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Case Study

The physicochemical seasonal effect on the quality of well drinking water in Lake Chad Basin: Case study Mayo Tsanaga (Far North region of Cameroon)

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Abstract

The Mayo Tsanaga which is located in the far north region Cameroon, shares boundary with Lake Chad basin between 10 ° 30 'and 10 ° 52' north latitude and 13 ° 43 'and 14 ° 37' east longitude. The majority of the population there uses well water whose quality is unknown in the monsoon season, pre-monsoon and post-monsoon season. This study was conducted to evaluate seasonal effect on the quality of water of these wells. The methodological approach was based on field work (monthly monitoring of water table, PH variations, temperature, electrical conductivity and redox potential) and those of the laboratory (using various techniques described by chemical studies). The results of chemical analysis shows that the seasonal effect is clearly perceptible for some items. For other items, the seasonal effect is not very noticeable. A third group of elements to which the seasonal effect is perceptible to some wells and not noticeable to others. There is changes of the anionic triangle chemical species and that of the diamond between the two seasons. The analysis of the correlation circle allows to differentiate: the factors positively correlated with and without seasonal effect; variables that are not correlated with and without seasonal effect; the elements are negative correlations with and without seasonal effect. The comparative study of the seasonal piezometry allowed to have the fluctuation of the water table for which changes can be low, medium or high.

Keywords: Mayo Tsanaga, Seasonal effect, Physico-chemical quality, Water, Wells.

Introduction

The problem of quality of drinking water is still a public health priority in developing countries. Necessary for all life, water is also a health promotion component of individuals and the social economic development of human communities. Water quality is a vital need that is not met for a number of individuals in the far north Cameroon. Over the years, the government and NGOs have developed activities related to the vulnerable population to ameliorate the difficulties of access to water. It is unfortunate that UN targets "access for all to drinking water" have never been achieved. According to the most recent statistics from the regional access to water monitoring committee and sanitation in the Far North region, only 25.95% of the population has access to safe drinking water[1].

This work is therefore in the context of scarcity of atmospheric and flow water (only four months of rain annually) making the population entirely dependent on well water. Yet, there is no quality control service of well water. The majority of the population (71.6%) in this environment uses either well water or water from the stream (alluvial) of mayo whose quality is unknown. These waters are yet vulnerable to various releases through irrigated agricultural practices in the Sahelian zone. Based on previous work, relatively few studies have been done on seasonal effect aspect of the quality of the water consumed by the majority of the population[2-6]. Also present studies aim to evaluate the seasonal influence on the quality of drinking water of the Mayo Tsanaga's well.

Study area: The Mayo Tsanaga is located in the Far North region of Cameroon and shares boundary with Lake Chad basin between 10°30 'and 10°52' north latitude and 13°43 'and 14°37' east longitude. It is in contrast with Western basin upstream half distinguished by its mountains and inselbergs, culminating at 1400 m, formed by crystalline and volcanic rocks and an eastern half swallow in the plain of Logone, a tributary of Lake Chad[3]. The river system is formed by the Mayo Tsanaga and its many tributaries, the most important of which are on the left bank: Mayo Kaliao, the Mayo Fogom, the Mayo Bao and right bank Mayo Goudoulou and Mayo Mododrof[7]. This watershed is subjected to a dry tropical climate with an alternation of a long pre-monsoon and post-monsoon season (October to May) when the intertropical Front is further south and a monsoon season

(June-September) further North. Interannual average rainfall of 792.13 mm for a long chronicle data of seventy years (1927-2013). The geological characteristics distinguish the massive formation of inselbergs and crystalline rocks (granites anatexic and synkinematic granites) more or less old. Mount Maroua consists of green volcanic rock. The formation of the Piedmont area consists of rocks of detrital original furniture from massive erosion[8].

The soils of the watershed Mayo Tsanaga are very diverse[9]. In the higher parts, between Mokolo and Gazawa we find bedrock, unaltered, with its detrital arenas as well as unsophisticated lithosols, clay and poor in organic matter but mostly sandy (80%). Between Gaza and Maroua, poorly developed soils encountered along the valley of the Mayos and Tsanaga Kaliao. These are soils derived from loose material (alluvial or pediments), sandy clay with gravel which are usually quartz. There are also piedmont soils early in evolution: they are gray semiarid soils. Finally, other foothill soils are vertisols, advanced, consisting of dark clays, limestone or not, and lightly sand.

Sampling and Analytical Methods

The methodological approach was based on two aspects including field work and those of the laboratory. The field work consisted in the census of forty wells in the study area based on the representativeness and accessibility of rainy season (Figure-1). Successful wells have been monitored on a monthly variations of pH, temperature, electrical conductivity, redox potential and groundwater level in situ for two consecutive water years (2012/2013 and 2013/2014). The equipments used in the field are a potentiometric probe multi-parameter TLC and a multi-parameter HANNA brand pH- meter. May and September 2013 respectively marked the end of the pre-monsoon season and the monsoon season. Two sampling campaigns were made for laboratory analysis of eight chemical elements (sodium, potassium, magnesium, calcium, chlorine, nitrate, sulfate, bicarbonate). Samples of the water were made using polyethylene bottles of 500 ml. The bottles were rinsed with water three times, filled, closed, labeled and placed immediately in the cooler at the temperature of 4°C as recommended[10]. Water samples were transported within 24 hours to the laboratory INSAI of the University of Ngaoundere for chemical analysis. The major elements were analyzed using various techniques described in the chemical studies: spectrophotometry (nitrate, sulfate), titrimetric (chloride, calcium, magnesium and carbonate) and flame spectrophotometer (potassium and sodium).

