Journal of Environmental Protection, 2011, 2, 620-628
doi:10.4236/jep.2011.25071 Published Online July 2011 (http://www.scirp.org/journal/jep)

Chemical and Bacteriological Analysis of Drinking Water from Alternative Sources in the Dschang Municipality, Cameroon

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Received February 28th, 2011; revised April 2nd, 2011; accepted May 9th, 2011.

ABSTRACT

In the poor zones of sub-Saharan Africa, the conventional drinking water network is very weak. The populations use alternative groundwater sources which are wells and springs. However, because of urbanization, the groundwater sources are degrading gradually making pure, safe, healthy and odourless drinking water a matter of deep concern. There are many pollutants in groundwater due to seepage of organic and inorganic pollutants, heavy metals, etc. Seventeen alternative water points created in 2008, for drinking water in Dschang municipality were examined for their physicochemical and bacteriological characteristics. The results revealed that water from managed points in Dschang is of poor quality. Most of the water samples were below or out of safety limits (standards) provided by WHO. The water is characterized by high turbidity and presence of feacal coliforms. It can be used for drinking and cooking only after prior treatment. This situation shows that water point management was limited only to the drawing up comfort. These water points require installation of suitable surfaces of filtration and the development of a chlorination follow-up plan. Specific concerns of well water were raised and the management options to be taken proposed.

Keywords: *Sub-Saharan Region, Alternative Water Assessing Point, Water Quality*

1. Introduction

From time immemorial, water assessment has always been a major concern. Today, the principal difficulty with which we are confronted is not so much access to water but more precisely the access to suitable water for drinking. Indeed the problem arises in terms of the quality of water resources and it is on this point that all the attention is focused, in Cameroon like elsewhere. Water can be the vehicle of a very high number of pathogenic agents voided into the external medium by the human or animal faeces and can thus be at the origin of many waterborne diseases. In 1996, WHO quantified to 4 billion, the number of diarrhea episodes which occurred in the world, and were responsible for the death of 3.1 million people of whom the large majority were children less than five years [1]. In the light of these figures, one realizes the importance of the problem of drinking water assessment and the capital need to seek solutions to improve the situation in this sector. In Cameroon, the rate of access to drinking water hardly reaches 32% [2]. The town of Dschang, like majority of the medium-sized cities in Cameroon, encounters enormous difficulties of access to drinking water. In a general way, the only one water supplier (CAMWATER) recognized by the State cannot satisfy the request of the increasing population. Thus, this population tries as it can to be supplied with water of very doubtful potability.

Many studies in African cities report that, wells, rivers and springs are ubiquitously used for water supply. For these points known as alternative sources (different from conventional network), the quality of water is not known and represents a considerable stake for the municipalities. No authority can authorize even less to invest for a water point of doubtful quality. The practices known as alternative are quite simply tolerated in the absence of being prohibited. Indeed, many neighbouring pit latrines are opened bottom and can create localised saturated flow conditions that imply great risks of using groundwater [3-5].

The standards only define, at a given moment, a level of acceptable risk for a given population. They depend in addition narrowly on scientific knowledge and the available techniques, in particular in health risks and the chemical analysis domains. They can thus be modified constantly according to made progress. Hence, all the countries do not follow the same standards. Some enact their own standards. Others adopt those advised by the World Health Organization (WHO). In Europe, standards are fixed by the European Communities Commission. Today, 63 parameters control the quality of the water for Europeans [6]. Groundwater is a valuable natural resource for various human activities [7]. Natural water always contains dissolved and suspended substances of organic and mineral origin. The pollution of groundwater is of major concern, firstly because of increasing utilization for human needs and secondly because of the ill effects of the increased industrial activity. High concentration of faecal pollutants in groundwater is a considerable health problem in several cities of the sub-Saharan region [5,8].

