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Effect of seasonal variability on the physico-chemical quality of surface and groundwater of the Mbe plateau in Pool-north (Republic of Congo)

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Abstract

Water is a vital resource for humanity. The quality of this resource is essential for the preservation of ecosystems and human health. This study examines the effect of seasonal variability on the physicochemical quality of surface and groundwater in the Mbe Plateau region of Pool-Nord in the Republic of Congo. One hundred and twenty (120) water samples from eight different water sources, including one well, four boreholes and three rivers, between November 2017 and August 2018 were studied. Laboratory analyzes of these samples make it possible to characterize the physicochemical elements of the water. These results are processed using a hydrochemical method, using the diagrams of: Piper, Schoeller Berkaloff, Stiff, and Wilcox. The results show that the values obtained after the analysis of the water samples do not present any significant variation and all comply with the WHO standards for drinking water, except for the temperature which is slightly higher than normal, with values between 24.1 and 27.1°C. The electrical conductivity values range from 5.14 to 16.3 μS/cm and do not show significant seasonal variation. The pH of the waters varies from 4.02 to 6.4, indicating an acidity that does not follow seasonal variation, confirming the acidic nature of the water in the study region. The values of the other physicochemical parameters of the water do not vary significantly depending on the seasons. The waters of the region belong to the calcic chloride facies. The dry season revealed the presence of a second calcic bicarbonate facies. The waters are weakly mineralized and belong to the excellent group on the Wilcox diagram, indicating their drinkability.

Keywords: Waters, Mbé plateau, seasonal variability, acidic pH, Pool-North-Congo.

Introduction

The problem of water resources is acute due to their irregularity in time and space. This irregularity of water resources induces crises linked either to its absence or to its excess. A water that is contaminated naturally or as a result of human activity becomes unsuitable for any use, hence it presents a danger to the environment. The degree of contamination or pollution is assessed by measuring the gap or difference between the natural chemistry of the water, whether on a local or regional scale, and certain chemistry newly acquired following the intervention. Negative impact of man on the hydrogeological environment if the concentration of certain elements exceeds drinking standards[1].

Over the past twenty years, different States have increasingly paid increasing attention to the concept of climate change, which remains a very broad concept (reduction in rainfall, increase in temperature, greenhouse effect, etc.). Particularly in Africa, the idea of climate change largely boils down to drastic reductions in rainfall, the most important climate factor, as several studies have found[2-5]. The reduction had some consequences, most of them serious (droughts occurred in some West African countries in the 1970s and 1980s, 1984, and 2006). In the Congo-Brazzaville Mbe Plateau (Figure-1), water quality and quantity issues become acute due to lack of surface water sources, poor water quality, and frequent droughts during the dry season[6]. Several reports assess this situation[7-12] and report on some projects[13]. However, there are no detailed studies on the impact of seasonal rainfall changes on the waters of the Mbe Plateau. Therefore, these water bodies should be characterized seasonally to study their impact on water resources, which may vary from season to season.

The scarcity of surface water and the non-sustainability of this surface resource on the Mbé plateau are due to the geological conditions consisting essentially of sand, which favored the use of the deep aquifer as a palliative to satisfy the needs of the populations[6,14]. This aquifer is mainly fed by rainwater infiltration into the ground[6,14].

Currently, many economic operators have undertaken different activities (livestock breeding, agriculture, agri-food industry, etc.) on this plateau[15]. This study therefore aims to see the effect of seasonal variation on the water quality of the study area.