Results and Discussion

Index cation exchange: To monitor the chemistry of water of the aquifer of Mayo Tsanaga and define the direction of ion exchange between the water and the surrounding ground, the index of base exchange (IBE) is used for dry season and rainy (Table-1). The expression of this index is as follows:

$$\text{IBE}= \frac{Cl-(K+Na)}{Cl}$$

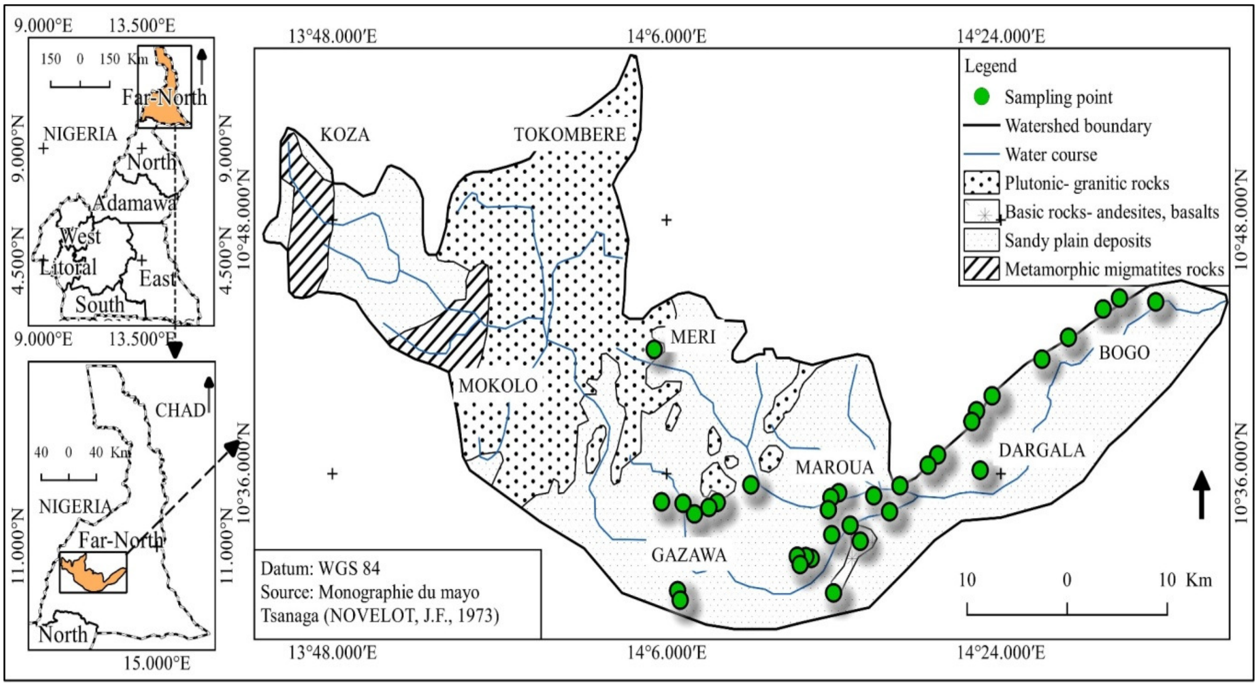


Figure-1
The study area showing the sampling locations and geological formation

This report is positive when the sodium and potassium content is low. In other words, law rate of water in contact with minerals can easily lead to the exchangeable of cations. This ion exchange in array with those present in the solution are very variable and dependent, inter alia, and the nature of the substrate. This report is negative when the sodium and potassium content is high, that is to say, when water is strongly in contact with minerals, it can easily lead to cations exchange. This base exchange phenomenon is mostly experienced with alumino-silicate clays formed of layers or sheets.

Where by cohesion is ensured by the presence of cations and interlayer water[11]. Indeed, the surface of the leaves is negatively charged, thus promoting the possibility of exchange of cations with those of the soil solution. In the case of the Mayo Tsanaga aquifer the base exchange index is positive (Table-1), this can be attributed to several phenomena: either to trade water alkaline against the alkaline earth of the host rocks; either to anthropogenic inputs causing excess of chloride ions in the water. The strong ionic alkali content (Na^+ and K^+) compared to ionic values of alkaline earth (Ca^{2+} and Mg^{2+}) obtained in the groundwater Mayo Tsanaga is told that there has probably been an exchange of alkaline earth waters against that of alkaline host rocks. These exchange contribute firstly to an increase in ions and weight contents of these alkaline water and also to lower the levels of alkaline earth. The exchange of cations Ca^{2+}, Mg^{2+} and Na^+ in conjunction with clay minerals leads to increased Na^+ and decreased Ca^{2+} and Mg^{2+} in water[12]. The season effect is not very noticeable in the calculation of Mayo basic exchange indexes.

Seasonal effect and Evaluation of the potability of water wells: The seasonal variation in physico-chemical characteristics of groundwater have been summarized in the Table-2.

Temperature: Assay results of physicochemical parameters of well water shows that the temperature of water wells varies between 30.1 and 47.1°C with a standard deviation of 3°C and an average of 35.7°C during the pre-monsoon season (Figure-2). Temperatures remain stable throughout the monsoon season with low variation coefficient (0.86). These temperatures are above groundwater potability standard.

Conductivities: The highest conductivities in the pre-monsoon season are stored in the wells P13, P15, P21 and P37 with the respective values of 1358, 1118.1175 and 1472 µS/cm (Figure 3). The electrical conductivity of these wells is much higher than the standard EU / WHO drinking water that is 250 µS /cm. The majority of wells has exacerbated average mineralization. The seasonal effect is clearly perceptible because almost all of electric conductivity of the pre-monsoon season is higher than those of the monsoon season. Decrease is explained by the groundwater recharge from rainfall that leads to a dilution of minerals.

