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Study of the Hydro-Chemical and Bacteriological Well Water Characteristics of M'Bahiakro (Central-Eastern Côte d'Ivoire)

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Abstract

The use of well water by disadvantaged populations in most African cities often presents health risks. The purpose of this study is to determine the physico-chemical and microbiological quality of M'bahiakro well water. A series of physico-chemical, microbiological and piezometric analyses were carried out on the well water in the area. The results of these analyses were processed using Piper and Schoeller-Berkaloff diagrams and the software R 3.1.2 for Principal Component Analysis. Physico-chemical analysis results show that the water has an average temperature of 28˚C. They are acidic, with a pH that generally varies from 4 to 6. M'bahiakro well waters are highly mineralized, with an average electrical conductivity of 369.1 µS/cm and 984.1 µS/cm and pass from sodium and potassium chlorinated facies in the dry season (February) to sodium chlorinated facies in the rainy season (October) with K^+, Na^+ and NO_3^- ions dominating. These ions would be the result of soil rainfall and the intervention of anthropogenic activities in the pollution of shallow groundwater. Bacteriological results exploitation shows that the well waters studied host high densities of enteritis bacteria (*E. coli*, *Fecal streptococcus*, and *Clostridium perfringens*) during the rainy period (October). M'Bahiakro's well water is of poor quality and unsuitable for human consumption without prior treatment. However, they deserve particular attention and would require further treatment in rainy periods.

Keywords

Well, Groundwater, Hydrochemistry, Microbiology

1. Introduction

Water has always been at the forefront of natural resources that are essential for human life. However, the ever-increasing degradation of water resources in most agricultural countries has taken on catastrophic proportions in recent decades and is one of the most worrying environmental dimensions of the twentieth century (Zgheib, 2009). This degradation is strongly linked, not only to biological pathogens, but also to chemical substances, especially man-made nitrates. Their presence in water resources, and more particularly in groundwater, is unprecedented in the history of mankind due to their effect on human health (Olusola & Odetokun, 2011; Hounsounou et al., 2016; Lukubye & Andama, 2017; Ondigo et al., 2018; Oswald et al., 2018).

In Côte d'Ivoire, various rice-growing activities have been established in several regions close to major cities, where the demographic pace has increased significantly with the popularization of city centres. This has resulted in excessive water consumption and significant wastewater discharges that unbalance the aquatic ecosystems, especially the main water tables of the country's major cities (Ahoussi et al., 2018). The locality of M'bahiakro, the subject of this study, is no exception to this observation. Indeed, the study area is subject to intensive agricultural practices and is reputed for an irrigated rice production of more than 2000 tons/year with an increase in population in the city centre. In the town of M'bahiakro, one of the main sources of water supply is provided by the use of domestic wells. However, aspects of the quality and adequacy of these wells, which mainly supports the domestic water needs of the population and rice farmers in particular, have still not been sufficiently studied for the well-being of consumers. This study aims to determine the physico-chemical and bacteriological quality of well water in the town of M'bahiakro. The study will assist stakeholders in planning and monitoring the quality of the water table to ensure its sustainable use in the exercise of M'bahiakro's rice-growing activity.

2. Material and Methods

2.1. Presentation of the Study Area

The study area is part of the Iffou region and the Lakes District, located in the central-eastern part of Ivory Coast. Its coordinates are located in the UTM reference frame, spindle 30, between 350,800 and 354,400 meters on the abscissa and between 823,200 and 826,000 meters on the ordinate (**Figure 1**). According to the 2014 General Population and Housing Census (GPHC), the department has a population of 53,802 inhabitants, 38,741 of whom reside in the M'Bahiakro sub-prefecture, with an estimated density of 20 inhabitants per square km.

