution of the concentration of each chemical parameter analyzed are heterogeneous (Table 3). The relationship between bacterial dynamics and the water salinity, TDS and EC appears to be related to local biotope (Table 3).

Discussion

These results show an increase in bacterial abundances during storage in households conditions. Several activities like transport and storage of water using unclean tools, scooping with contaminated hands in the container, manually cleaning vessels could be the means of increase in water contamination in households [16]. The bacteriological quality of these waters varies from one well point to another spatially (Table 2). These fluctuations were also observed by several authors in the study of groundwater quality in some parts of the city of Yaoundé [17]. They are likely to relate to differences in human population density, spatial fluctuations in physical properties of the soil of the region, as well as the variability of potential retention by the soil microorganisms.

The Spearman correlation test was done using the data obtained from 51 samples collected from well and stored well water. All statistically significant correlations obtained were negative. All biological systems are subject to environmental changes that may impair function. These are referred to as 'stress factors' and can operate at the level of ecosystems, individual organisms and molecular systems [18]. However, [19] found that increase in salt concentration in a medium at times can minimize the inhibition by irradiation of some bacterial species such as *Escherichia coli*. Although the pH does not seem to significantly affect the abundance dynamics of faecal coliforms, Enterobacteriaceae and HAMB in sampling sites (Table 3), it has been indicated the inhibition of microbial development by indirect influence of pH on the penetration into the microbial cell, by toxic compounds in the medium [20]. This indirect action of pH modifies the assimilation of different mineral or organic nutrients by the bacteria. The difference between the influences of environmental factors in the well biotope may result in a high and variable vulnerability in well water points with respect to human impact.

Most families collect well water and store it at home for drinking or household use; they often remove the water by dipping a cup in the opening of the storage container. Bacteria counts from the well and stored well water samples showed that most of the water samples were excessively contaminated (Table 3). Our study found that most of the well waters were unprotected and easily liable to contamination by human and excreta and other pollutants.

Conclusion

Our study revealed that populations who consume well water in the Garoua region are conscious of their own protection from waterborne diseases but ignorance and poverty compel them to adopt unhygienic behaviors. The wells in this region had poor hygienic quality due to their proximity to unhygienic latrines. Almost all the wells studied needed protection and upgrading for safe drinking and domestic water sources. Different levels of contamination using both the microbiological and chemical test were found in studied wells. Storage in households for further uses of well water increased the contamination. It is recommended that regular assessment of well water quality be undertaken to create awareness among communities and local authorities for further protection and upgrading of well water sources. Safe storage of well water after proper treatment should also be promoted.

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Table 1. Maximum, minimum and average values of physicochemical components in the various well water and stored well water samples.

	N	Minimum	Maximum	Mean	Std. Deviation
pH (UC)	51	4.43	8.09	6.86	0.83
Electrical conductivity (µS/cm)	51	81.50	2180.00	348.86	324.54
salinity (ppm)	51	42.30	1100.00	173.66	163.16
TDS (mg/L)	51	60.10	1530.00	245.72	227.00
Valid N (listwise)	51				

Table 2. Average bacterial abundances of sampled drinking water from different wells and Storage types.

Sample origin	Bacterial Abundances				Storage type
	HAMB (CFU. mL^{-1})	Enterobacteriaceae (CFU.100 mL^{-1})	Fecal Coliforms (CFU.100mL^{-1})	Staphylococci (CFU.100 mL^{-1})	
Base Aérienne	1210	1480	133	50	well
	2400	62	40	40	can
	28300	4200	790	35	Clay pot
	65000	800	110	205	Plastic bucket
	33000	82	76	0	barrel
Ngalbidjé	19500	14100	2300	730	well
	36000	19800	6900	760	can
	265000	37000	12200	216	Clay pot
	45000	16200	5300	255	Plastic bucket
	29700	11000	11600	245	barrel
Roumdé Adjia	73000	22200	7000	2100	well
	4800	7200	5300	570	can
	29700	21100	10400	3400	Clay pot
	38000	20100	16300	2500	Plastic bucket
	6800	2940	2500	800	barrel

Table 3. Spearman correlation coefficients between chemical parameters and abundances of faecal coliforms, HAMB, staphylococci and Enterobacteriaceae in stored and well sampled water.