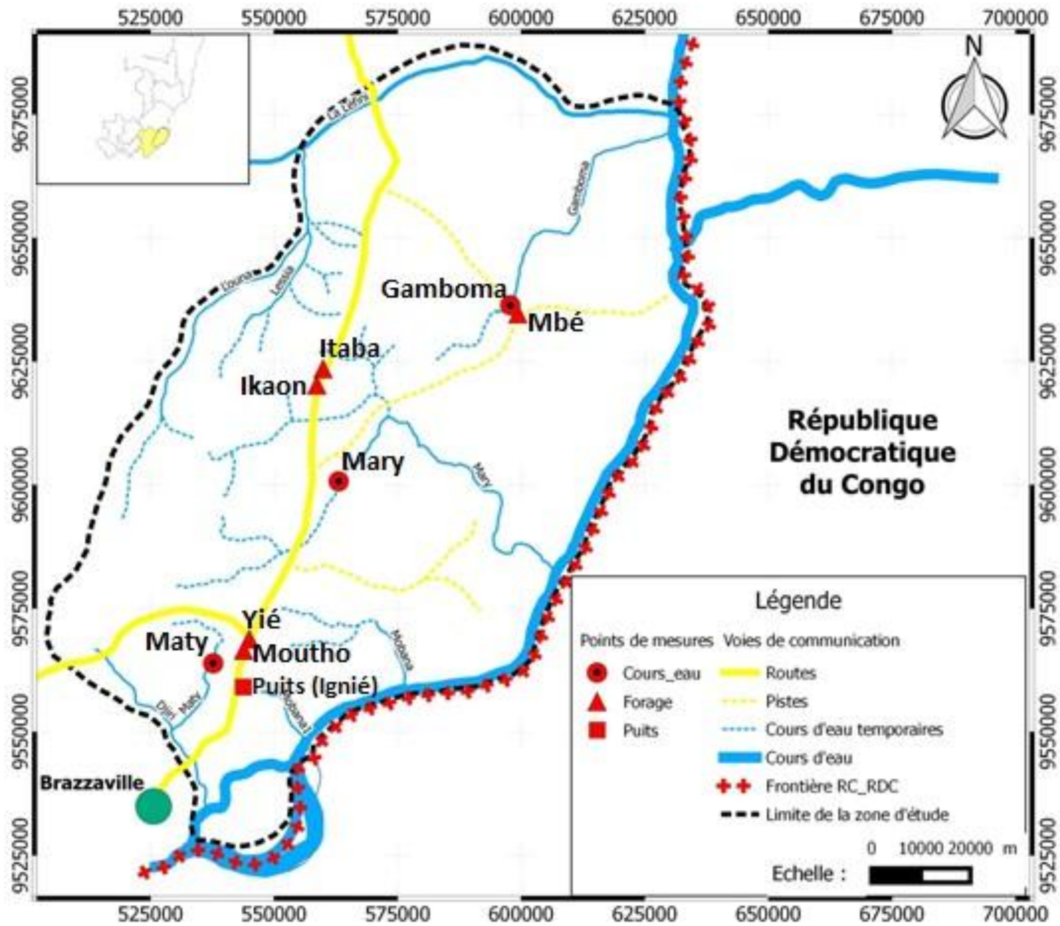


Figure-1: Location of the study area and sampling points[13].

Methodology

Eight (08) water levels (1 well, 4 boreholes, 3 streams) sampled over 4 seasons were geographically located using GPS and 120 samples were collected between November 2017 and May 2018 Perform physical and chemical analysis (Figure-1). The samples were taken and packaged in 1.5 liter polyethylene bottles specially prepared for this purpose. The samples for the boreholes equipped with taps were taken after running the water in a vacuum for several minutes. The sampling bottles before filling were rinsed several times with the water to be sampled and immediately stored in a cooler at 4°C. The analyzes were carried out quickly within 24 hours. The analysis concerned the physical, major, some heavy metals and many others in the laboratory of the IRSEN Exact and Natural Sciences Research Institute in Brazzaville using a spectrophotometer using the classic methods recommended by French standards (AFNOR). Comparison of physical and chemical element content in water in different seasons with World Health Organization standards[16]; conducted[17] times. To understand the aqueous phase, geochemical studies were performed using Piper, Schoeller-Berkalof, and Wilcox directed drinking water capacity plots. Check the quality of the analysis using ion balance to ensure the reliability of the results.

Results and Discussion

Fluctuation of interannual monthly averages of rainfall and temperature between 1987-2022: The variation of rainfall indices in the study area is represented for the synoptic stations of Brazzaville and Djambala of interannual monthly averages and temperature between 1987 and 2022 (Figure-2). The analysis of the evolution of rainfall indices shows a rainy period (September-May) of 9 months with a decrease in rain (mid-January-February) and a dry period (June-September in Brazzaville) of 3 to 4 months.

Results of physicochemical measurements of water: The results of the different physicochemical analyzes carried out in the rainy season and in the dry season on the waters of the Mbé plateau are recorded in Table-1. The water analyzes carried out have an ionic balance of between 5 and 10%, these analyzes are therefore of acceptable qualities.