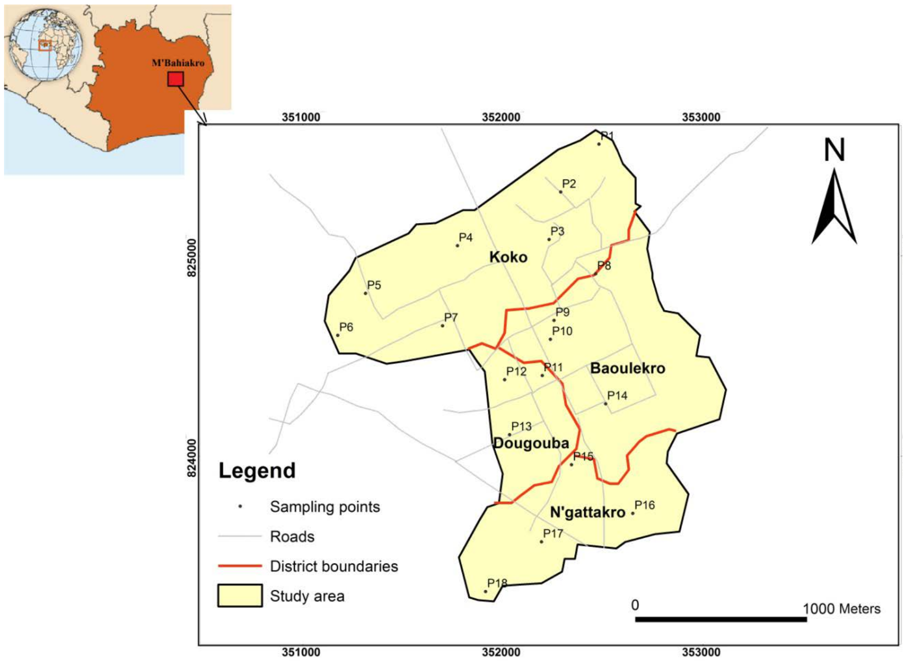

Figure 1. Presentation of the study area.

The city covers an area of 5.538 km^2 and is divided into 4 districts including: Koko, Baoulekro, Dougouba, and N'gattakro. It is under the influence of the transition equatorial climate with four distinct seasons (Goula et al., 2007): a long dry season (November-March), a long rainy season (April-July), a short dry season (August-September) and a short rainy season (October-November). The average monthly temperatures vary between 25.2˚C and 28.5˚C. The M'Bahiakro region receives an average of 1154.71 mm of rainfall each year and the potential interannual evapotranspiration (FTE) is 1691.44 mm with a real evapotranspiration (REE) of 869.67 mm. The surface runoff is 179.38 mm, resulting in 105.65 mm of water likely to infiltrate to recharge aquifers, or 9.15% of precipitation (Kouassi et al., 2017).

2.2. Hydrogeological Study Method

The study of M'bahiakro's groundwater required a census of 19 water points, all represented by traditional wells and located in the courtyards of the houses in the four districts. These wells are free of protective perimeters and most are close to sanitation facilities (septic tanks, pit latrines, cesspools) and uncovered. The copings are more or less flat. Cement agglomerates or used tires sometimes serve as copings. The walls of these wells are sometimes poorly cemented, so they crumble easily. All the identified wells are used for domestic purposes (drinking, bathing, ablution and washing up) by the population. Once the various sites were identified, the well water was subjected to a piezometric study. The field work required the use of a GPS Garmin Map 60 CSX to locate the various measurement points (**Figure 1**). The piezometric measurements were taken using a light and sound piezometric probe equipped with a bottom switch for measuring the depth of the well.

2.3. Hydrochemical Study Method

Water sampling was carried out during the dry periods (February), when groundwater becomes relatively the only source of water supply for residents (Amadou et al., 2014), and rainy periods (October) when groundwater is more likely to be contaminated (Biémi, 1992). The equipment used to carry out the hydrochemical campaign is composed of a portable multi-parameter device of the HANNA brand HI 9828 type for in situ measurements of temperature (T), hydrogen potential (pH), electrical conductivity (EC), TDS, salinity and oxidation-reduction potential (Eh). The 500 ml polyethylene sample bottles were also used for field sampling. Samples were collected, transported and stored according to Rodier (2009). Water samples for physico-chemical analyses were collected in 500 mL polyethylene bottles. Each bottle is rinsed three times with the water to be sampled, then filled to refusal and hermetically sealed before being transported cold (4˚C) in a cooler to the laboratory. The elements to be dosed are: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, for cations and SO_4^{2-}, HCO_3^{-}, NO_3^{-}, NO_2^{-}, PO_4^{2-}, Cl^{-} for anions. The physico-chemical analyses of the water were carried out using a spectrophotometer according to the standards recommended by AFNOR (2001) or those approved by Rodier (2009). The validity of the results of our chemical analyses in the laboratory is based on the calculation of the ion balance and electrical conductivity measurements as suggested by many publications (Appelo & Postma, 2005). The electrical conductivity at 25˚C divided by 100 gives a good approximation of the sum of the concentrations (expressed in meq/L) of the major cations or anions according to the relationship:

$$\Sigma\text{anions} = \Sigma\text{cations (meq/L)} \approx \text{EC}/100\ (\mu\text{S/cm}),\ \text{EC} \leq 1500\ \mu\text{S/cm}.$$

2.4. Microbiological Study Method

Water samples for microbiological analysis were collected in 250 mL glass bottles and stored at minus 4˚C in a cooler for subsequent analysis by the laboratory. It concerns the 19 well water samples. The identification, both qualitative and quantitative, of germs in our water samples is achieved by filtering 100 mL of the water to be analyzed on a cellulosic filter membrane (MF) with pores of uniform diameter equal to 0.45 µM. The Membrane Filtration Technique (TMF) used in this selective medium is simple, faster and safer (Rodier, 2009). Due to the very high-water charge (colour intensity), the samples were diluted at the 10th dilution with sterilized water and then reduced to 100%. The liquid was first bound by the lactose agar with TTC (Triphenyl-tetrazolium chloride) and Tergitol 7 before being filtered (AFNOR, 2001). The parameters analysed are shown in **Table 1**. These analyses were carried out in accordance with French standards in force in Ivory Coast.