Table-1
Results of groundwater basic exchange indexes Mayo Tsanaga watershed

Wells	[Cl-(Na+K)]/Cl	
	Pre-monsoon season	Monsoon season
P_1	9.10^{-3}	68.10^{-3}
P_2	89.10^{-3}	84.10^{-3}
P_3	71.10^{-3}	86.10^{-3}
P_4	71.10^{-3}	23.10^{-3}
P_5	74.10^{-3}	49.10^{-3}
P_6	69.10^{-3}	31.10^{-3}
P_7	88.10^{-3}	11.10^{-3}
P_8	55.10^{-3}	35.10^{-3}
P_9	82.10^{-3}	88.10^{-3}
P_{10}	49.10^{-3}	20.10^{-3}
P_{11}	71.10^{-3}	90.10^{-3}
P_{12}	88.10^{-3}	22.10^{-3}
P_{13}	92.10^{-3}	4.10^{-3}
P_{14}	8.10^{-3}	55.10^{-3}
P_{15}	77.10^{-3}	19.10^{-3}
P_{16}	52.10^{-3}	2.10^{-3}
P_{17}	92.10^{-3}	41.10^{-3}
P_{18}	81.10^{-3}	10.10^{-3}
P_{19}	85.10^{-3}	59.10^{-3}
P_{20}	76.10^{-3}	61.10^{-3}
P_{21}	9.10^{-3}	70.10^{-3}
P_{22}	52.10^{-3}	51.10^{-3}
P_{23}	73.10^{-3}	36.10^{-3}
P_{24}	88.10^{-3}	21.10^{-3}
P_{25}	81.10^{-3}	59.10^{-3}
P_{26}	76.10^{-3}	86.10^{-3}
P_{27}	92.10^{-3}	34.10^{-3}
P_{28}	85.10^{-3}	25.10^{-3}
P_{29}	6.10^{-3}	89.10^{-3}
P_{30}	91.10^{-3}	74.10^{-3}
P_{31}	51.10^{-3}	9.10^{-3}
P_{32}	47.10^{-3}	74.10^{-3}
P_{33}	92.10^{-3}	20.10^{-3}
P_{34}	56.10^{-3}	29.10^{-3}
P_{35}	92.10^{-3}	2.10^{-3}
P_{36}	85.10^{-3}	3.10^{-3}
P_{37}	90.10^{-3}	71.10^{-3}
P_{38}	81.10^{-3}	70.10^{-3}
P_{39}	93.10^{-3}	6.10^{-3}
P_{40}	96.10^{-3}	61.10^{-3}

Table-2
Basic statistics of groundwater sample

Variables	Units	Monsoon season				Pre-monsoon season			
		Maximum	Mean	Minimum	SD	Maximum	Mean	Minimum	SD
n = 40									
Ca	mg/l	157,59	49,06	2,01	36,11	342.86	100.67	14.04	91.54
Mg	mg/l	207,89	51,67	2,35	41,34	616.7	143.84	0	138.55
K	mg/l	78	10,64	0	18,96	0.64	0.12	0.001	0.17
Na	mg/l	1,9	0,28	0,06	0,32	0.26	0.14	0.03	0.07
Cl	mg/l	217,43	95,06	39,93	39,13	195.25	118.03	53.25	33.94
NO3	mg/l	520	97,77	10	107,32	22.07	6.68	0	9.06
SO4	mg/l	90	19,37	0	24,33	90	21.73	0	26.67
HCO3	mg/l	96,38	38,21	8,54	22,20	1268.8	484.34	122	284.14
T	°C	31,5	29,99	27,9	0,86	47.1	35.7	30.1	2.67
EC	µs/cm	1009	335,75	29	7,13	1472	456.8	43	345.18
pH		8,68	7,7	7,13	0,36	8.89	7.65	7.17	0.38
Eh	mV	-10,3	-54,11	-115,7	-22,30	-10.7	-53.86	-123.2	24.48

T: Temperature, CE : Electrical conductivity, Eh : Potentiel Redox, n : Sample count, SD : standard deviation

Redox potential: The results of in situ measurements show an oscillations of the Eh between -123.2 and - 53.86 for an average of 10.7 mV during the pre-monsoon season (Figure-4). The value of Eh varies in the monsoon season between -115.7 and -10.3 mV for an average of -54.11 mV. The seasonal effect is not very noticeable in Maroua. However, all these well waters are reducing milieu because all redox potentials are negative.

pH: pH of the water wells in the study area are basic in both pre-monsoon season and monsoon season which testifies to the low activity of the hydrolysis of silicates (Which has the effect of releasing the alkali ions and bring the pH to values above neutral)[13]. pH of well water varies between 7.13 and 8.68 with an average of 7.70during the monsoon season and between 7.17 and 8.89 with an average of 7.65during the pre-monsoon season (Figure-5). In general, the water is neutral to alkaline. This is related to the nature of the rocks in the region which are constituted mainly of sedimentary rocks. Referring to WHO standards (pH 6.5 to 8.5) for drinking water, 100% of the analyzed waters are therefore recommended for human consumption.