Regarding water sources that could be supplied for drinking supply in the region of greater urban Dschang there are over 3,000 discrete access points public and private plus additional sources such as bottled, river and rain water. Since 2003 the municipal administration of Dschang devoted considerable resources for development of the water supply and waste management infrastructure at Dschang in partnership with a variety of domestic and foreign non-profits. This municipal initiative has endured through two administrations and two generations of diagnostic study and constructive innovation spearheaded by the Cameroonian nonprofit making organization (NGO) Environment Research Action (ERA) in 2003, in collaboration with AIMF and the city of Nantes, France in 2005 [9].

The most recent generation of municipal development in urban Dschang's public water supply sector has been primarily concerned with the expansion of the capacity to deliver adequate *quantities* of water to a needy population, while the issue of water *quality* has been largely left for the individual to address. However, existing data on trends in public water use and perceptions of water quality reveals a distressingly low prevalence of home-based treatment by the individual. In addition, where treatment solutions are employed by the individual, the elevated level of contamination in the original public water supply often surpasses the effective capacity of the treatment options available [10].

An analysis of the potability of available drinking water has been synthesized from a body of over 200 microbial analyses describing 98 drinking water access points collected by five different studies [5,9,11-13] over the past seven years. These sources can be divided into nine distinct categories: unmanaged springs, treated tap water, managed springs, public wells, private wells, bottled water, rainwater, untreated tap water, and surface water.

- Wells include cased and uncased hand dug wells as well as boreholes/tube wells supplying populations, and may be equipped with hand pumps or bucket systems for drawing water.
- Managed springs is a category that comprises all constructed ground water capture systems, many of which incorporate slow sand filtration and piped delivery to public stand posts.
- Unmanaged springs include natural flowing springs and small hillside stream banks which may or may not have modest improvements such as cemented discharge points and outlet pipes.
- The surface water category includes larger rivers and streams.

Summarizing these studies, one notes the predominant reliance of the population on unmanaged and generally polluted water source. The categories of public wells and managed springs falling within the Dschang municipality reveal the extensive scope (approximately 30% of all consumption) of the city's role in supplying residents with drinking water. Following close behind comes the second largest single actor, CAMWATER with 23% of total consumption, a significant but largely inadequate figure considering CAMWATER's position as the sole provider of uniformly uncontaminated drinking water.

Water points managed by AIMF concern six (06) drillings, seven (07) wells and nine (09) managed springs.

So the present study was undertaken to assess the quality of water for 17 of the 22 AWAP of Dschang council where water is available. The sampling for water analysis was done in the month of July 2009 at various location viz. drillings, open wells, and managed springs from Dschang council in Cameroon.

2. Methods

During the field work, we made *in situ* measurement of the physical parameters (electric conductivity, Temperature and pH). We also described the environment of each point and when it was possible the water collecting technique was described. We sampled water for physico-chemical and bacteriological analyses (**Table 1**).

3. Results and discussion

Seventeen (17) water points were described and sampled for analysis. These points are shown on **Figures 1** and **2**.

3.1. Physicochemical Parameters and Cations in Studied Water

The results of these parameters in water of the Dschang council are presented in **Table 2**.

3.1.1. pH

The pH values were between 5.1 and 6.9; they excep-

Table 1. Types of apparatuses used, techniques of selected analyses and laboratories requested for the practical realization of work.

physico-chemical parameters	*Type of used apparatus*	*Analysis technique*	*Laboratory*
pH	Portatif SympHony SP80PD de VWR	Direct reading	In the field
conductivity	WTW LF318 portatif	Direct reading	In the field
Nitrates NO_3^-	Spectrophotometer DR2500 Hach	Cadmium Reduction Method	
DBO5	BodTrack^{TM} Hach	Respirometric Method, incubation at 20˚C during 5 days	Laboratoire de physiologie végétale
TDS			
DCO	Spectrophotometer DR2500 Hach	Reactor digestion	
Turbidity	Spectrophotometer DR2500 Hach	Photometric method	-//-
Faecal Coliforms	Culture on Petri boxes	With the lactosed gelose with the including TTC and tergitol and counting of the elements	Laboratoire de Biochimie
Faecal Streptococci	Filter membranes	Culture in Petri boxes (gelose to the bile, the esculine and the sodium acid) counting of the elements	
Chlore, bicarbonates, sulfates	Titration	Direct measurement	Laboratoire d'analyse des sols et de chimie de l'environnement (LASCE)
Na, K, Ca, Mg	Flame Photometer JENWAY PFP7	Direct reading	

