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Physico-chemical and Bacteriological Assessment of Groundwater from Peri-urban Area of Douala – Cameroon

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Abstract: The physicochemical characterization of water of the peri-urban area of Douala city was carried out from 04 springs and 21 wells in February 2013 and August 2013 corresponding to the dry season and the rainy season respectively. For bacteriological analyzes, thirteen water points were sampled, including 4 sources, 08 wells in the rainy and dry season. All the water points yielded pH values below 7,0 and were classified as acidic water. Electrical conductivity ranged between 44.30-483µm/cm and then waters are poor mineralized. The relative abundance of major ions (mg/l) was $Ca^{2+} > Na^+ > K^+ > Mg^{2+}$ for cations in dry season whereas and $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ in the rainy season. For the anions, $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ in the dry season whereas in the rainy season $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-}$. Major ion concentrations were within the WHO guidelines for drinking water, but a few points have a concentrations below the WHO limits. Main water types in the both seasons were Ca-Mg-HCO$_3$ and Ca-Mg-Cl. Bacteriological analysis revealed that all water points sampled during the rainy season and some (67%) during dry season contain feacal contamination control germs. Bacteriological contamination of the water is of human and animal origin. Human origin is linked outflow from latrines used by the population. The spring and well waters analysed are not suitable for drinking and domestic purposes except two springs in the dry season.

Keywords: Physicochemistry, Bacteriology, Groundwater, Periurban, Douala, Cameroon

1. Introduction

Water, an essential natural resource for all life, is unevenly distributed over the surface of the earth. Fresh water, which is that directly used for various human activities, must be preserved in quantity and quality. In the peri-urban areas of large cities in most sub-Saharan countries, groundwater is the main source of drinking water. However, collected water may contain elements that can have undesirable effects on health, such as pathogenic microorganisms, undesirable substances or even toxic substances [1]. It is therefore necessary to have better knowledge of the water resources consumed by the population. Numerous studies carried out in Cameroon and particularly in the city of Douala, have made it possible to characterize well water for domestic use in densely populated neighborhoods and to highlight the sources of pollution from these wells. The results of these studies show chemical and bacteriological pollution of anthropogenic origin [2-5]. The use of these waters represents a danger for the population. Cases of cholera, diarrhea, dysentery, typhoid fever, malaria and skin diseases have been reported in many households in Douala [6, 7]. In the city of Douala, the rate of household connection to the drinking water network is low, around 30% [8]. To obtain drinking water, many people lean towards wells, springs and boreholes. To date, the peri-urban areas of the city of Douala do not have significant data on the quality of groundwater. Water has no quality in itself, except in the context for which it is used. Its quality depends on its use under specific conditions. Indeed, water intended for human consumption would not have the same quality standards as that of water for industrial or irrigation use. Hydrochemical

and bacteriological variability is studied in order to assess the potential of the resource and to identify the water quality issues in the peri-urban districts of the Douala city.

Presentation of the study area

The area concerned by this study is located between latitudes 4°00'29 "and 4°02'08"North; longitudes 9°46'11" and 9°48'06'E. It covers an area of approximately 5000m^2 (Figure 1). The hydrographic network is sparse fed by the main river, which is the Kambo, and a few tributaries. The activities practiced are mainly small trade, cattle and poultry farming, market gardening. In this area, the population density is between 26 and 150 inhabitants per km^2 [9]. Average annual precipitation is very abundant around 3664.86 mm [10]. Most of the soils encountered are of the ferralitic type [11-13]. They have a sandy to sandy-clay texture more or less leached, favorable to rainwater infiltration. The hydromorphic soils are formed from recent or sub-recent deposits. These can be gley soils belonging to the group of marsh soils rich in organic matter [14] or pseudogley soils.

The rocks found in the study area are part of the sedimentary formations that make up the Douala basin [15]. Waters studied capture the Mio Pliocene aquifer consisting of alternating clay and sands with gravel transitions.