Nitrates: It records high concentrations of nitrates in the monsoon season and low concentrations in the pre-monsoon season; an opposite scenario was expected to be due to dilution during the monsoon season (Figure-6). Indeed nitrate values ranged from a minimum of 10 mg/L to a maximum of 520 mg/L in the monsoon season and from a minimum of 0 mg/L to a maximum of 22.07 mg/L in the pre-monsoon season. These results are concordant with those of other authors[14]. In the pre-monsoon season, almost half of well has no nitrate which would imply that the nitrates do not come from the surrounding geological formations, while the standard deviation is higher than in monsoon season, all the wells have nitrate levels above the lower bound of the WHO standard that nitrate must be between 3mg/L and 50 mg/L. Half of the wells contents of nitrate greater than the upper limit of normal of WHO in the monsoon season which affirm the idea that the contributions come from the leaching of fertilizers from farms and nitrogen mineralized zones. The presence of nitrates in these areas in agro vocation, owes its origin to an explanation related to redox reactions of organic materials associated with human activities or to animal or plant production. The long stay of animal waste on the banks of water sources is fundamental to the pollution of the aquifer.

Sulphate: The waters of half of the wells have concentrations of zero sulphate both in the pre-monsoon season and in the monsoon season (Figure-7). In addition to the wells that contain the sulphate, the sulphate contents are very low and well below the indicative value of the WHO, which is 500 mg/L. In the pre-monsoon season, sulphate fluctuate from 0 to 90 mg/L, an average is 21.73 mg/L. Sulphates mean in the monsoon season is 19.37 mg/L, extreme being 0 mg/L for minimum and 90 mg/L for maximum. The absence or low sulphate concentration shall be explained considering that surrounding soil don't have rocks, such as gypsum and pyrite.

Bicarbonates: The concentrations of bicarbonates observed in the Mayo Tsanaga water wells range between 1268.8 mg/L and 122 mg/L with an average of 456.8 mg/L in the pre-monsoon season (Figure-8). In terms of the monsoon season, the average is 38.217 mg/L and extremes are 8.540 mg/L for the minimum and the maximum to 96.380. The seasonal effect is very visible, levels of bicarbonate of water in the pre-monsoon season is higher than those of the monsoon season for all wells. Bicarbonate values obtained are all in line with WHO standards in the monsoon season but in the pre-monsoon season, 21 wells have values above the standards, and even reach the peak of 1268.8 mg/L for wells P30. The same observations were made in Mokolo Lake upstream watershed[15].

Potassium: The potassium contents have relatively low values in the pre-monsoon season, the values of the standard deviation is confirmed (0.179mg/L) (Figure-9). This parameter fluctuates around 0.123 mg /L. Maximum and minimum values are respectively 0.643 mg/L and 0.001 mg/L. During the monsoon season, there is 0.00 mg/L for minimum 10.62 mg/L for medium and 78 mg / l for maximum. The origin of high levels of potassium in the monsoon season is due to the contributions of seepage water with diluted fertilizer. The seasonal effect is clearly visible with the concentration differences between the two seasons. For this element, the concentrations obtained are rather consistent with WHO standard in the pre-monsoon season than in the monsoon season, 4 wells have higher standards values[16].

Magnesium: The behavior of the magnesium ion varies with seasons. Indeed magnesium levels are three to four times higher in wells P10, P15, P18, P26, P33 in the monsoon season. Overall almost all values of the pre-monsoon season are high compared to the results obtained in the monsoon season except seven wells. High levels of magnesium can be explained by the fact that warm period action of evaporation combined with the high temperature Sahel promotes dissolution of the rock. Magnesium values range from a minimum of 0.00 mg/L to a maximum of 616.7 mg /L in the monsoon season and between 2,350 mg/L and 207.890 mg /L in the pre-monsoon season (Figure-10). The WHO water potability standard is met in the monsoon season by cons in ten wells and the pre-monsoon season has higher contents standards.

Calcium: The concentrations of calcium observed in Mayo Tsanaga basin ranged from 14.04 mg/L to 342.860 mg/L in the pre-monsoon season (Figure-11). In terms of the monsoon season, a mean is 49.06 mg/L and the extremes are 2.01 mg/L for minimum and 157.590 mg/L for the maximum. The seasonal effect is very visible; levels of Calcium water in the pre-monsoon season are higher than those of the monsoon season for all except three wells. All concentrations are normal in the monsoon season and five wells have higher contents to the drinking water standards in the pre-monsoon season.

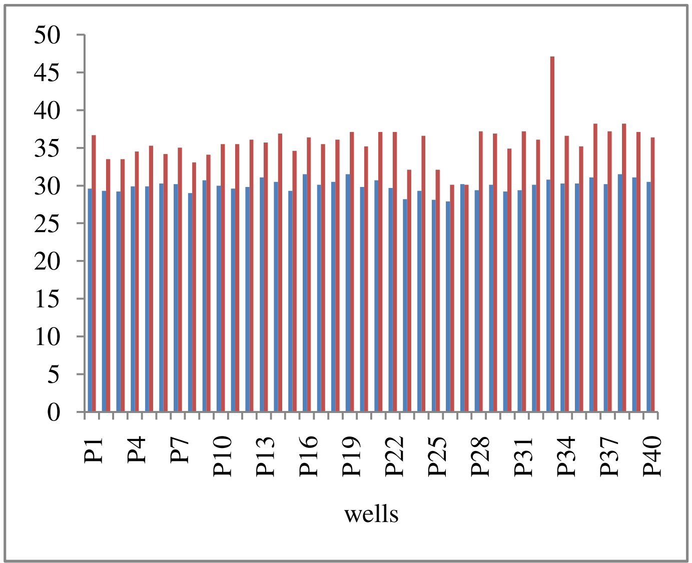
Sodium: Sodium contents have relatively low values for the two seasons; therefore there is seasonal effect that is very significant (Figure-12). Indeed, concentration varies and very low standard deviations for each season. An average of pre-monsoon season is about 0.141 mg/L. The maximum and minimum values are respectively 0.263 mg/L and 0.038 mg/L. During monsoon season, sodium fluctuates from 0.060 mg/L to 1.90 mg/L. Potability standard is respected regardless of the season.