	Enterobacteriaceae	Staphylococci	HAMB	Faecal coliforms
pH	0.045	0.029	-0.066	-0.069
Electrical conductivity	-0.598(**)	-0.362(*)	-0.401(**)	-0.266
Salinity	-0.598(**)	-0.160	-0.401(**)	-0.264
TDS	-0.577(*)	-0.249	-0.406(**)	-0.258

*= correlation is significant at the level 0.05
**= correlation is significant at the level 0.01

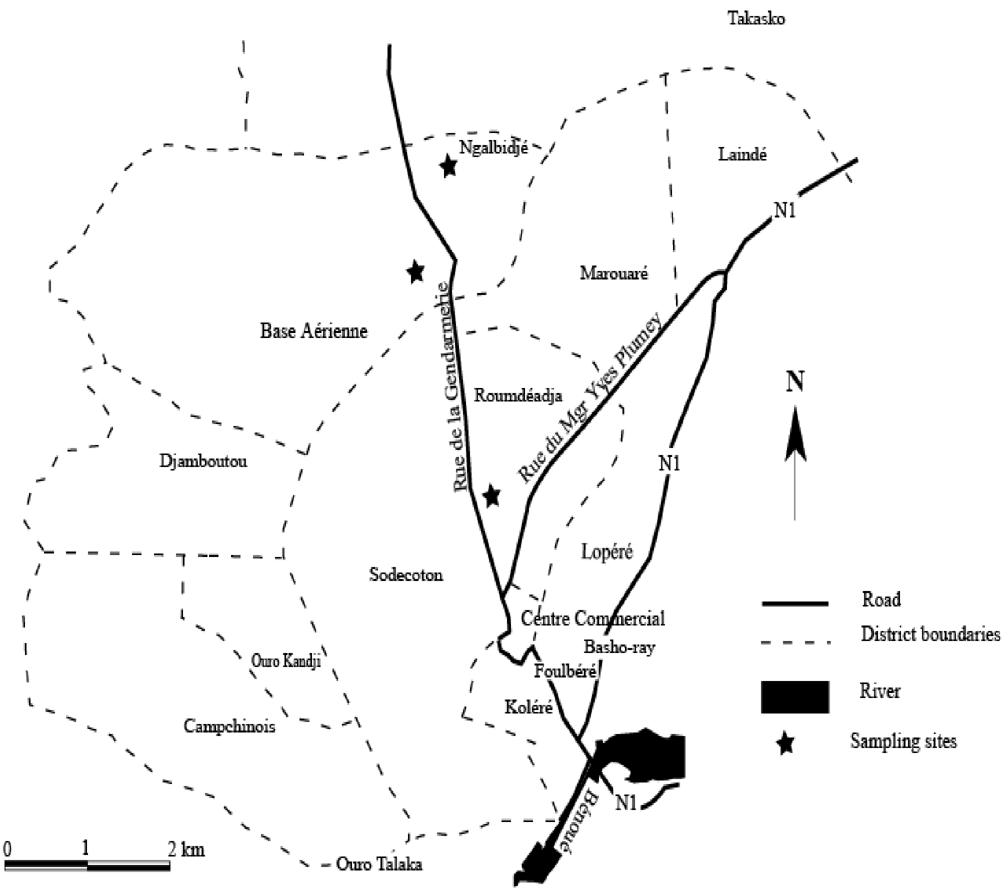

Figure. 1. Map of Garoua region showing the sampling sites

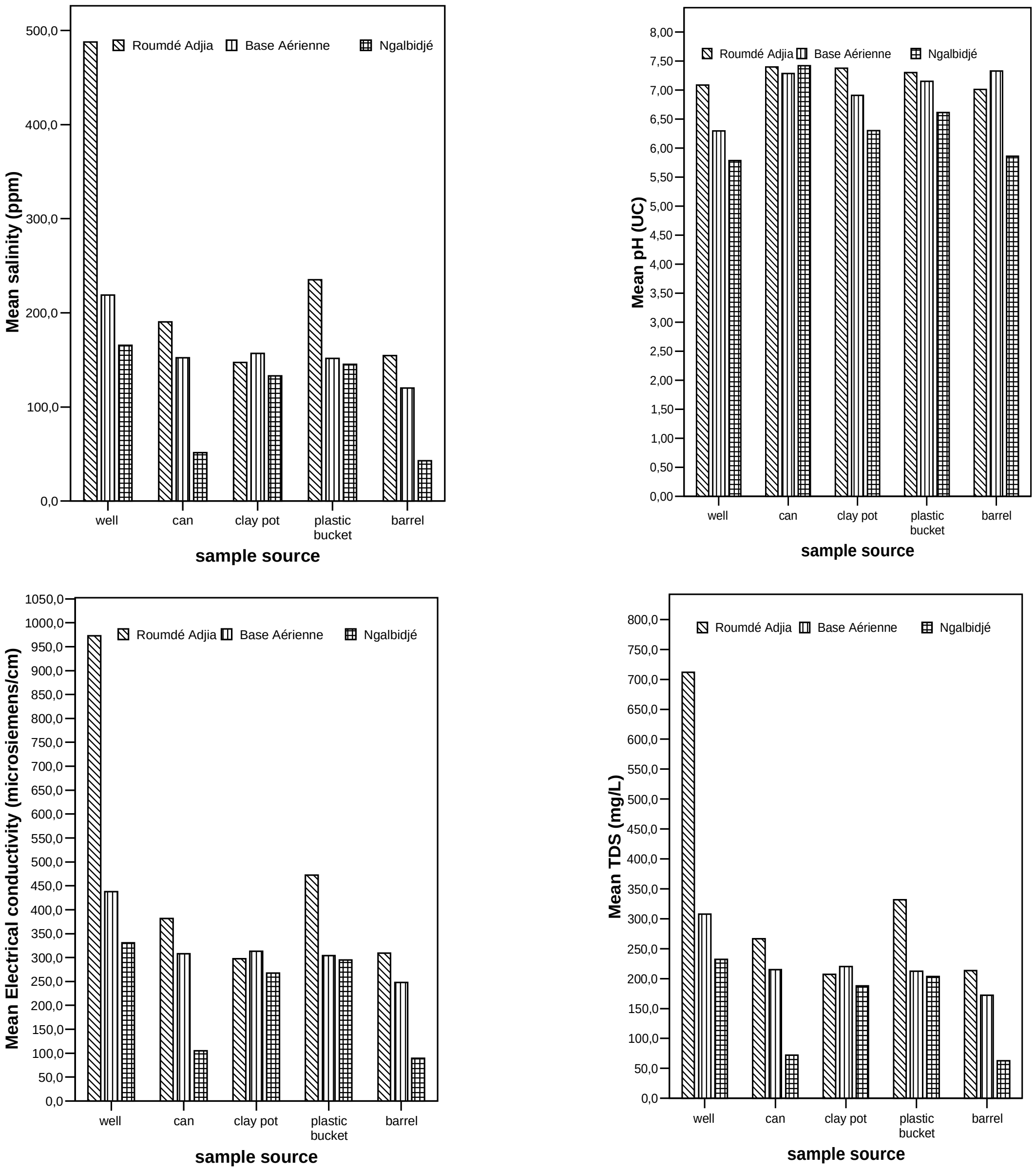

Figure 2. Values of physico-chemical parameters in analyzed wells and stored wells water samples.