Table 1. Microbiological parameters analysis of water.

Parameters	Standards
Escherichia coli count	NF EN ISO 9308-1
Fecal streptococcus count	NF EN ISO 7899-1
Clostridium perfringens count	NF T 90-415

2.5. Data Processing Methods

The collected data were processed using a combination of hydrochemical methods, multiivariate statistical methods and graphs. A first approach uses hydrochemical water classification based on major physico-chemical variables, carried out under Piper and Schöeller-Berkaloff using the DIAGRAMMES 2.0 software. These diagrams are very commonly used in the field of water hydrochemistry, with very good results in Pakistan, Ivory Coast, Ghana and India by authors such as (Eblin et al., 2014; Oga et al., 2010; Bashir et al., 2017; Salifu et al., 2017; Srinivas et al., 2017). Indeed, these representations, which have the disadvantage of representing the major elements of well water in the form of percentages and milligrams per litre respectively, allow us to have an overall view of the chemical content of our water samples and to identify any changes. In addition, in order to consolidate the first observations derived from these diagrams and to better understand the links between physico-chemical parameters, a second approach based on Principal Component Analysis (PCA) was applied on reduced centred variables. According to the authors Akatumbila et al. (2016) and Orou et al. (2016), the PCA is a descriptive multidimensional statistical method that can be used as a tool to assist in the interpretation of a data matrix. This analysis makes it possible to synthesize and classify a large number of data in order to extract the main factors that are at the origin of the simultaneous evolution of the variables and their reciprocal relationship. It makes it possible to highlight the similarities and graphical position of two or more chemical variables as they evolve. The PCA was conducted on 17 variables. The parameters used for this analysis are: T, CE, pH, TDS, salinity, depth, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, NO_2^{-}, PO_4^{2-}, Cl^{-}. The statistical analysis was carried out using software R.3.1.2. The results of the microbiological analyses were represented in graph form and compared with WHO (2017) guidelines for drinking water, not influenced by human activities.

3. Results

3.1. Physico-Chemical Characteristics of the Groundwater Table

1) ***Evolution of physical parameters***

Table 2 presents the seasonal evolution (February and October) of the physical parameters of well water in the city of M'bahiakro. The average pH changes from 4.12 ± 0.73 in February to 5.73 ± 0.69 in October. These values obtained over all seasons are generally below the WHO standard, recommending values between 6.5 - 8 for drinking water. The temperature of well water is generally around 28˚C on average and is higher in February with a maximum value of 30.5˚C compared to 28.7˚C in October. The redox potential for these sampling campaigns varies on average from 78.6 ± 12.3 mV to 87.5 ± 10.1 mV in February and October respectively and is generally lower in February. Mineralization is strong and results in high EC values and well above the WHO recommended standard. It is generally high in the short rainy season (October) and evolves on average from 369.4 ± 256.8 µS/cm (February) to 984.1 ± 736.03 µS/cm (October).

Table 2. Evolution of the physical parameters of M'bahiakro well water.

		Year 2018								
		February				October				WHO Standards
Parameters	Units	Min	mean	Max	SD	Min	mean	Max	SD	2017
Total (n = 19)										
pH		4.45	**4.12**	5.97	±0.73	3.09	**5.73**	7.72	±0.69	**6.5 - 8**
T	˚C	27.3	**28.85**	30.5	±0.74	26.8	**28. 3**	28.7	±0.58	
Eh	mV	25.1	**78.6**	102.8	±12.3	35.7	**87.5**	114.3	±10.1	**25**
EC	µS/cm	118.5	**369.4**	841	±256.8	187.5	**984.1**	2539.1	±736.03	**250**
O_2	mg/L	0	**0.38**	1.13	±0.26	1.01	**6.64**	19.75	±4.68	
depth	m	1.98	**4.64**	7.18	±1.14	1.58	**3.45**	6.65	±1.21	

Dissolved oxygen (O_2) increases from 0.38 mg/l in February to 2.45 mg/l in October. The greatest depth is observed over the February period (4.64 ± 1.14 m on average) and the lowest over the October period (3.45 ± 1.21 m on average).

2) ***Evolution of chemical parameters***

The results of the chemical analyses of the M'bahiakro well water are shown in Figure 2. Ca^{2+} and Mg^{2+} ions remain relatively variable and are more marked during the dry season. Ca^{2+} ions vary on average by 26.7 mg/L during the February period and by 7.5 mg/L in October. As for Mg^{2+} ions, they evolve on average from 18.3 mg/L (February) to 3.15 mg/L in October.