Chloride: The chloride ion has different characteristics from those of other elements. It is not absorbed by the geological formations, is not easily combined with the chemical elements and is very mobile (Figure-13). Monsoon season chloride range from 217. 43 mg/L to 39.93 mg/L, an average is 95.06 mg/L. During the pre-monsoon season, these concentrations fluctuate from 195.25 mg/L to 53.25 mg/L. The recorded chloride content for the whole year is normal, according to WHO standard which is set at 250 mg /L.

Seasonal effect and Piper Diagram: Note on the piper diagram, two water groups are distinguished from the two seasons. In the cationic triangle, the chemical species are magnesium in both pre-monsoon and monsoon season except chemical species of which eight wells comprise of calcium (Figure-14). The chemical species of anionic triangle are composed of chloride in the monsoon season except one of the wells which is composed of sulphate. There are changes in chemical species of bicarbonate chloride during the pre-monsoon season. In the diamond chemical species, we have the hyperchloride calcium in the monsoon season, which evolves from hyperchloride calcium to calcium bicarbonate in the pre-monsoon season. The chemical species obtained in this study are discordant with those of the work of other authors because of lithology and hydrodynamics that differ[17].

Seasonal effect and Principal Components Analysis

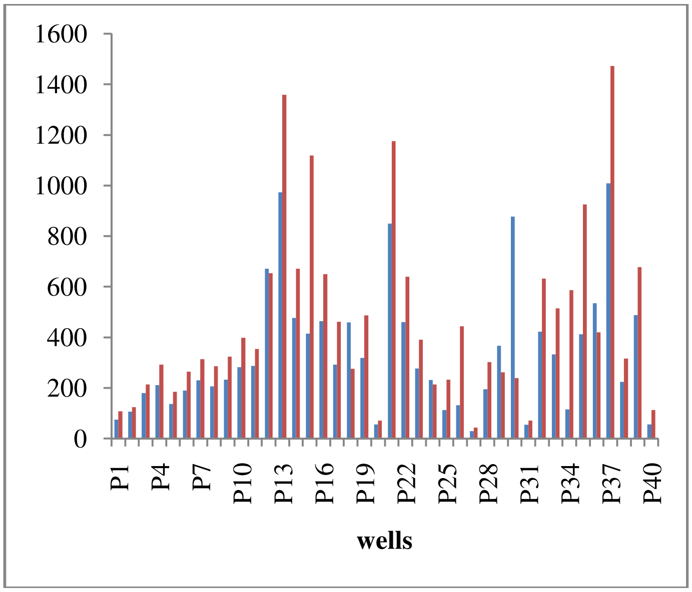
Statistical analysis was performed on variables using the R software. From the results, it was deduced the contribution of each element in achieving the factorial axes F1 and F2. In the plane formed by the main components 1 and 2 during the pre-monsoon season, the information is explained 48.166% against 57.618% of the information explained during the monsoon season (Figure-15 and Figure-16). The relationship between the variables and the factorial design shows that the representativeness of all elements is not good on the correlation circle. Some variables are too small square cosine relative to the unit. Consequently, they are not well represented in the projection of circles where they should not take much space in the explanation of the factorial axis. We quote for the axis F1: K^+, Na^+, T°, pH for the rainy season and HCO_3^-, T°, Eh, K^+, Na^+ for the dry season. However, the variables contribute a major way for the establishment of the F2 axis which are the same with regard to Ca^{2+}, Mg^{2+}, CE, Cl^-, SO_4^{2-} for both the monsoon and the pre-monsoon seasons except HCO_3^- for the monsoon season.



•Pre-monsoon season, • Monsoon season

Figure-2

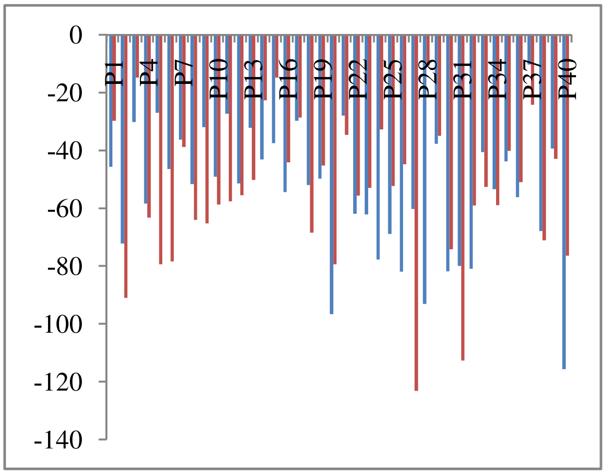
Seasonal fluctuation of temperature



•Pre-monsoon season, • Monsoon season

Figure-3

Seasonal fluctuation of conductivity



•Pre-monsoon season, • Monsoon season

Figure-4

Seasonal fluctuation of redox potential

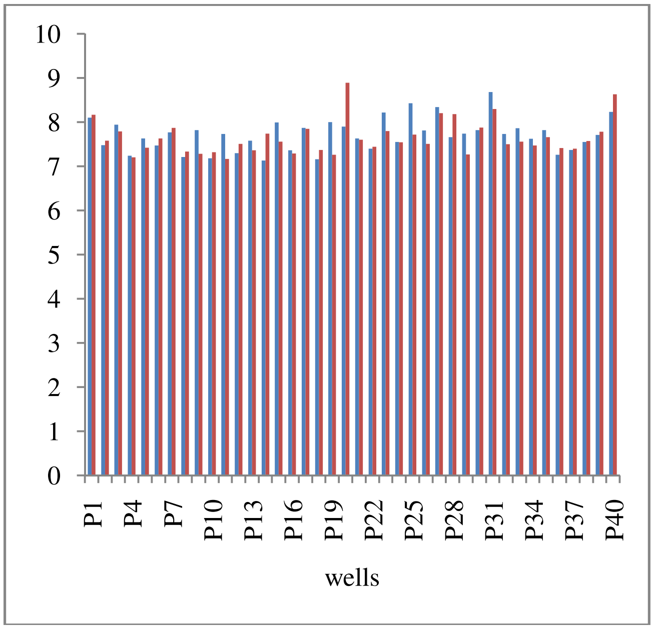
Seasonal effect and Factorial F1 × F2 plans Analysis