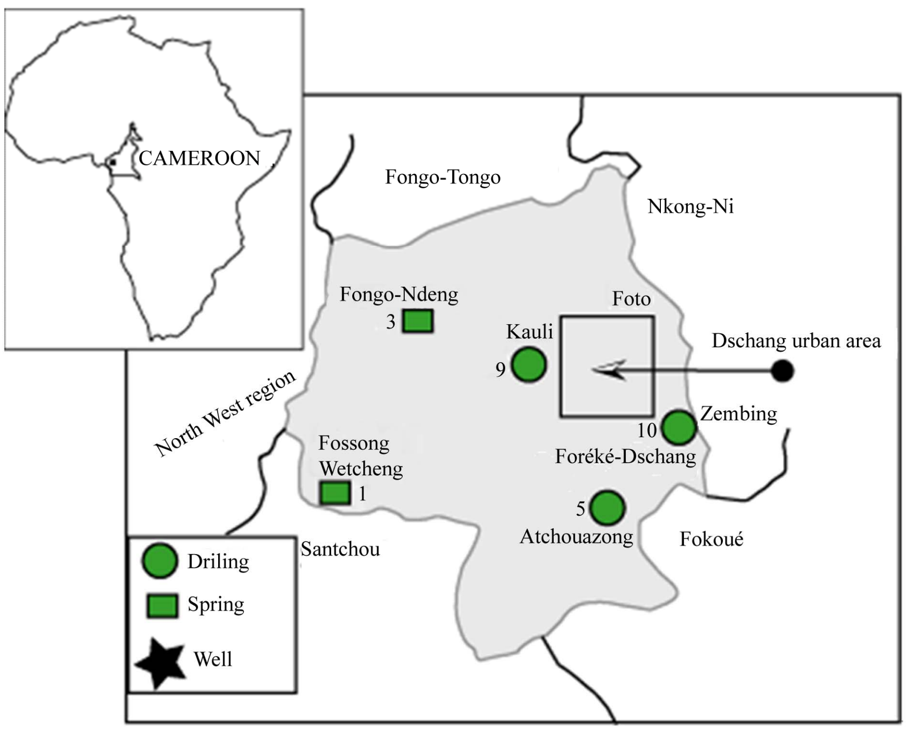

Figure 1. **Localization of the Dschang Council in the Western Region of Cameroon in Africa, and various Drinking Water Points managed by AIMF in the rural zone of Dschang and analyzed within the framework of this study. Source: Services techniques, Dschang council.**