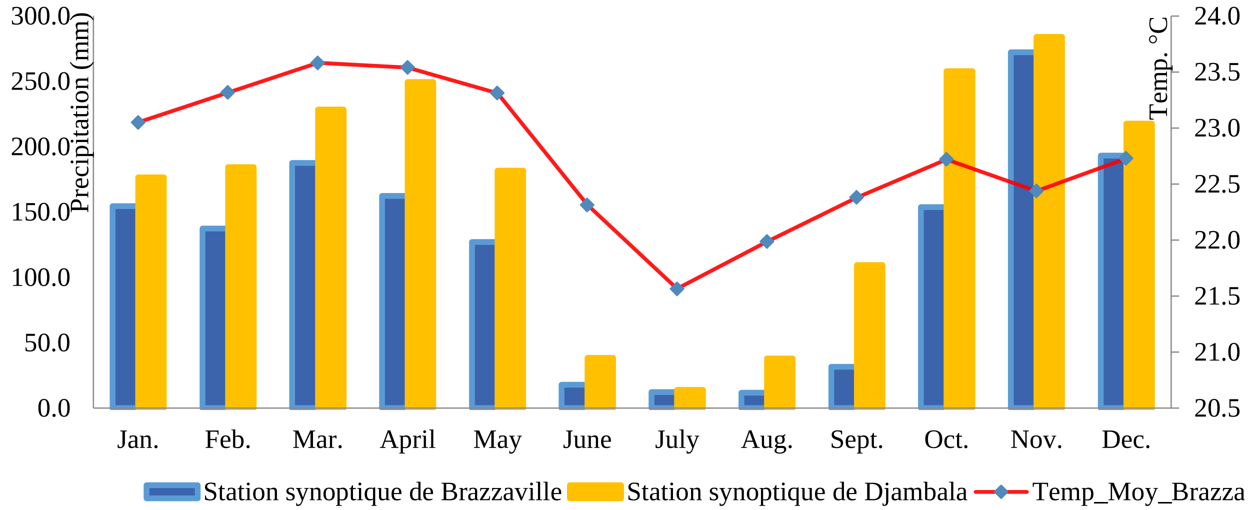


Figure-2: Variation in average monthly precipitation at the Brazzaville and Djambala stations for the period (1987-2022), source National Civil Aviation Agency (ANAC) of Brazzaville.

Table-1: Physico-chemical laboratory results.

Work	Period	pH	T°C	THIS	TDS	Ca2+	Mg^{2}+	K^{+}	Na^{+}	Al^{3}+	NH_4+	Cu^{2}+	Fe^{2}+	Pb^{2}+	Cd^{2}+	Mn^{2}+	HCO_3-	Cl^{-}	SO_4^{2}-	NO^{3}-	PO_4^{3}-	TH	Alc.
Well 45	Nov. 2017	4.3	26.9	12.8	10.0	6	7	1.4	0.1	0.4	0.1	0.7	0.0	0.2	0.0	0.1	12.2	9.7	4.2	0.4	0.1	7.7	62
	Feb. 2018	5.2	26.4	7.5	9.0	10.0	7.0	1.5	0.1	0.5	0.1	0.1	0.1	0.2	0.0	0.1	12.4	11.6	4.1	0.3	0.1	8.0	22.0
	May 2018	5.3	26.9	8.8	11.0	13.0	10.0	2.0	0.2	0.8	1.1	0.1	0.1	0.2	0.0	0.1	14.1	18.1	4.0	3.9	0.4	13.0	5.0
	August 2018	4.2	25.8	5.1	7.0	8.0	5.0	1.1	0.1	0.3	0.1	0.8	0.1	0.1	0.0	0.0	10.2	9.4	2.3	0.3	0.1	7.0	19.0
Massa	Nov. 2017	5.1	26.3	6.4	7.0	13	10	1.5	0.2	0.3	0.0	0.6	0.0	0.1	0.0	0.0	8.9	7.6	9.1	0.1	0.0	4	54
	Feb. 2018	6.2	25.9	9.0	7.0	18.0	6.0	1.7	0.2	0.8	0.1	0.8	0.1	0.9	0.0	0.0	9.6	8.0	3.7	0.1	0.1	4.0	25.0
	May 2018	6.4	26.2	9.1	13.0	16.0	8.0	2.1	0.2	0.1	0.1	0.1	0.1	0.3	0.0	0.0	10.1	12.4	8.0	0.3	0.5	7.0	30.0
	August 2018	5.0	24.6	8.2	6.0	14.0	4.0	1.1	0.1	0.3	0.1	0.5	0.0	0.5	0.0	0.0	7.2	6.4	2.7	0.1	0.1	2.0	20.0
Dieu Le Veut	Nov. 2017	5.2	26.4	9.1	11.1	11	11	1.4	0.2	0.2	0.0	0.5	0.0	0.2	0.0	0.0	10	4.1	3.6	0.2	0.1	7.8	48
	Feb. 2018	5.0	26.1	7.2	11.0	10.0	11.0	1.5	0.2	0.2	0.1	0.5	0.0	0.2	0.0	0.0	10.1	4.3	4.3	0.3	0.1	8.0	32.0
	May 2018	5.1	26.9	7.9	13.0	6.0	7.0	2.0	0.2	0.4	0.1	0.7	0.1	0.3	0.0	0.0	13.2	9.1	4.0	0.7	0.1	16.0	13.0
	August 2018	4.4	25.8	6.3	8.0	7.0	9.0	1.1	0.2	0.2	0.0	0.2	0.0	0.1	0.0	0.0	8.2	28.0	2.1	0.2	0.1	6.0	28.0