2. Methodology

Water sample collection campaigns for the various physicochemical analyzing took place in two phases. Twenty five water samples were collected from four sources and 21 wells in February 2013 and August 2013 corresponding to the dry season and the rainy season respectively.
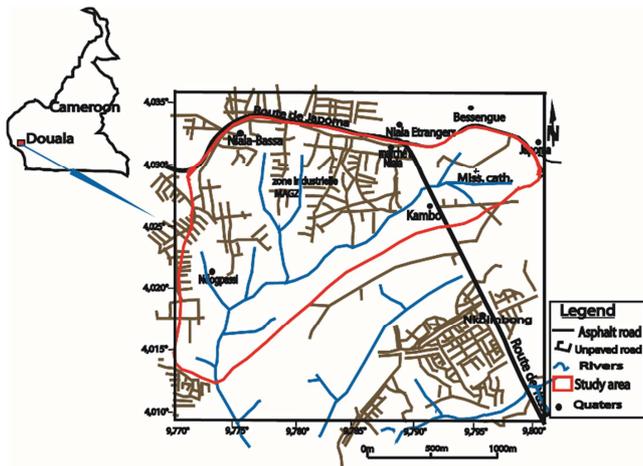
Figure 1. Location of study area.

Samples were carried out in 500ml PVC bottles at the request of the laboratory while respecting the recommendations of Rodier [16]. Physical parameters (temperature, pH, conductivity) were measured in the field using a multiparameter. Chemical analyzes (Ca^{2+}, Mg^{2+}, Na$^+$, K$^+$, Cl$^-$, HCO$_3$$^{2-}$, SO$_4$$^{2-}$, NO$_3$$^-$, Fe) were carried out at the LASPEE laboratory of the Institute of Agronomic Research

for Development (IRAD) of Yaounde. Major cations were analyzed using a flame atomic absorption spectrophotometer. Chlorides and bicarbonates were analyzed by titration and sulfates and nitrates by colorimetry. The research and enumeration of bacteriological germs (coliforms and faecal streptococci) took place at the WWRU laboratory of the University of Yaounde I. Method used is the filter membrane using an appropriate support under sterile conditions [16].
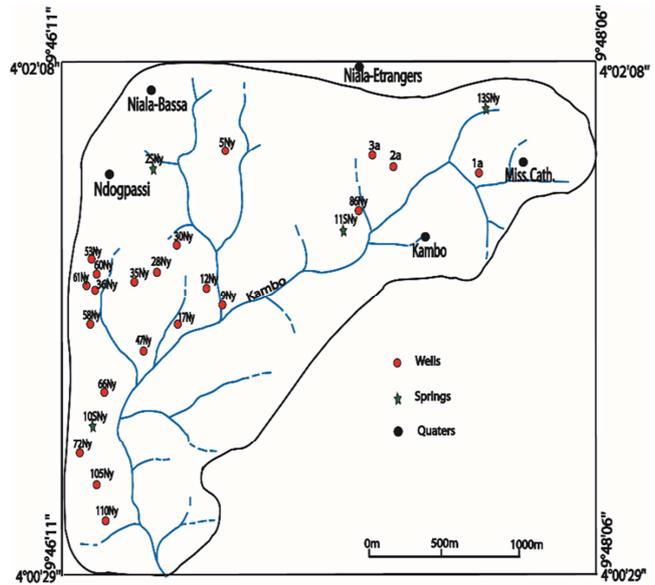

Figure2. Location of sample points.

3. Results and Discussion

3.1. Physical Parameters

The pH measured in the water sampled is in the range of 4.18 to 6.67 (mean=5.05) in dry season and of 4.08 to 6.48 (mean=5.29) in rainy season. pH of all samples makes it possible to attribute an acidic character to these waters. pH tends towards neutrality in some wells. Conductivity varies between 48.70 and 430μS/Cm (mean181.13) in dry season and between 44.30 and 483 μS/Cm for an average of 214.95 μS/Cm in rainy season. This low conductivity shows that waters are poor mineralized.