The levels of potassium (K^+) and sodium (Na^+) vary from 75.62 mg/L (February) to 116.31 mg/L (October) and 86.48 mg/L (February) to 96.54 mg/L (October) respectively. The K^+ and Na^+ ions appear more in the high rainy season (October). In M'Bahiakro well water, bicarbonate (HCO_3^-) has average concentrations of 67.87 mg/L in February and 35.9 mg/L in October. Chloride (Cl^-) levels are also low, ranging from 92.71 mg/L (February) to 128.83 mg/L (October). Sulphate (SO_4^{2-}) is weakly present in the waters studied, with concentrations ranging from 26.45 mg/L (February) to 70.38 mg/L (October). All these chemical parameters defined above generally comply with the drinking water standards for drinking water. However, for NO_3^- ions, there is a clear distinction between average levels above the recommended standard (>50 mg/l) over all the seasons studied and more marked in the rainy season (October). Mean values range from 106.52 mg/L in February to 121.13 mg/L in October. In the study area, the order of variation in well water mineralization over the two seasons is as follows: (K^+ + Na^+) > Ca^{2+} > Mg^{2+} at cation level and (Cl^- + NO_3^-) > SO_4^{2-} > HCO_3^- at anion level. Therefore, the definition of the different chemical facies of the groundwater during our study is given in Figure 3, because the chemical analyses for the 19 water points taken over the seasons (February and October), shown on the Piper diagram indicate, according to the seasons, that our waters are sodium and potassium chlorinated in February and sodium hyperchlorinated in October.

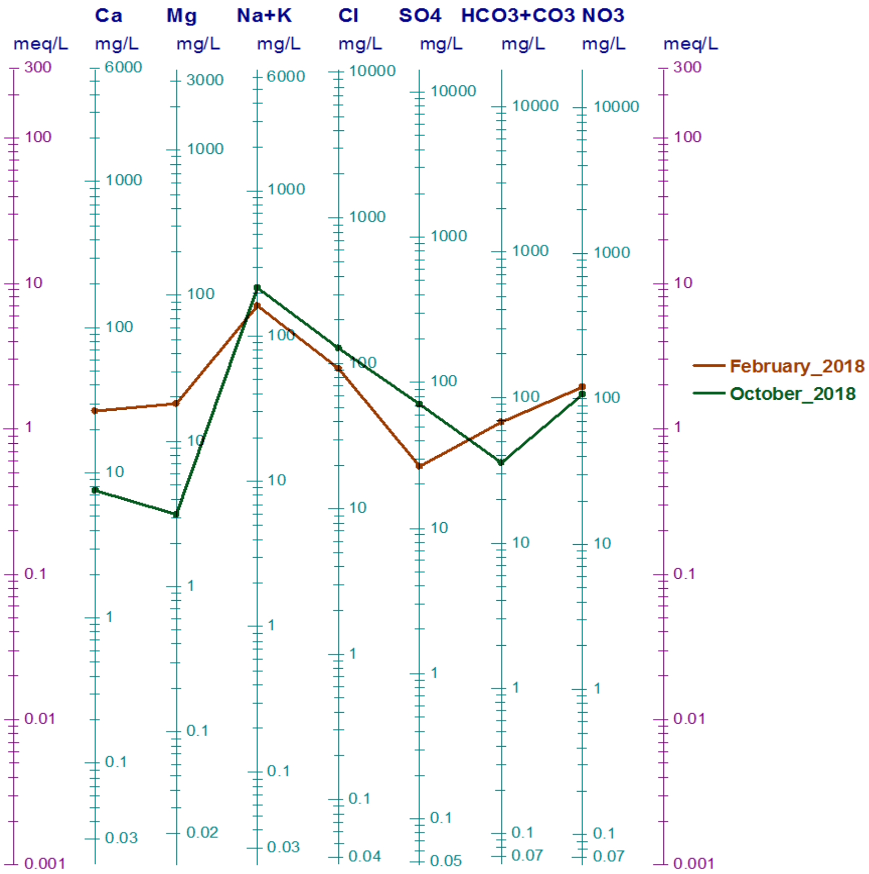

Figure 2. Evolution of chemical parameters of M'bahiakro well water.