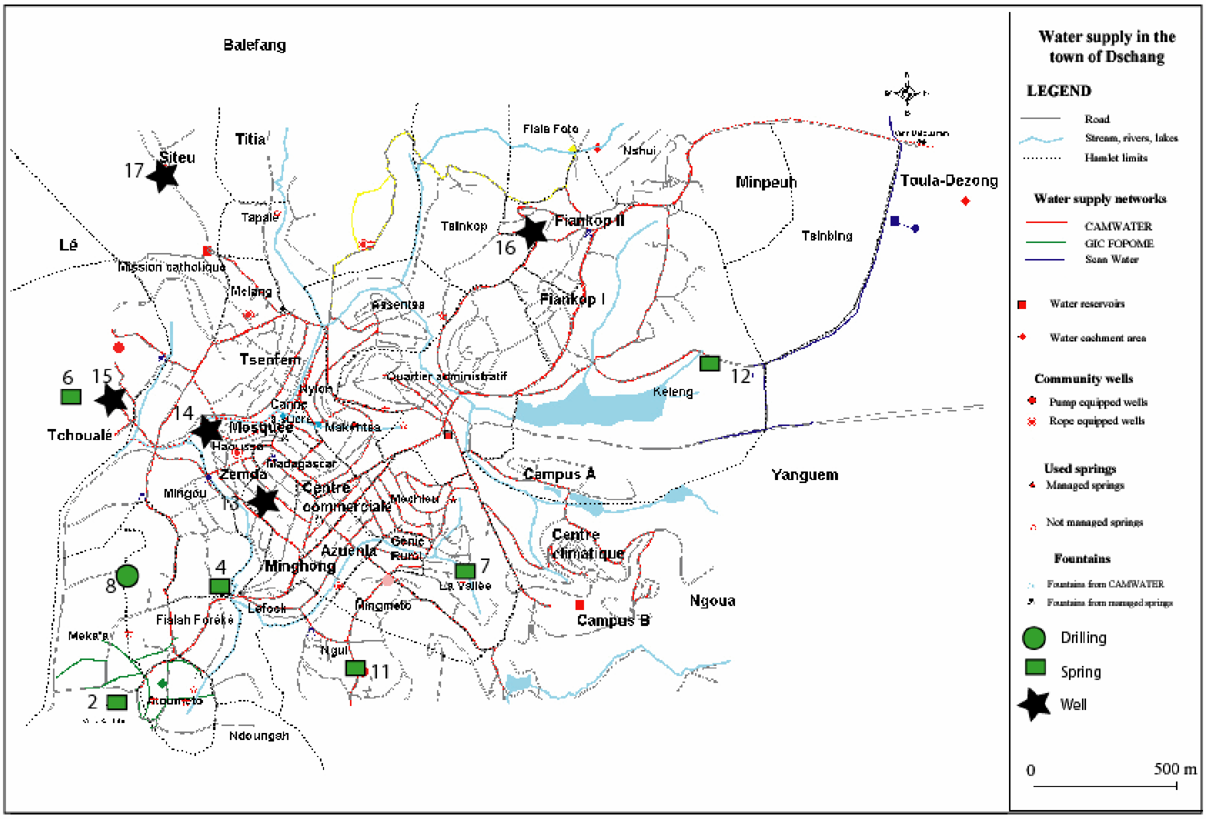

Figure 2. Localization of various Drinking Water Points managed by the AIMF in the town of Dschang and analyzed within the framework of this study; Source: Services techniques, Dschang municipality.

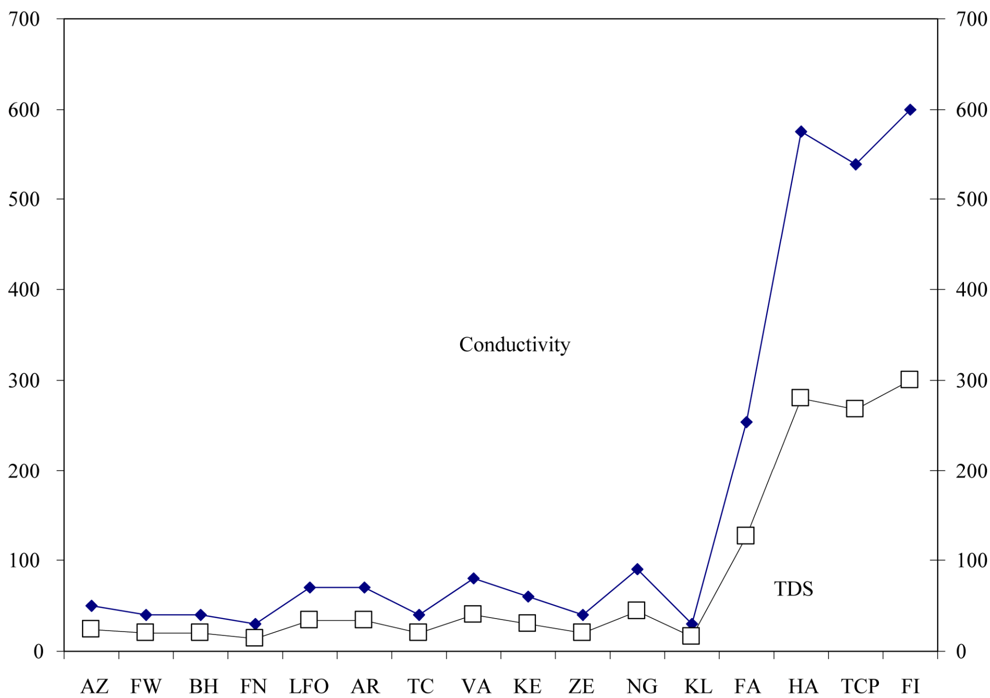

Figure 3. Showing 100% of correlation between conductivity and Total Dissolved Solid.