Ingha	Nov. 2017	5.2	26.8	6.3	8.2	12	8	1.9	0.3	0.3	0.0	0.7	0.0	0.1	0.0	0.0	8.6	5.7	8.3	0.1	0.0	7.1	39
	Feb. 2018	5.0	26.3	8.4	8.5	12.8	8.3	1.5	0.2	0.5	0.1	0.6	0.1	0.4	0.0	0.0	8.8	7.8	4.1	0.3	0.1	7.5	25.0
	May 2018	5.4	26.2	8.0	15.0	10.0	12.0	2.1	0.3	0.3	0.1	0.5	0.1	0.9	0.0	0.0	9.1	12.8	11.0	0.5	0.1	12.0	32.0
	August 2018	4.2	24.1	7.2	12.0	8.0	9.0	1.0	0.2	0.2	0.0	0.2	0.0	0.7	0.0	0.0	28.3	1.2	1.8	0.4	0.1	5.0	29.0
Imvoumba	Nov. 2017	5.4	27.1	11.1	7.0	15	12	2.1	0.2	0.2	0.1	0.6	0.0	0.3	0.0	0.1	3	4.2	3.1	0.3	0.1	9	38
	Feb. 2018	5.3	26.7	9.9	7.0	13.0	9.0	1.2	0.3	0.5	0.1	0.9	0.1	0.3	0.0	0.1	3.2	7.3	4.1	0.3	0.1	10.0	21.0
	May 2018	5.5	27.0	10.1	16.0	18.0	12.0	1.8	0.3	0.7	1.1	0.1	0.1	0.4	0.0	0.1	8.4	10.1	7.0	1.0	0.6	15.0	28.0
	August 2018	4.0	25.6	9.2	4.0	9.0	7.0	1.0	0.2	0.3	0.1	0.6	0.0	0.2	0.0	0.1	2.8	5.6	3.0	0.3	0.1	8.0	19.0
La Maty	Nov. 2017	5.1	26.7	8.8	8.2	11	7	1.1	0.3	0.2	0.0	0.5	0.0	0.9	0.0	0.0	4.9	5.9	2.5	0.1	0.0	3.1	89
	Feb. 2018	5.0	26.3	7.9	8.0	11.0	7.0	1.1	0.3	0.3	0.1	0.5	0.0	0.7	0.0	0.0	5.3	6.7	1.9	0.1	0.0	3.0	79.0
	May 2018	5.2	26.7	8.2	10.0	12.0	10.0	2.2	0.2	0.5	0.0	0.8	0.0	0.9	0.0	0.0	10.0	5.2	7.0	1.2	0.5	10.0	7.0
	August 2018	4.3	26.1	6.4	6.0	7.0	4.0	1.0	0.3	0.2	0.1	0.0	0.0	0.4	0.0	0.1	3.1	3.6	0.8	0.0	0.0	2.0	71.0
La Mary	Nov. 2017	5.2	26.9	7.7	9.8	13	9	1.7	0.3	0.2	0.0	0.5	0.0	0.1	0.0	0.1	7.0	5.0	2.8	0.1	0.0	5	77
	Feb. 2018	5.1	26.7	8.2	10.0	10.0	8.0	1.2	0.4	0.2	0.1	0.5	0.0	0.8	0.0	0.0	7.3	3.7	2.1	0.1	0.0	5.0	72.0
	May 2018	5.1	26.8	8.1	14.0	14.0	6.0	1.4	0.4	0.5	0.1	0.7	0.0	0.1	0.0	0.1	11.4	7.0	10.0	1.1	0.7	11.0	8.0
	August 2018	4.3	26.1	6.4	6.0	7.0	4.0	1.0	0.3	0.2	0.1	0.0	0.0	0.4	0.0	0.1	3.1	3.6	0.8	0.0	0.0	2.0	71.0
Gamboma	Nov. 2017	5.0	27	16.3	9	10	14	2.9	0.3	0.5	0.1	0.6	0.0	0.3	0.0	0.1	4.1	5.8	4.2	0.1	0.0	6	54
	Feb. 2018	4.2	26.0	12.4	9.0	8.0	12.0	1.7	0.4	0.7	0.1	0.8	0.0	0.3	0.0	0.1	4.3	6.2	4.1	0.1	0.0	6.0	51.0
	May 2018	5.0	27.1	13.6	14.0	10.0	13.0	2.6	0.4	0.9	0.5	0.1	0.1	0.3	0.0	0.0	10.2	6.1	5.2	0.6	0.8	13.0	54.0
	August 2018	4.4	25.4	10.4	9.0	7.0	8.0	1.1	0.3	0.2	0.1	0.5	0.0	0.2	0.0	0.1	2.7	5.9	2.1	0.1	0.0	4.0	47.0
WHO standards (mg/l)		6.5 – 8.5 (1)	25 (1)	< 300.0 (2)	$<600^{(1)}$	75.0 (2)	$50^{(2)}$	$12^{(2)}$	< 200 (1)	0.9 (1)	0.2 (1)	2 (1)	0.2 (1)	0.01 (A, T) (1)	0.003 (1)	0.5 (2)	$<200^{(2)}$	<250 (1)	<250 (1)	50 (1)	$5^{(2)}$	$100 – 300^{(1)}$	$100^{(2)}$