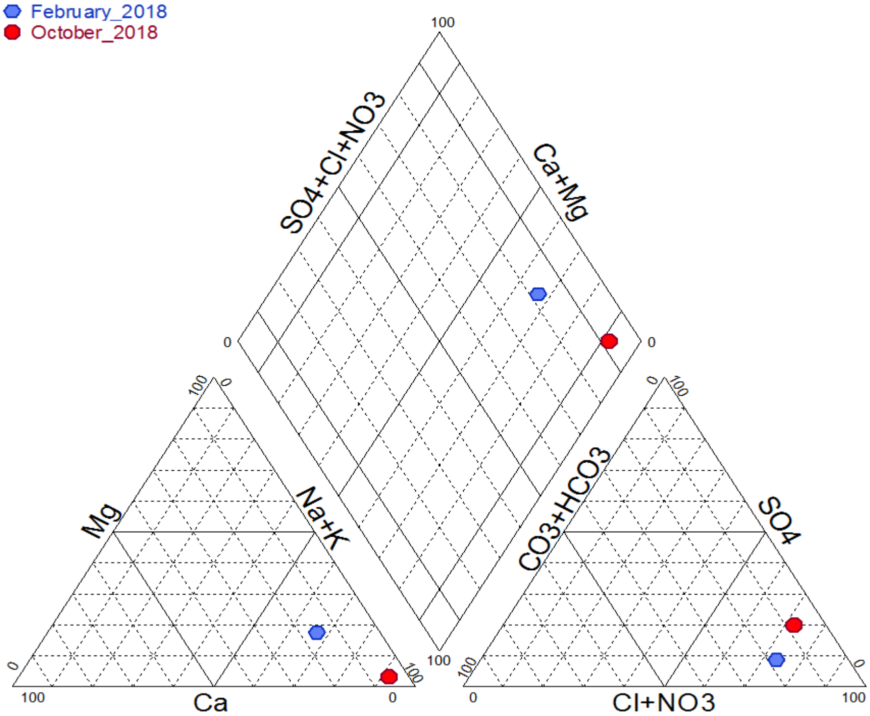

Figure 3. Classification of M'bahiakro well water in the Piper diagram.

3.2. Origin of the Mineralization of the M'bahiakro Groundwater Table

Since the variables are at different scales, the PCA development involves the standardization of data. Bartlett's sphericity test, conducted prior to development, showed a statistically significant correlation ($p < 0.0005$) between the variables and therefore the PCA reasonableness. The resulting eigenvalues and explained percentages of variance are reported in Table 3. In theory, according to the Kaiser criterion, four components (PC1-PC4) could be considered, having an eigenvalue greater than 1, but depending on the diagrams trend (not shown), taking into account the amount of variance explained by the components and finally evaluating the composition of the components themselves, the first two (PC1 and PC2) are sufficient to represent the initial data set (PC1 and PC2 together represent 67.94% of the variance). In fact, the significant drop in variance from the PC3, which retains less than 17% of the total inertia (PC3 (10.54%), PC4 (8.41%), PC5 (4.60%) < average threshold 1/6 = 17%), allows us to retain the first two components (Table 3).

The first two components thus reflect most of the information sought on hydrogeochemical interactions in the groundwater table and make it possible to significantly represent the point cloud because the sum of the variance expressed by is 67.94% (Table 3). The contribution of different variables in main components definition is given by Table 4. Each component is defined by a number of variables that are essential in highlighting the mechanism of water mineralization. PC1, the most important, alone explains 41.39% of the cloud inertia of points representative of the wells and is defined by the ions NO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, K^+, Na^+, EC, TDS, dissolved oxygen (O_2), salinity, pH and Eh. The grouping of the majority of the variables supported by mineralization is described around this axis. PC2 expresses 26.55% of the variance and includes Ca^{2+}, Mg^{2+}, NO_2^-, NH_4^+, PO_4^{2-}, pH, temperature (T), dissolved oxygen (O2) and depth (Table 4).

Significant links between the different physical and chemical parameters are given by the correlation matrix (Table 5). These links reflect the different correlations between the variables studied. Thus, this matrix indicates that the chemical parameters influencing the mineralization of the wells waters are NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} because the correlations between these parameters with electrical conductivity are significant: (r(EC-NO_3^-) = 0.610, r(EC-Ca^{2+})= −0.549, r(EC-Mg^{2+}) = −0.549, r(EC-Na^+) = −0.658 and r(EC-Na^+) = −0.745. In addition, the graphical representation in the variable and statistical unit spaces of the F1-F2

Table 3. Eigenvalues and percentages expressed for the main axes.

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	7.41	4.77	1.79	1.43	0.78
total % of the variance expressed	41.39	26.55	10.54	8.41	4.60
Cumulative variance expressed	41.39	67.94	78.43	86.84	91.44

Table 4. Correlations between variables and factors.

Variables	PC1	PC2
pH	**−0.720**	**0.560**
Eh	**0.718**	**−0.561**
T	0.431	**−0.721**
EC	**0.866**	0.107
TDS	**0.916**	0.238
Sal.	**0.915**	0.241
depth	**0.560**	**0.786**
O_2	**−0.584**	**−0.648**
Ca^{2+}	**−0.673**	**0.638**
Mg^{2+}	**−0.673**	**0.638**
Na^+	**−0.788**	0.107
K^+	**−0.567**	0.003
Cl	**0.506**	−0.104
NO_2^-	**0.494**	**0.586**
NO_3^-	**0.708**	−0.104
NH_4^+	**0.835**	**0.488**
SO_4^{2-}	−0.217	−0.092
PO_4^{3-}	0.215	**0.757**

Table 5. Correlation matrix of physico-chemical parameters of well water.