Table 2. Physicochemical parameters and cations in studied water.

	Water point	Type	*pH*	*Conductivity*	*Turbidity*	*TDS*	*Ca*	*Mg*	*K*	*Na*	SO_4^{2-}	Cl^-	HCO_3^-	NO_3^-
				microS/cm	FTU	mg/l								
1	Fossong Wentcheng	Spring	5.80	47	6	20	0.16	1.22	2.40	3.50	1.25	0	42.70	3.5
2	Busy Home	Spring	5.50	31	7	20	0.34	2.64	0.67	0.83	0.96	0	6.10	3.0
3	Fongo Ndeng	Spring	5.95	17	3	15	0.12	2.60	1.77	0.83	1.23	0	34.16	17.0
4	Lefock	Spring	5.26	81	0	35	0.36	1.56	2.61	8.54	1.23	1.9	21.35	3.5
5	Atchouazong	Spring	6.15	65	0	35	0.64	1.96	0.54	1.69	1.19	0	91.50	2.8
6	Tchouale	Spring	5.50	40	0	20	0.26	1.66	1.43	2.58	0.23	0	70.15	2.5
7	La Vallée	Spring	5.51	80	0	40	0.64	1.90	2.61	5.43	2.32	0	48.80	5.6
8	Aza'a Foreke-Dschang	Drilling	6.15	35	6	25	0.18	1.12	1.84	2.58	3.90	0	27.45	2.2
9	Centre de santé de Nkeuli	Drilling	5.52	51	0	30	0.36	1.18	1.29	4.45	1.25	0	112.85	3.0
10	Zembing	Drilling	5.15	30	2	20	0.22	1.48	1.43	0.83	2.44	0	54.90	2.7
11	Ngui	Spring	5.60	102	4	45	0.54	1.08	1.50	2.58	2.98	0	149.45	2.6
12	Keleng	Spring	8.80	27	10	15.6	0.24	0.36	0.06	0.83	4.87	1.07	67.10	0.9
13	Famla	Well	6.54	570	6	127	2.76	0.44	6.49	37.73	4.11	1.07	549	2.6
14	Haoussa	Well	9.94	1400	11	280	1.44	0.16	17.71	91.83	6.16	0.88	45.75	1.9
15	Tchouale	Well	6.94	480	10	268	1.84	1.22	6.13	26.56	1.62	0	1210.00	2.7
16	Fiankop	Well	6.14	619	12	300	1.34	0.06	8.96	48.45	2.16	3.15	161.65	12.2
17	Siteu	Drilling	5.20	14	4	20								

tionally high (8 to 9) in Keleng and the Haoussa quarters respectively. The pH is evaluated between 0 and 14 and expresses the concentration of the H^+ ions in solution. This value for water of good quality must be between 6.9 and 9.2 according to WHO [1] standards. Thus, water sources with pH values lower than 6 are numerous in Dschang. This water is slightly acid. Acid water is corrosive for the pipes of distribution.

3.1.2. Electrical Conductivity

Electrical conductivity is the ability of a solution to lead electrical current. It expresses also the quantity of dissolved matter (often called salinity). USEPA [14] recommends the limiting value of 300 µS/cm. The electrical conductivity of analyzed water varies between 30 and 100 for the majority of cases examined, except for the following wells (Famla, Haoussa, Tchoualé and Fiankop) whose conductivities were between 480 and 1400 µS/cm. With the exception of well water, all other water points had electrical conductivities in the acceptable range.

3.1.3. Turbidity

The turbidity values of less than 5 FTU are limiting for WHO [1]. In line with this, only water obtained in drilling of the "Centre de santé de Nkeuli'' and that of Zembing met this condition. All other water sources were turbid and required filtration before distribution. This is due to the fact that surface water contributes to these sources.