The variation of the physical parameters (pH, T°C, EC and TDS) of the 8 points sampled is represented in Figure-3 and the analysis of the evolution of the physical parameters is made according to the seasonal variability (season of heavy rains). with a seasonal intercalation in February called the short dry season, resumption of rains between March and May which designates the short rainy season and finally, the cessation of rains which marks the long dry season from June to September (Figure-2). In Figure-3 we see that temperatures decrease at all points sampled in August, which corresponds to the long dry season (Figure-2). However, TDS shows an increase in all points during the May campaign. This can be explained by the fact that in the month of April we observe the second peak of rainfall in the area and the month of May being the last month of the rainy season, records the consequences due to the contributions of precipitation from month of April; however, these values are still below the drinking water standards set by the World Health Organization. It can also be noted that the pH values do not change much across the study area (decreasing from May to August). Therefore, we can say that seasonal changes have no direct impact on the physical parameters of the waters in the region. These values are still below the drinking water standards set by the World Health Organization. It can also be noted that the pH values do not change much across the study area (decreasing from May to August). Therefore, we can say that seasonal changes have no direct impact on the physical parameters of the waters in the region. These values are still below the drinking water standards set by the World Health Organization. It can also be noted that the pH values do not change much across the study area (decreasing from May to August). Therefore, we can say that seasonal changes have no direct impact on the physical parameters of the waters in the region.