Variables	pH	Eh	T	EC	TDS	salinity	depth	Ca^{2+}	Mg^{2+}	NO_2^-	NO_3^-	NH_4^+	SO_4^{2-}	PO_4^{3-}	Cl^-	O_2	Na^+	K^+
pH	**1**																	
Eh	**−1**	**1**																
T	**−0.704**	**0.705**	**1**															
EC	−0.458	0.455	0.166	**1**														
TDS	−0.455	0.453	0.165	**0.964**	**1**													
salinity	−0.452	0.449	0.164	**0.963**	1	**1**												
depth	0.026	−0.028	−0.392	**0.548**	**0.667**	**0.668**	**1**											
Ca^{2+}	**0.784**	**−0.782**	**−0.653**	**−0.549**	−0.458	−0.455	0.055	**1**										
Mg^{2+}	**0.785**	**−0.783**	**−0.654**	**−0.549**	−0.458	−0.455	0.056	**1**	**1**									
NO_2^-	−0.216	0.218	−0.129	0.254	0.444	0.443	**0.798**	0.11	0.11	**1**								
NO_3^-	**−0.558**	**0.555**	0.445	**0.610**	**0.639**	**0.630**	0.217	−0.476	−0.476	0.258	**1**							
NH_4^+	0.082	−0.084	−0.368	0.451	**0.58**	**0.579**	**0.906**	0.250	0.251	**0.767**	0.314	**1**						
SO_4^{2-}	0.014	−0.213	−0.257	−0.142	−0.227	−0.145	−0.080	0.172	0.170	−0.051	−0.266	−0.115	**1**					
PO_4^{3-}	0.287	−0.290	−0.459	0.290	0.392	0.396	**0.660**	0.271	0.272	0.371	0.068	**0.710**	**−0.136**	**1**				
Cl^-	−0.431	0.436	0.23	0.394	0.483	0.492	0.220	−0.325	−0.325	0.344	0.478	0.007	−0.024	−0.096	**1**			
O_2	0.047	−0.047	0.076	−0.432	**−0.605**	**−0.609**	**−0.873**	−0.027	−0.027	**−0.786**	−0.182	**−0.789**	**0.149**	−0.480	−0.293	**1**		
Na^+	**0.516**	**−0.51**	−0.295	**−0.745**	**−0.707**	**−0.706**	−0.441	**0.731**	**0.730**	−0.146	−0.377	−0.262	0.138	−0.077	−0.220	0.491	**1**	
K^+	**0.474**	−0.473	**−0.62**	**−0.658**	−0.403	−0.405	−0.182	0.207	0.208	−0.374	**−0.554**	−0.375	0.187	−0.211	−0.183	0.442	0.254	**1**

In bold, significant values (excluding diagonal) at the alpha threshold = 0.050.

factorial design (Figure 4) shows three main groupings of chemical elements and two main groupings of water points. Class 1 contains the majority of the water points in the study area (84%) (Figure 4(b)). These water points correspond to highly mineralized well waters containing the chemical elements of group 2 and 3 (Figure 4(a)) whose ionic acquisition is mostly supported by NO_3^- due to the positive and significant correlation between EC and NO_3 (r(EC-NO_3^-)= 0.610) (Table 4). Class 2 includes well water (16%) that is moderately mineralized and whose ionic acquisition is controlled by the Na^+, K^+, Ca^{2+} and Mg^{2+} ions of group 1 elements (Figure 4(a)).