3.2. Cations

Calcium is the most represented cation. It varies from 2.83 to 74.90 mg/l for an average of 17.95 in dry season and from 0.2 to 23.85 for an average of 6.65 in rainy season. Magnesium is present in the water in low proportions. Its overall content ranges from 0.51 to 8.70 mg/l (mean=2.91) in dry season and from 1.59 to 2.36 (mean=6.98) in rainy season. Sodium ranges from 1.33 and 14.96mg/l (mean 7.21mg/l) in dry season and from 1.89 to 22.11 for an average of 9.96 in rainy season. In these waters, sodium represents the second abundant cation. Potassium has levels close to those of sodium in all waters and varies between 0 and 14.62 mg/l (mean= 4.76) in dry season and from 0.6 to 23.03 (mean=5.78) in rainy season.

3.3. Anions

In the water samples analyzed, bicarbonate contents vary from 0 to 286.7 mg/l (average 28.86) in dry season and from 0.97 to 256.85 (average of 43.81) in rainy season. For chlorides, contents are between 0 and 209.45 mg/l (mean=16.81) in dry season and from 0 to 26.98 (mean=8.98) in rainy season. In low proportions, the nitrate contents are between 0 to 3.61 mg/l (mean 1.14) in dry season and between 0.31 and 25.78 (mean=8.64) in rainy season. Sulphates are the weakest represented anions, their contents range from 0 to 16.4 mg/l (mean=2.43) in dry season and from 0.41 to 11.81 (mean=4.92) in rainy season.

The iron contents vary between 0 and 19.42 mg/ l (average=3.43) in dry season and between 0 and 1.017 (mean=0.15) in rainy season. Iron is abundant in some water points exclusively in the dry season. In fact, Iron is a fairly abundant element in rocks (a few percentage) in the form of silicates, oxides and hydroxides, carbonates and sulphides. Presence of iron has been reported in groundwater in the Douala basin [17-18]. However, contents rarely exceed 1 mg/l in water. Several hypotheses are put forward to justify the presence of this ion in the water. In the soil profiles (between 3 and 15m) in the study area as well as in other localities of Douala, there is a level of iron accumulation [13]. which leaching of would lead it towards the waters especially since most of the wells are shallow. Significant levels of iron were found in borehole water in the Tiassalé region in Côte d'Ivoire [19], in the waters of the Morsott-Laouinet aquifer complex in south-eastern Algeria [20], also in groundwater in urban areas southwest of Brazzaville [21]. The high grades are linked to the geological context of the area. In the sedimentary materials of the Douala sub-basin, pyrite deposits have been detected [22, 23]. This suggests that abundance of iron in the waters of the upstream Kambo watershed reflects the probable existence of pyrite in the sediments. Otherwise, the static level of the water would coincide with the levels of accumulation leading to excessive iron levels in the water. In the rainy season, the iron content drops considerably in the water. This can be explained by the increase in static levels leading to a high water dilution. This justifies that the origin of this iron is intimately linked to the geochemical content of the site where the sample is taken.

Table 1. Result of physico chemical parameters.

Paramètres	Dry season			Rainy season			OMS Standard
	MIN	MAX	MOY	MIN	MAX	MOY	
pH	4,18	6,65	5,05	4,08	6,48	5,23	6,5-8,5
C. E.(µS/cm)	48,7	430	181,13	44,3	483	214,95	<300
Ca^{2+}(mg/l)	2,83	74,9	17,95	0,2	23,85	6,65	250
Mg^{2+}(mg/l)	0,51	8,7	2,91	1,59	21,36	6,98	50
Na^+(mg/l)	1,33	14,96	7,21	1,89	22,11	9,96	200
K^+(mg/l)	0	14,62	4,76	0,6	23,03	5,78	12
NO_3^-(mg/l)	0	3,61	1,14	0,31	25,78	8,64	50
Cl^-(mg/l)	0	209,45	16,81	0	26,98	8,98	250
SO_4^{2-}(mg/l)	0	16,21	2,43	0,41	11,81	4,92	250
HCO_3^-(mg/l)	0	286,7	28,86	0,97	256,2	43,81	250
Fe (mg/l) *	0	19,42	3,43	0	1,017	0,15	0,3