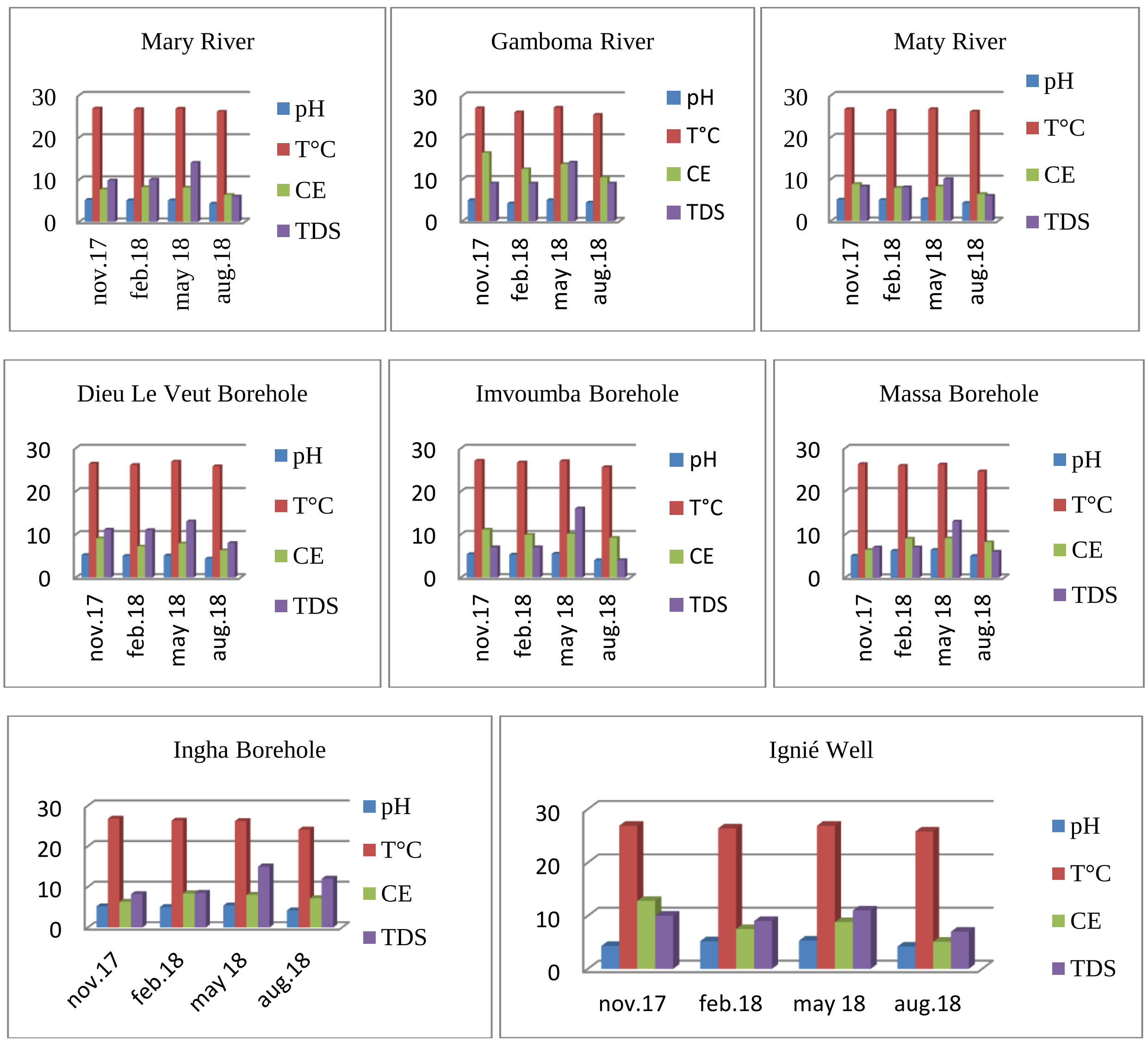


Figure-3: Seasonal variation of pH, T, EC and TDS during the year 2017-2018.

Among the metals and pollutants studied (Figure-4), we note values strictly lower than 1, we could say that they are almost non-existent in the study area. On the other hand, the Cl^- and SO_4^{2-} ions, although these values are lower than those specified by the World Health Organization and show unusual dynamics in all aspects during the month of May. This change is due to the time it takes for rainwater to transfer to groundwater. In the same month, the TDS (Figure-3) of all water points in the study area also changed.

From the prediction of the activity results, the Piper diagram shows only one (01) phase (Figure-5): the calcareous chloride phase. However, the situation was different in August 2018 (dry season) as two phases appeared, specifically the calcareous chloride phase and the calcareous bicarbonate phase. We see that the same well in Massa village is far away from the other wells in the cation triangle. This must be due to the discharge of domestic wastewater from domestic activities and the presence of pigs near the well. Generally speaking, the water in the Mbe Plateau consists of calcium chloride throughout the year and does not show any significant vitality.

Figure-4: Seasonal variation of heavy metals and pollutants measured during the year 2017-2018.

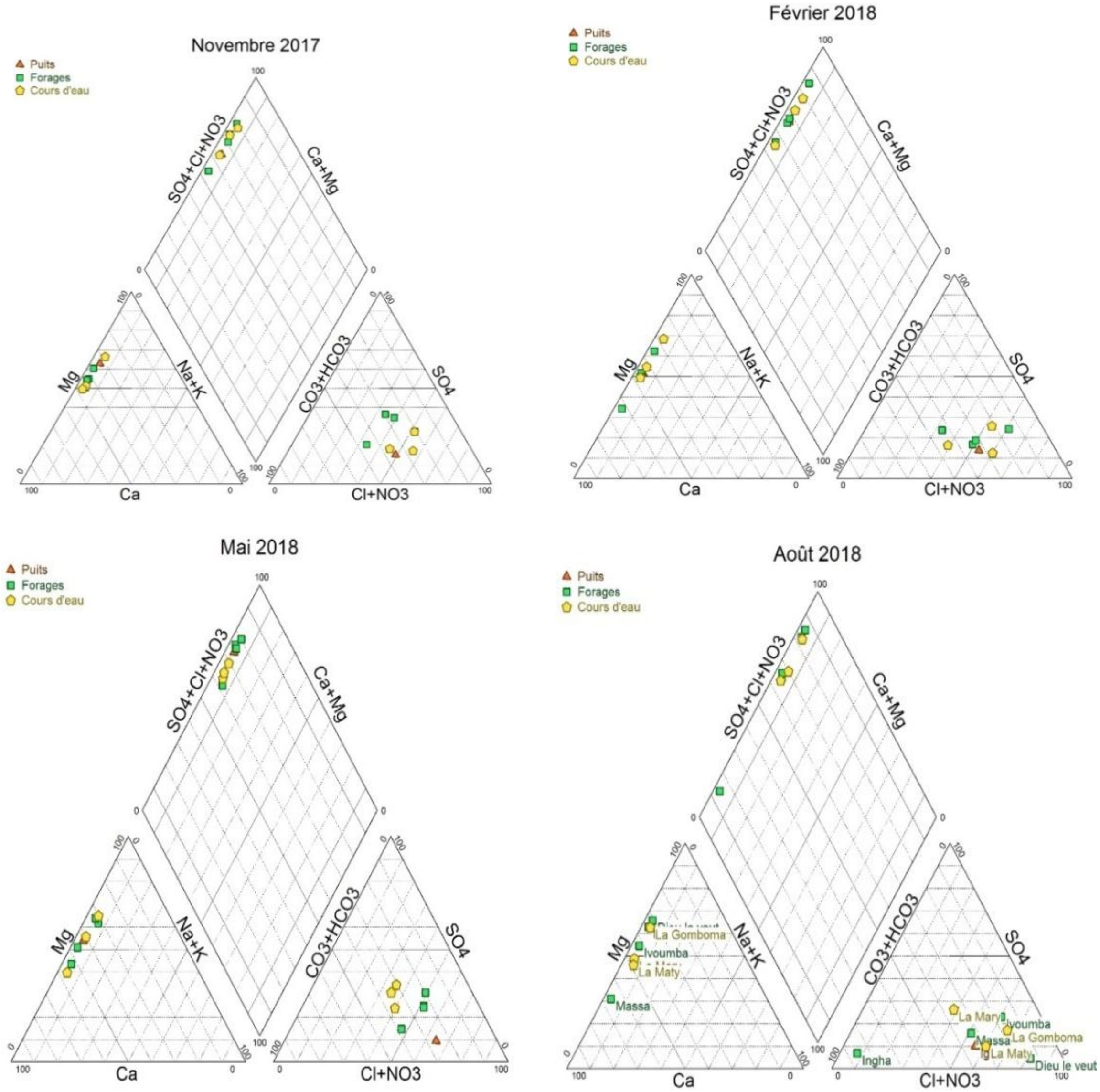
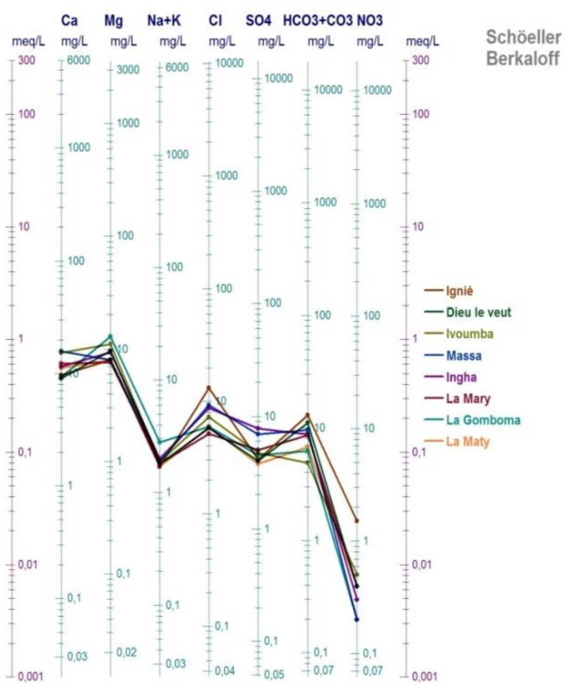