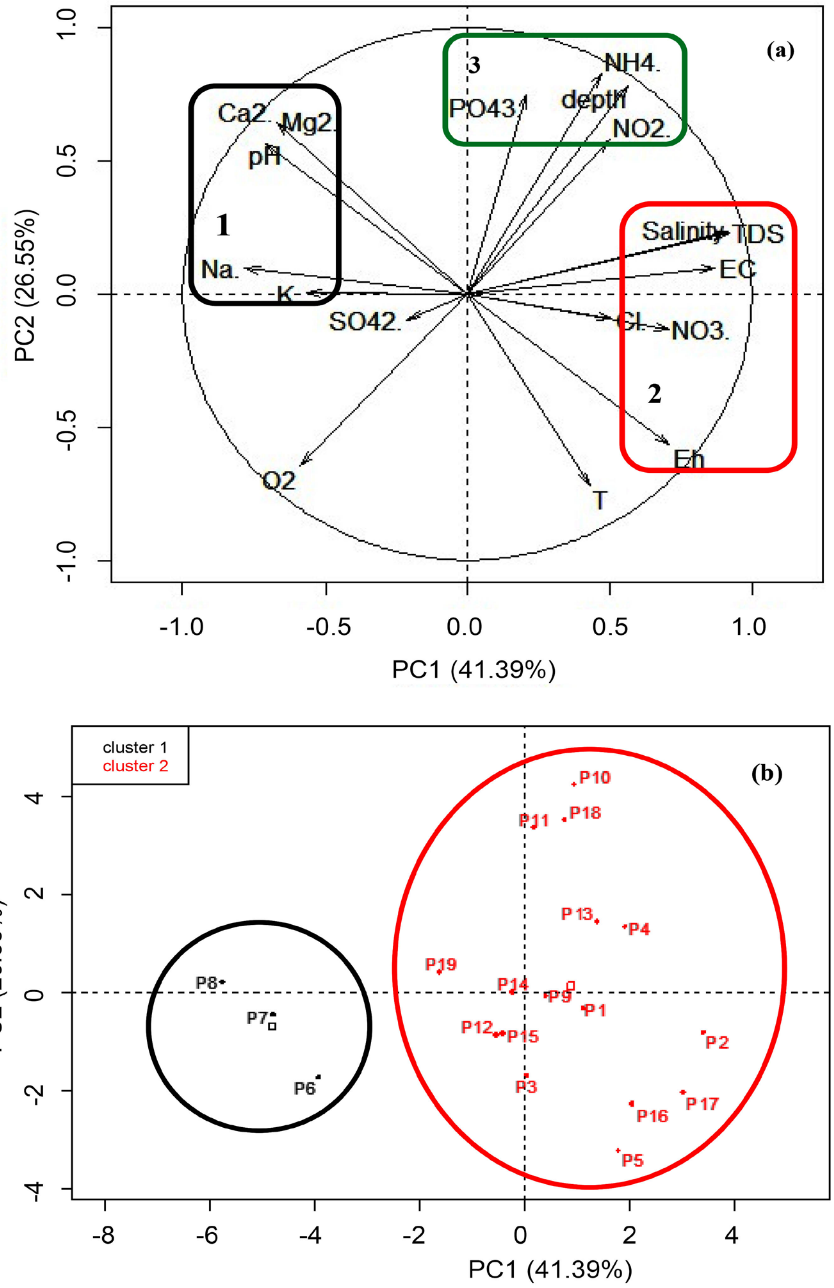

Figure 4. Results of the PCA analysis in the PC1 × PC2 plan: clustering of parameters (a), clustering of statistical units (b).

3.3. Microbiological Characteristics of the Groundwater Table

Microbiological quality assessment includes the analysis of fecal *E. coli*, *fecal streptococci* and *Clostridium perfringens* in well water. Figures 5 shows the seasonal variations in the densities of these bacteria in the water of the wells studied.

In October, 100% of the wells studied contain *E. coli* and *fecal streptococci* germs, with the exception of *Clostridium perfringens*, which are present in 95% of the wells studied (excluding wells P5, P6 and P8). The densities of these germs are generally much higher than those measured in the dry period. *E. coli* densities range from 0 to 8500 CFU/100 mL in February and from 130 to 69,000 CFU/100 mL in October (Figure 5(a)). *E. coli* are present in 79% of wells (P2, P5, P7 to P19) in February. The search for *fecal streptococci* in the well water analysed showed that in February 16% of the wells (P1, P8, P9) are free of these germs. The recorded FS densities range from 0 to 15,000 CFU/100mL (February) and from 80 to 2400 CFU/100mL (October) (Figure 5(b)). *Clostridium perfringens* appear in wells P8, P14, P15 and P17, representing 21% of the wells studied in February. Their values range from 0 to 700 CFU/100mL during the February period compared to 0 to 290 CFU/100mL during the October period (Figure 5(c)).