3.1.4. Total Dissolved Solids (TDS)

This parameter expresses the salt reaction in solution, or the organic level of pollution of water. Allowable values of TDS range between 500 and 1500 mg/l [1]. For analyzed water, the values of TDS were between 15 and 45 mg/l for the majority of sources examined; water from wells was exceptions where the values of TDS were between 120 and 300 mg/l. In all the cases, TDS values were lower than the range accepted by the standards.

3.1.5. The Cations Ca, Mg, K and Na

The presence of cations in water expresses the hardness of water. The limiting values according to WHO standards are 75 - 200, 30 - 150, 20, 50 - 60 mg/l respectively for Ca, Mg, K and Na. For the Office cantonal of Vaud (Switzerland), the limiting values of these parameters are 40 - 125, 5 - 30, ≤ 10 and ≤ 20 respectively. The values of these parameters in analyzed water ranged between 0.1 and 0.6; 0.06 to 2.6; 1 to 2.6; 0.8 to 8 mg/l respectively for Ca, Mg, K and Na. Calcium (1.3 to 2.7 mg/l), potassium (6 to 17 mg/l) and sodium (37 to 91 mg/l) values were slightly higher in the wells. It appears that only well water has the recommended sodium value. All the other water sources were very slightly mineral-bearing.

3.2. Anions in Studied Water

The results of the anions in water of the Dschang council are presented in **Table 2**.

3.2.1. Sulphates

The sulphates in water represent agricultural pollution. The value allowed by the USEPA is ≤ 250 mg/l. For water of the Dschang council, the values of sulphates were between 0.2 and 6 mg/l; with the high values reported coming from wells (1.6 to 6.16 mg/l). In all the cases, water of Dschang is not polluted according to their sulphates content.

3.2.2. Chlorides

The chlorides in water are known to come from rainwater. The accepted values are between 200 and 600 mg/l. In water of Dschang, the values obtained were between 0 and 3 mg/l. This water is thus low in chlorides and thus of good quality with respect to chlorides.

3.2.3. Bicarbonates

Total alkalinity is the sum of carbonates and bicarbonates. The values of bicarbonates are also used to express alkalinity, in the absence of carbonates. Only one sample showed the presence of carbonates (16 mg/l in the Haoussa well). The acceptable values of alkalinity are 200 mg/l. Water of strong alkalinity has a bad taste. For water of Dschang, alkalinity was between 6 and 160 mg/l; however, the water of Tchoualé well had an alkalinity of almost 1200 mg/l. Apart from this point, the other sources were of good alkalinity.

3.2.4. Nitrates

The nitrates in water result from pollution by urines and agricultural entrants. The value recommended by WHO is between 40 - 50 mg/l. The elevated nitrate contents cause the disease known as "Blue-baby" or Methaemoglobinase [15]. In Dschang, values were between 0.9 and 3.5 mg/l for the majority of management points. The Fongo Ndeng spring water, and Fiankop wells have raised rates (17 and 12 mg/l respectively) because of nitrates. Agriculture and free grazing animals can explain the first case whereas the second could be an effect of the urban environment.

3.3. Microbiological Parameters in Studied Water

Studied water average microbiological density is represented in **Table 3**. The total coliforms are observed in all water, except for the drilling of Aza'a Foréké- Dschang, and that of the "Centre de santé de NKeuli", the spring of Keleng and the Haoussa well. The pathogenic bacteria here are faecal coliforms. They result from the contamination by excreta. The allowed value by WHO is 0 CFU for 100 ml of water. However, Duchemin [16], sanitary engineer of pS-Eau (France cooperation NGO) delimited in sub saharian zone, less than 20 faecal CFU/100 ml the number of coliforms and faecal streptococci in water intended for human use. One found them in great quantity in water of Busy Home, Atchouazong, spring of Tchoualé, spring of Ngui, spring *La Vallée* and the well of Fiankop. The faecal streptococci sp. were detected only in the spring of Ngui.