Figure-5: Piper diagram during the year 2017-2018.

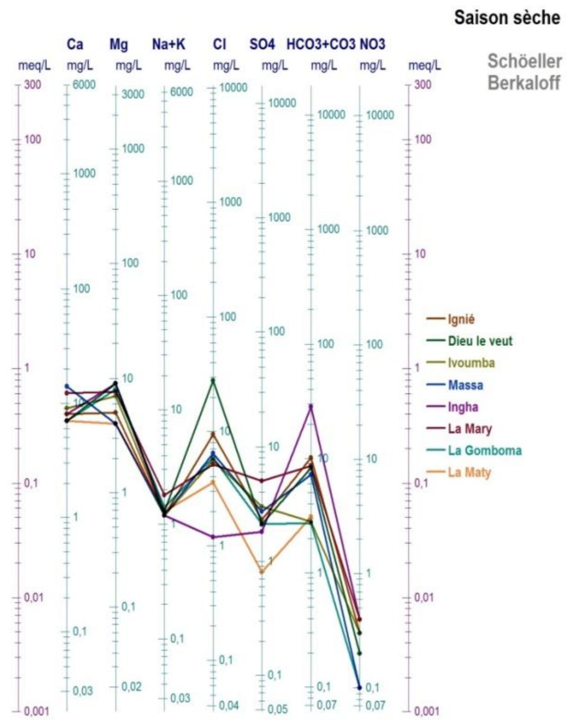
Cations are shown on the left and anions on the right. According to the Schöeller-Berkaloff diagram (Figure-6), the dominant ions are chlorides for anions and magnesium for cations. In Figure-6.b of the dry season, the “Dieu Le Veut” borehole presents the concentration of chlorides higher than those of the rainy season. The same observation is made in the Ingha borehole by the concentration of HCO_3+CO_3. We could therefore emphasize that, during the dry season, the profile of the drillings of Dieu le Veut, Ingha and the La Mary watercourse, presents a very different contrast from the rainy season. This can be explained by the presence of human activities around the boreholes. Because the elements that show more variation are the chlorides. As part of the drinking water quality of the region, the 120 samples represented on the Wilcox diagram (Figure-7) are divided into 1 single group (Excellent) in the rainy season as well as in the dry season.