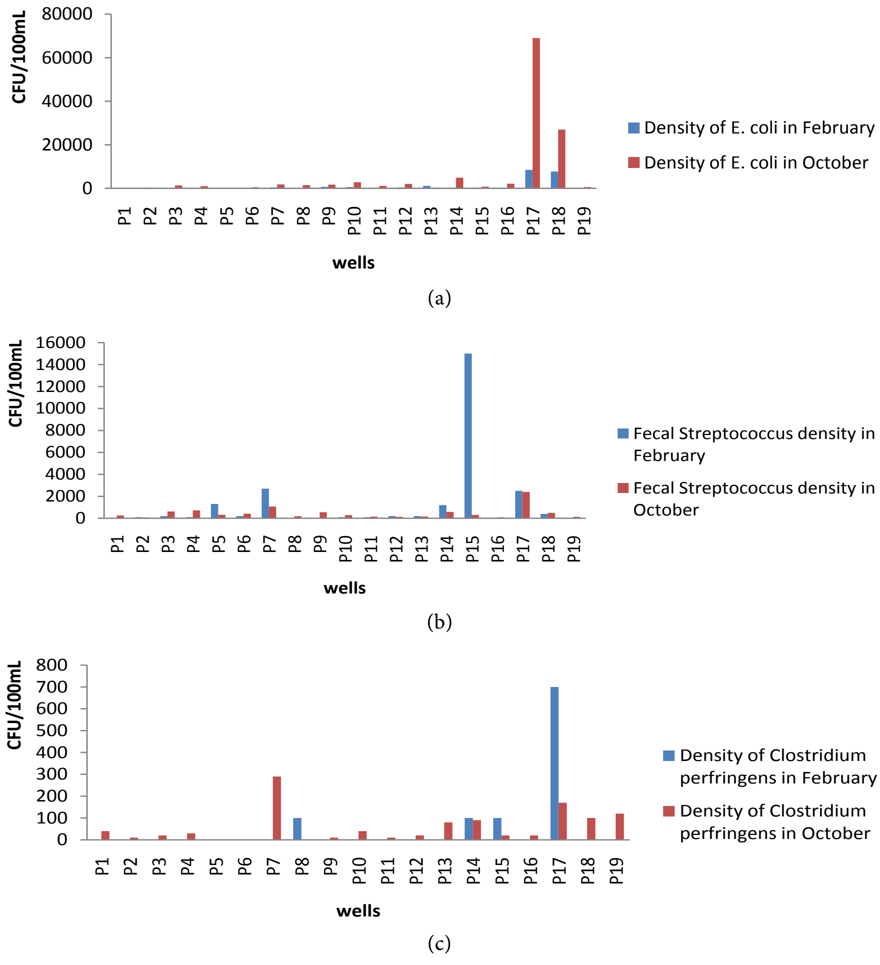

Figure 5. Results of microbiological analysis of M'bahiakro well water: (a) *E. Coli*; (b) *Fecal Streptococci*; (c) *Clostridium perfringens*.

4. Discussion

The well water in the M'Bahiakro city is acidic and has pH values that vary on average between 4 and 6 over all seasons. It rises on average from 4.12 in February to 5.73 in October. This acidity is related to that of the characteristic aquifers of Cote d'Ivoire, particularly in the basement area (Savané & Soro, 2001). The water temperature varies between 27˚C and 30˚C. This temperature corresponds to the seasonal variations in ambient atmospheric temperatures defined by meteorological data (30˚C). The redox potential (Eh) for these sampling campaigns varies on average from 78 mV to 88 mV. Dissolved oxygen (O_2) increases from 0.38 mg/L in February to 2.45 mg/L in October. These values show that the waters in the study area are open to the atmosphere and evolve in an oxidizing environment (Ahoussi et al., 2018). These waters are also highly mineralized with average Electrical Conductivity values ranging from 824.2 to 950 µS/cm, well above the acceptable drinking water value recommended by WHO (2017). Their chemical composition is characterized by variations and dominance of the main chemical elements such as Na^+, K^+ and NO_3^-. Variations in these parameters would therefore be responsible for the evolution of the chemical facies of the groundwater from sodium and potassium chloride in the dry season to sodium hyperchloride in the rainy season. Enrichment of well waters with these major chemical parameters would justify contamination of groundwater by domestic discharges (latrine, septic tank) (Kouamé et al., 2012).

Two phenomena contribute to the mineralization of the waters in the study area, such as the hydrolysis of aquifer minerals and the contamination of well water by anthropogenic sources. These results agree with those of Shahbazi & Esmaeili-Sari (2009) and de Amadou et al. (2014) who also highlighted the same phenomena of mineralization in the groundwater of the province of Mazandaran (Iran) and the region of Tahoua (Niger). Also, Lapworth et al. (2017) have pointed out that, high concentrations of chemical parameters such as NO_3^- may be associated with a high number of enteritis bacteria which show fecal contamination of urban groundwater. Groundwater in M'Bahiakro city contains high amounts of enteritis bacteria. Presence of *E. coli*, faecal streptococci and *Clostridium perfringens* in well water may be due to contamination from faeces. This result is consistent with those of Hassane et al. (2016) and Ouattara et al. (2016), indicating that the sensitivity of aquifers to pollution appears mainly during the rainy season, at the time of groundwater recharge. The presence of these bacteria would confirm the influence of septic tanks on the quality of M'Bahiakro well water and by extension would be linked to the redox of organic matter in well water. These results are in agreement with those of Ahoussi et al. (2011), Kouamé et al. (2012), Ayad & Kahoul (2016) and Orou et al. (2016) who showed that the presence of these bacteria is due to the degradation of organic matter due to contamination of wells by nearby septic tanks.

5. Conclusion

The hydrochemical and bacteriological study of well water in the city of

M'Bahiakro made it possible to characterize this natural resource. Physicochemical analyses show that the waters are acidic and very highly mineralized. These waters belong to the chlorinated water family and evolve from one season to another with a dominance of NO_3^- anions and Na^+ and K^+ cations. The different processes responsible for the mineralization of M'Bahiakro's well water are: the intervention of anthropogenic activities in the pollution of groundwater, which is represented in the majority of the city's well water, and the leaching of minerals from the soil. Also the exploitation of bacteriological results shows that the wells studied host high densities of enteritis bacteria (*E. coli*, *Fecal Streptococci* and *Clostridium perfringens*) according to the seasons. These waters are of poor quality and therefore not recommended for human consumption without prior treatment.

It is therefore recommended that effective management systems be implemented for enteric bacteria and that nitrate in well water be monitored to prevent adverse effects on population health.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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