Table 3. Microbiological analysis of studied water (average of three analyses).

	samples	*DBO5*	*DCO mg/l*	*Total coliforms (CFU/100 ml)*	*Faecal coliforms (CFU/100 ml)*	*Faecal streptococci (CFU/100 ml)*
1	Fossong Wentcheng	9.4	9	42×10^4	0	nd
2	Busy Home	5.6	20	4.55×10^6	2×10^3	nd
3	Fongo Ndeng	11.3	6	3.50×10^6	0	nd
4	Lefock	6.0	5	3.75×10^6	0	nd
5	Atchouazong	5.5	7	2.05×10^4	1×10^3	nd
6	Tchouale	5.5	10	1.50×10^4	1.15×10^4	nd
7	La Vallée	6.6	5	3×10^3	1×10^3	nd
8	Aza'a Foreke-Dschang	9.4	12	0	0	nd
9	Centre de santé de Nkeuli	5.5	15	0	0	nd
10	Zembing	8.5	20	0	0	nd
11	Ngui	12.5	19	3.40×10^4	3×10^3	4×10^3
12	Keleng	10.7	17	0	0	nd
13	Famla	10.5	10	13×10^4	0	nd
14	Haoussa	4.2	12	0	0	nd
15	Tchouale	7.5	13	1×10^3	0	nd
16	Fiankop	8.5	25	9×10^3	3×10^3	nd
17	Siteu	23	nd	nd	20	10

The DBO5 and DCO are parameters which present organic pollution. They present acceptable values [1,16].

3.4. Water Quality in Dschang is Due to Urban Environment and Type of Water Point Management

Popular practices regarding the raising of livestock and management of human and household wastes reveal additional knowledge gaps regarding the link between poor sanitation practices and the incidence of water-borne disease. Studies performed in the Dschang area have shown that both human and animal waste contain significant concentrations of pathogenic organisms.

Each inhabitant of the Dschang city, as far as possible, builds its water supply (well in particular) and sanitation devices. Generally there exist in Dschang nearly 8000 open bottom pit toilets, built not far from the water wells [17] and, dug to the groundwater [5]. The full pits are quite simply closed and others dug in the vicinity. The old pits remain thus hidden, becoming a durable source of pollution for the groundwater. Solid waste is voided in the backwaters, the gutters or on open lands. Also, a study conducted in 2002 [18] on the fecal matter of domestic chickens, goats, pigs, dogs found that zoonotic infection was prevalent across a variety of species. Infestation by Nematode species was predominant (57.1% testing positive), followed by Cestodes (21.4%), Trematodes (14.3%) and various Protozoa (7.1%).

In a study on quality of drinking water of Kalama region in Egypt, 30% of samples from public waters were contaminated with coliform bacteria [19]. Other studies in Iran showed that total bacteria mean count for tap water was 1.3×10^4 CFU/ml, and 41% - 67% of water samples from open water sources in India contained coliform and/or faecal coliform bacteria [20]. Djuikom *et al*. [21] in a study on bacteriological quality of water used by population in Douala stated that faecal coliforms densities varied from 200 and 44×10^3 CFU/100 ml.

The management of water points consisted in setting up curbstones, hillocks and the feet supports (Oral communication from Dschang Technical Staff). This improves much esthetics of drawing up but the analysis of laboratory for the quality of water required was necessary before installation. Then, no precaution of protection against anthropic pollution was taken.

3.5. Chemical Pollution is Minimized

The health concerns associated with chemical constituents of drinking-water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure [1]. There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a drinking-water supply. Moreover, experience shows that in many, but not all, such incidents, the water becomes undrinkable owing to unacceptable taste, odour and appearance.

Figure 3 shows the better correlation between TDS and conductivity. **Table 4** shows that correlations are also good (86% to 100%) between K and Na, between K and Na and finally between the DBO5 and the DCO. This shows that these parameters are affected between them and that the change of the one influences the other.