3.4. Hydrochemical Facies

Interpretation of the values of different physicochemical parameters shows that, whatever the sampling period, two main facies are illustrated for groundwater in the study area. It is the chlorinated and sulphated calcium and magnesian facies and calcium and magnesian bicarbonate facies. The predominance of calcium ions gives them the calcium character. However, Piper's diagram (figure 3), show a migration to the sodium and potassium pole for samples taken in August corresponding to the rainy season. The obtained facies agree is obtained by Tatou [24] who dealt in detail with a larger number of samples in this area.

3.5. Bacteriological Parameters

In all analyzed samples in the rainy season, rate of feacal coliforms (FC) varies between 15 and 600 CFU/100ml for an average of 224.83 while rate of streptococci (FS) vary between 10 and 270 CFU/100ml for an average of 110.33. No sample is exempt from those germs which are evidence of feacal pollution (Table 2). FC/FS ratio is greater than 4 for two water points and others have values between 0.7 and 4.
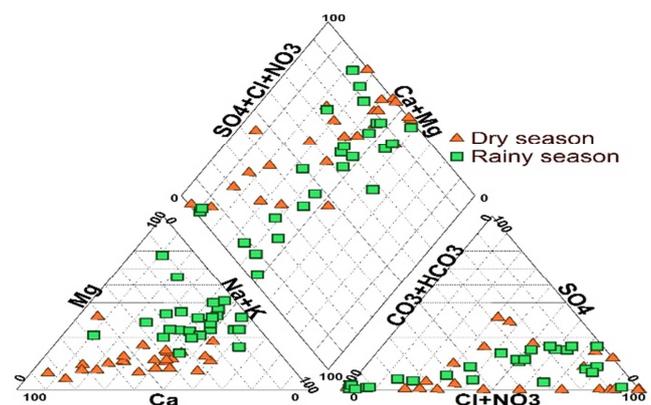

Figure 3. Piper diagram for analysed samples.

For the dry season, feacal coliforms content are from 0 to 320 UFC/100ml for an average of 85.42. Feacal streptococci range from 0 to 130 CFU/100ml for an average of 31.25. A single well (35Ny) has the highest values. Two sources (10SNy and 11SNy) are free of feacal germ during this dry

season sampling. In other samples, the number of feacal streptococci is lower than the number of feacal coliforms. Concerning the FC/FS ratio, six (6) wells have values between 0.7 and 4, only one well with a value greater than 4

and one with a value less than 0,7. The rate of feacal germs counted in dry season is overall lower than the rate obtained in rainy season.

***Table 2.** Results of bacteriological analyses.*

code		Rainy season.				Dry season			
		FC	FS	FC/FS	origin	FC	FS	FC/FS	origin
5NY	W	460	170	2,71	mixte	200	74	2,7	mixed
12NY	W	50	12	4,17	Human	4	8	0,5	Animal
35NY	W	400	96	4,17	Human	320	130	2,46	Mixed
47NY	W	600	270	2,22	Mixed	280	90	3,11	mixed
58ND	W	320	260	1,23	Mixed	2	0	0	
105ND	W	28	12	2,33	Mixed	0	7	0	
2a	W	30	10	3	Mixed	33	10	3,3	Mixed
76Ny	W	180	100	1,8	Mixed	101	37	2,73	mixed
10SNy	S	75	44	1,7	Mixed	0	0	0	
2SNy	S	220	160	1,37	Mixed	72	13	5,54	Human
11SNy	S	320	180	1,78	Mixed	0	0	0	
13SNy	S	15	10	1,5	Mixed	13	6	2,17	mixed
MAX		600	270	4,17		320	130	5,54	
MIN		15	10	1,23		0	0	0	
MOY		224,83	110,33	2,33		85,42	31,25	1,87	