The analysis of the factorial map F1 × F2 can be distinguished into three groups of elements for the monsoon season: The first group consists of well represented axis elements (near the axis and the edge of the circle) that are correlated positively CE, Eh, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-. A second group is formed by variables that are not correlated (T°, HCO_3^-, K^+, Na^+). The third group consists of a variable pH which has a negative correlation.

Regarding the pre-monsoon season, the variables that are positively correlated are Ca^{2+}, Mg^{2+}, CE, Cl^-, SO_4^{2-}; the variables that are uncorrelated are T°, HCO_3^-, K^+ et Eh; variables that have negative correlations are Na^+, NO_3^- and Ph. The effect of Factor "season" is clearly discernible for Eh and NO_3 variables which have positive correlations; Na^+ and Eh for variables that have no correlation and Na^+, NO_3^- for variables that have negative correlations.

Seasonal effect and Water table fluctuation

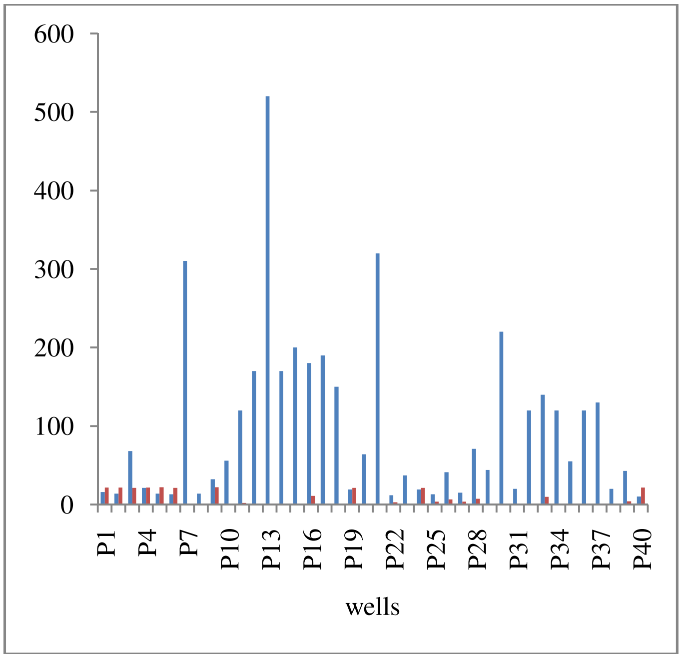
Comparing piezometry the period of the pre-monsoon season and the monsoon season has to have the Figure-17 of the fluctuation of water table for the water years 2012/2013 and 2013/2014. It shows the evolution of the maximum level, minimum and the amplitude of the variation according to the different wells. We can group these variations in slight variations, the mean changes and big variations. Slight variations whose amplitude variation is between 1 m and 2 m are observable especially downstream of the basin. These small variations are explained by the fact that the sedimentary areas are highly productive basin which converge towards water drainage lines. This is the case of the wells (P1, P4, P5, P9, P10, P11, P12 and P37) whose variations are comparable to those obtained by Ntep at the crests of mountains in the equatorial zone and Gouaidia[18,19]. The mean fluctuation were observed in wells P6, P7, P8, P20, P24, P35, their amplitudes varies between 3 and 7 m. The most significant changes occur in wells P23, P33, P28 and can respectively reach 10.1 m, 14.6 mm and 13.72 m. Water table fluctuation obtained are similar to the results of others research in the big Yaéré.