Discussion: The average water temperature on the Mbé plateau is 27°C. This temperature corresponds to the seasonal variation in ambient air temperature as defined by meteorological data (30°C). Water pH ranged from 4.02 to 6.4; the average score was 5.0. This shows that the water is acidic and therefore corrosive. In fact, water acidity has been noted in several studies. These are the Mbé plateau[18], Brazzaville[19], the Tiassalé zone[20] and San Pedro Luo[21]. According to Oga M.S.[19], Water acidity in the humid tropics is mainly associated with the decomposition of plant organic matter which produces carbon dioxide in the first layer of soil. Low levels of heavy metals have been observed in the region's waters. This would be due to the power of the batéké sands (geology) varying between 300 and 400 m thick and to the absence of industrial agriculture, processing industries, etc.

These results are consistent with recent work in this area of research by Moukolo N.[13] and Obami-Ondon, H.[21]. However, the activity in August 2018 (dry season) was different, notably showing two phases: a calcium chloride phase and a calcium bicarbonate phase. These results are in harmony with those obtained by Moukolo N.[13,] Matini L.[18] and Oga M.S.[19] in the region. According to these authors, the quasi-homogeneity of the aqueous phase in the study area is linked to its low lithological heterogeneity. The electrical conductivity values obtained indicate that the waters of this area are weakly mineralized, as indicated by the work of Matini L.[18] and Oga M.S.[19]. These results are generally consistent with those of Directives[15]. As indicated by the work of Matini L.[18] and Oga M.S.[19]. These results are generally consistent with those of Obami Ondon H.[14] and Obami-Ondon, H.[21]. As indicated by the work of Matini L.[18] and Oga M.S.[19]. These results are generally consistent with those of Directives[15].

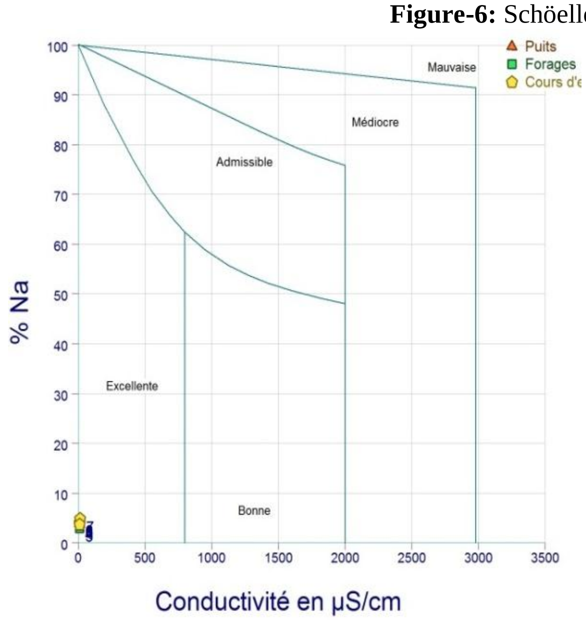


SchöellerBerkaloff diagram in the rainy season[15].

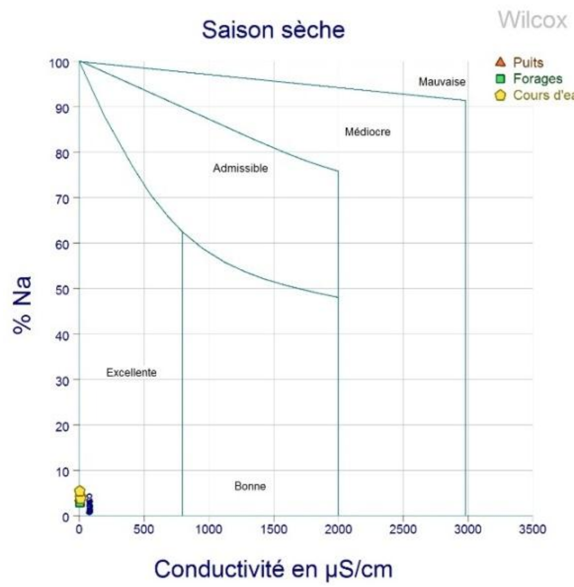


SchöellerBerkaloff diagram in the dry season.

Figure-6: Schöeller-Berkaloff diagram between the 2 major seasons.



Wilcox diagram in rainy season[15].



Stiff diagram in dry season.

Figure-7: Wilcox diagram in wet and dry seasons.

Conclusion

This study characterized physicochemical parameters by tracking seasonal changes in the region. The results showed that all parameters measured in the four (04) seasons were in compliance with the World Health Organization drinking water standards and did not change due to seasonal changes. However, water temperatures in the region vary between 24.1 and 27.1°C without specific dynamics with the seasons; these temperatures are close to World Health Organization recommendations. This water is acidic, with a pH between 4.02 and 6.4, and is corrosive. This change does not vary with the seasons. Conductivity values range from 5.14 to 16.3µS/cm. Ultimately, we could say that the local index of anthropogenic pollution is almost existent for the physicochemical quality of water. People who do not have other sources of water can consume it without significant danger. The level of minerals being insufficient in the water of the region, it would therefore not be good for the consumption of young children.

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