W=wells; S=springs, FC= Feacal coliform, FS Feacal streptococci

3.6. Assessment of Hydrochemical Potability

Based on hydrochemistry, all water points sampled have a pH below 7.0 during all seasons. The results of the hydrochemical facies show that waters of the wells are subject to natural mineralization. Low mineralization observed reflects the nature of geological formations in which these waters circulate mainly composed of secondary minerals such as sands and clays [10]. However, note that, water consumed by humans must contain sufficient minerals to ensure their health according to the WHO standard. Water intended for consumption must have a minimum of 60 mg/l for total hardness, either 10mg/l for magnesium and 20mg/l for calcium [25]. Water with calcium and magnesium deficiency presents a health risk [26]. Dissanayake [27]. found a negative correlation between hardness and several forms of cardiovascular disease and leukemia in Siri Lanka. Similarly, COMA [28] also found an inverse relationship between water hardness and cardiovascular disease. This implies that people who consume water with low calcium (less than 20mg/l) and magnesium (less than 10mg/l) are likely to suffer from these diseases. Water points sampled have low levels of calcium and magnesium, indicating that populations consuming these waters are at risk of cardiovascular disease.

Iron is essential for human health in trace conditions. The presence of iron in drinking water, do not pose any real risks to human health. Thus, the nuisance of iron in the water is [29]: the neutralization of some disinfectants due to iron oxidation; the distribution of rust-colored water, which is aesthetically unattractive to the consumer, and which can stain laundry and sanitary; the metallic taste of water; the risk of corrosion of pipes due to the development of micro-organisms (ferrobacteria). Based on the physicochemical

characteristics of raw water, the elimination of iron in the water is done through biological processes such as biological treatment and physico-chemical treatment [30].

3.7. Bacteriological Potability Assessment

All water points sampled during the rainy season and some (67%) during dry season contain feacal contamination control germs. This indicates that, waters receive contaminated water. High values obtained in rainy season range from 10 to 600 CFU/100 ml for CF and from 10 to 270 CFU/100 ml for SF. Similar results were obtained by Eneke [4] in certain peri-urban areas of the city of Douala. Similar results to those in the study area were also recorded in spring's waters of the western mountainous Côte d'Ivoire (village of Mangouin-Yrongouin) by Ahoussi [31]. Contamination of these waters may result from the leaching of microorganisms by rainwater that seeps into the soil and reaches the water table without being effectively filtered [32].

The sources of pollution are determined from the ratio of feacal coliforms to feacal streptococci [33-36]. According to those authors, when ratio (FC/FS) is greater than 4, the pollution is of human origin, where it is less than 0,7, the pollution have animal origin. Theoretically according to the same authors, where the ratio is between 0.7 and 4, pollution is both of animal and human origin.

FC/FS ratio between 0.7 and 4 in the majority (83% in the rainy season and 50% in the dry season) of the water samples analyzed (Table 2) shows that bacteriological contamination of the water is of human and animal origin. Human origin is linked outflow from latrines used by the population as noted in other locations in Douala [3, 18]. Animal pollution would come from animal waste. In fact, in the study area, breeding (poultry farming, pig farming) is one of the most practiced activities by the population. Thus, discharges from this

livestock farming would be a major factor in groundwater contamination [37] following the infiltration of rain water that drains waste to the soil depths. This is consistent with the increase in nitrate levels in the water during the rainy season. Influence of anthropogenic activities on water quality has been observed in the Baikunthpur region, the Rewa District, Madhya and Pradesh in India [38].