•Pre-monsoon season, • Monsoon season

Figure-5

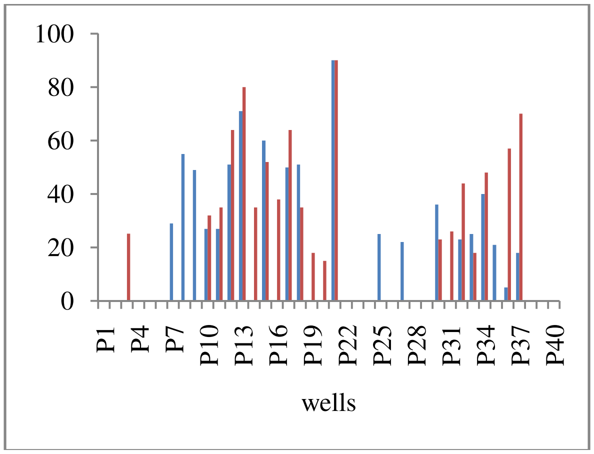
Seasonal fluctuation of pH



•Pre-monsoon season, • Monsoon season

Figure-6

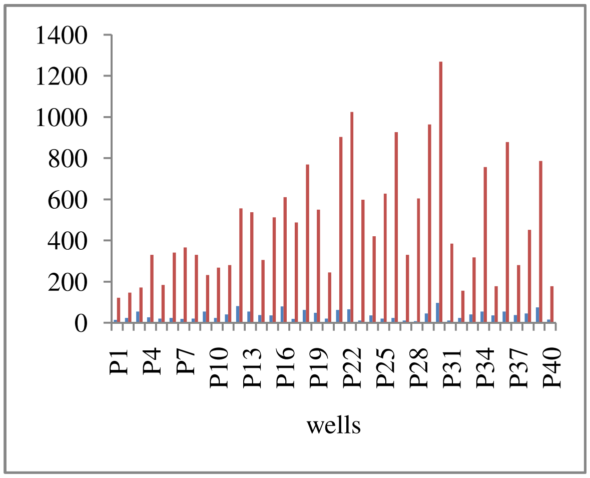
Seasonal fluctuation of nitrate



•Pre-monsoon season, • Monsoon season

Figure-7

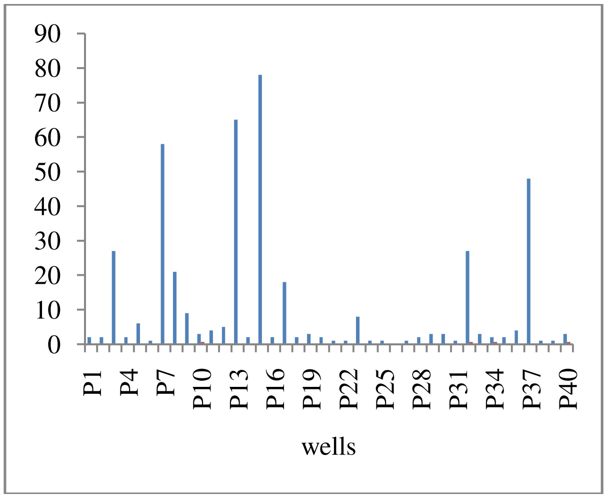
Seasonal fluctuation of sulfate



•Pre-monsoon season, • Monsoon season

Figure-8

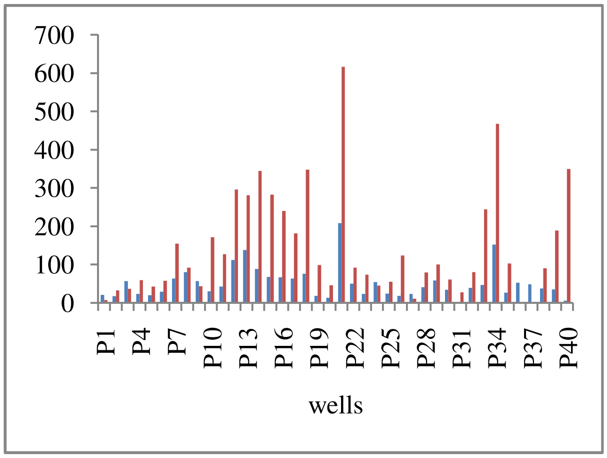
Seasonal fluctuation of bicarbonate



•Pre-monsoon season, • Monsoon season

Figure-9

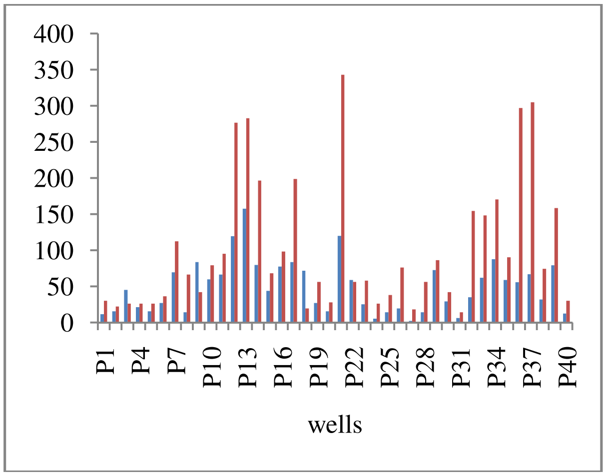
Seasonal fluctuation of potassium



•Pre-monsoon season, • Monsoon season

Figure-10

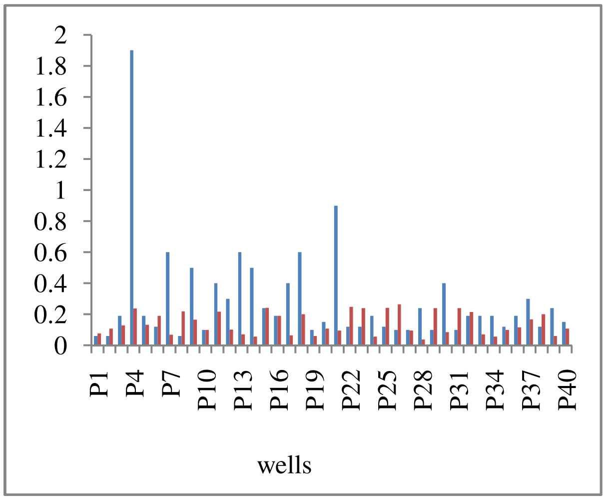
Seasonal fluctuation of magnesium



•Pre-monsoon season, • Monsoon season

Figure-11

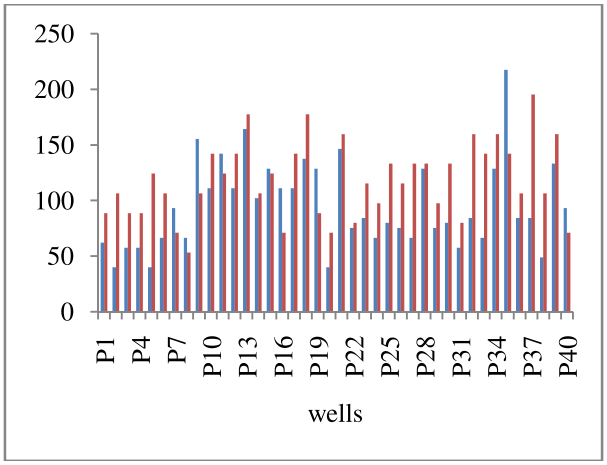
Seasonal fluctuation of calcium



•Pre-monsoon season, • Monsoon season

Figure-12

Seasonal fluctuation of sodium



•Pre-monsoon season, • Monsoon season

Figure-13

Seasonal fluctuation of Chloride

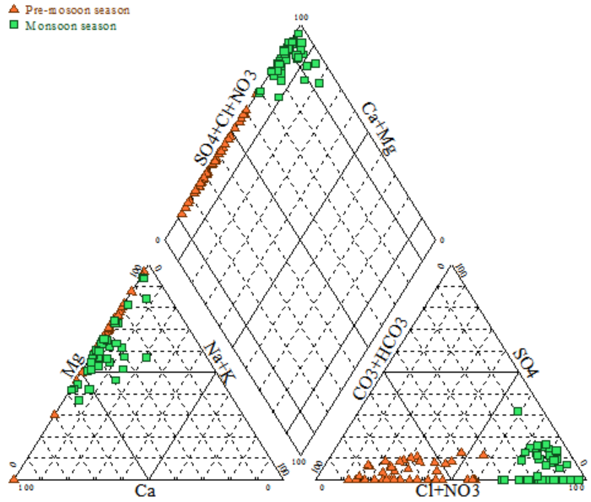


Figure-14

Piper diagram

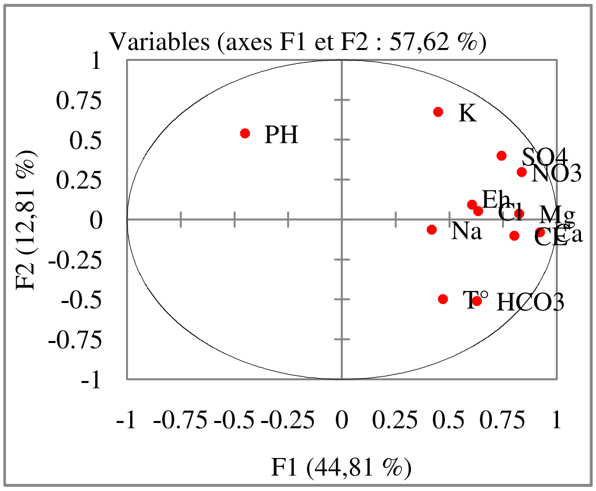


Figure-15

PCA monsoon season

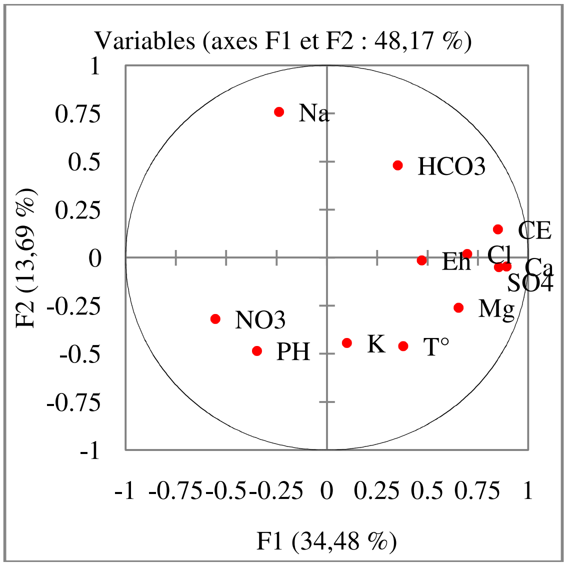