Table 4. Correlations between the various studied parameters.

	pH	*Cond*	*Turb*	*TDS*	*Ca*	*Mg*	*K*	*Na*	*SO_4^{2-}*	*Cl^-*	*HCO_3*	*NO_3*	*DBO_5*	*DCO*
pH	1.00													
Cond	0.52	1.00												
Turb	0.67	0.70	1.00											
TDS	0.51	**1.00**	0.70	1.00										
Ca	0.35	0.73	0.44	0.73	1.00									
Mg	–0.60	–0.60	–0.61	–0.60	–0.51	1.00								
K	0.65	**0.86**	0.59	**0.86**	0.63	–0.60	1.00							
Na	0.68	**0.87**	0.61	0.87	0.68	–0.65	**0.99**	1.00						
SO_4	0.79	0.36	0.56	0.35	0.37	–0.70	0.56	0.59	1.00					
Cl	0.21	0.53	0.43	0.53	0.35	–0.59	0.44	0.49	0.23	1.00				
HCO3	0.14	0.54	0.34	0.54	0.69	–0.20	0.22	0.23	0.00	–0.03	1.00			
NO_3	–0.21	0.13	0.04	0.14	–0.07	0.25	0.05	0.02	–0.28	0.27	–0.12	1.00		
DBO_5	0.01	0.26	0.48	0.26	–0.13	–0.27	0.03	0.06	0.11	0.32	–0.07	0.09	1.00	
DCO	0.06	0.29	0.52	0.30	0.05	–0.37	0.08	0.14	0.17	0.29	0.03	–0.05	**0.94**	1.00

3.6. Health Risks from Water Quality

Given the extensive contamination of available water supplies and the health *risks* posed, the health *impacts* are going to be largely dependent on the methods and prevalence of home treatment. A limited survey conducted on 148 households by ERA-Cameroun [17] revealed that only 43% of reporting households subject their drinking water to home based physical or chemical treatment. Of the treatment methods most commonly employed (boiling, bleach, chloramines, ceramic candle filter, membrane filter, cotton filter), their weighted effectiveness amounts to a pathogen removal rate of 92%; inadequate for the levels of contamination observed in one half of the sources analyzed [10].

The inhabitants complain about many diseases, especially the enteric ones which are diseases related to water that they use and with the lack of hygiene. This situation was already revealed by several studies of which:

- The diagnosis of UN Habitat [22] which announces the cases of typhoid, of the intestinal parasites and diarrhea like recurring diseases in the city;
- The study of Boon [9] which announces 18.8% of the patients suffering from the diseases related to water on a whole of 8000 patients indexed in the hospitals, pharmacies and in the tradi-experts of the city: helminthiasis: 7.2%, typhoid: 6%, amoebic diarrhea/dysentery: 4.9%, intestinal mushrooms: 0.7%).

The study of Boon [9] attributes these diseases to the proximity between the Men and the domestic animals (breeding behind the houses). ERA-Cameroun [17] announces that the proximity of the open pit toilets is a main factor at 70%.

4. Conclusions

In a general way, the water studied in the Dschang council is unacceptable for human consumption. For the concerns raised below, this consumption could be favorable only when certain constraints will have been overcome:

1) Water from well is turbid and has a high electric conductivity. It is essential to install there a filtration device.

2) All water is slightly mineral-bearing.

3) The water of the Tchoualé well has a high percentage of bicarbonates (and thus alkalinity). This parameter should be controlled: research of the source and remediation.

4) Water of Busy Home, Atchouazong, spring of Tchoualé, spring of Ngui, spring *La Vallée* and of the well of Fiankop contains feacal coliforms in great quantity. Their treatment by chlorine or bleach is essential. Also, the source of pollution must be detected and eliminated.

5) And spring waters of Fongo Ndeng and well of Fiankop, have high rates of nitrates. The sources of pollution must be eliminated

6) Sand in water observed in Fossong Wentcheng calls for a complete revision of the system of filtration. For example by laying out filter materials according to adapted particle size, and supporting the water run-off by the filter roof.

These water points were already provided to the populations but they require the installation of filtration area and the development of a follow-up plan of chlorination. If the use of chlorine is tiresome, the bleach amounts can be prescribed.

5. Acknowledgements

The author is grateful to the International Foundation for Sciences (IFS) for the research grant (Grant W/4206-2). I also appreciate Dr TABI and NIBA of the University of Dschang for proofreading this paper.

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