Feacal coliforms are witnesses of recent feacal contamination whereas streptococci show ancient feacal contamination [39]. The presence of these germs in all samples collected during the rainy season indicates a mixture between recent and ancient feacal contamination. However, in dry season, 67% of samples contain feacal coliforms and streptococci, their contamination is both recent and ancient. One point (105ND) is marked by an ancient contamination, which reflected the absence of feacal coliforms and another point (58ND) is marked by recent pollution, which reflected by the absence of feacal streptococci. Two wells (12Ny and 35Ny) in the rainy season and one spring in the dry season show a sign of human contamination (CF/SF=4.17). This would result from a larger number of latrine around these sampling points. Only one well (12Ny) shows a sign of animal contamination (CF/SF=0.5) in dry season, although the count of germ is quite low. This is due to a large number of feacal streptococci at this point, however, contamination is of human origin (CF/SF=4.17) at this point in the rainy season. This seasonal variation in germ count at this point is a sign of occasional contamination. The high dispersion between waters of wells and springs reflects dispersed sources of contamination in the study area. Results obtained are in line with the less anthropogenic situation of the study area. Comparing the maximum values obtained from feacal coliforms and streptococci in the study area with those obtained from densely populated areas in Douala such as the catchment areas of Ngoua and Bobongo [40], the Bepanda1 [3], the Besseke watershed [18], it is noted that the results obtained in this work are significantly lower than those achieved. This indicates that situation in this area is not alarming and requires consideration of groundwater protection to prevent pollution.

The intensity of groundwater contamination depends on the soil type and the level of pollutants [41]. The presence of these germs in the water, even in low rate, nevertheless attests to the vulnerability of the water table in Douala. Groundwater generally appears more vulnerable as the top of the groundwater is close to the surface, as the soils above the water table is permeable and the surface origin of pollution are significant, numerous and close to the study site [32, 42]. The soils of the study area have high permeability [17], this characteristic exposes groundwater to direct contamination by infiltration of charged water. Low feacal seed values indicate low environmental pollution sources in the study area. Indeed, the low population density in the study area may explain the reduced dose of germs pollutants.

Comparing the results obtained in both seasons, water is more contaminated in rainy seasons than in dry seasons. The low number of feacal germs in the dry season is thought to be due to a decrease in the rate of infiltration in the dry season, reflected in the lower piezometric level of water table [10]. In fact, during infiltration, the water leaches the soil, training with it the germs retained towards the depths. During the high water period, piezometric surface becomes shallow and moves closer to the surface at the bottom wells that connect surface water with groundwater. Such hydraulic contact would promote groundwater contamination.

With reference to the WHO standard, a few points (10SNy, 11SNy, 105ND, 58ND) are suitable for drinking water during dry season. However, during the rainy season, no water samples analyzed is recommended without any prior treatment. The presence of faecal coliforms and streptococci in excess of the WHO standard in the waters analysed presents a health risk to the population consuming them. Many authors have linked contaminated water from these two groups of bacteria to water-borne diseases [43, 44, 40]. Children aged 0-5 are the most affected population [43].

In some precarious neighborhoods of the Douala city, there has been a high incidence of water-borne diseases (dysentery, diarrhea, typhoid fever) among populations [40, 45] show that the presence of fecal coliforms of fecal streptococci in the drinking water can cause many gastrointestinal diseases, diarrhea, dysentery. Thus, drinking water containing these germs poses a serious threat to the population health [46]. Waters use in the study area requires disinfection and decantation before consumption, especially during the rainy season [47].

4. Conclusion

The assessment of the health quality of surface water from the shallow water in peri-urban areas has enabled us to characterize this natural resource. Most chemical quality parameters are below the WHO's drinking water standard. Well water is acidic and poorly mineralized. The majority of water points in this area of study is characterized by a predominance of calcium and magnesium chloride facies and calcium and magnesium bicarbonate facies. The rate of feacal coliforms and streptococci show that, studied water requires disinfection and decantation before consumption.

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