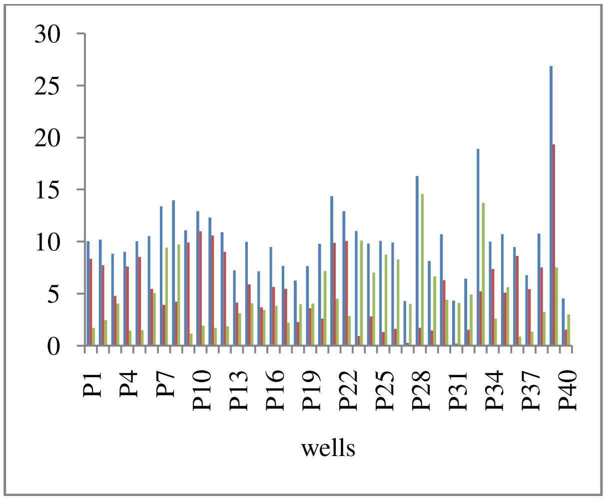


Figure-16
PCA pre-monsoon season



●Maximum water level, ●Minimum water level,
● fluctuation

Figure-17
Seasonal fluctuation of water table

Conclusion

Mayo Tsanaga Basin is part of the Cameroonian basin of Lake Chad where only 25.95% of the population has access to drinking water from the water supply network. The 74.15% of the population consuming well water whose quality is unknown both in the monsoon and the pre-monsoon season. Thus, a study was undertaken to evaluate the seasonal effect on the water quality of these wells used by the majority of the population. To achieve this goal, the methodology adopted was based on the results of chemical analyzes, those of R software, Piper diagram and the monthly monitoring changes in the level of groundwater for two water years. The results of chemical analysis show that the seasonal effect is clearly perceptible for some elements (conductivity, temperature, nitrate, bicarbonate, potassium). For other items, the seasonal effect is not very noticeable (indices base exchange, pH, sulfate). A third group element for which the seasonal effect is noticeable for some wells and not noticeable for others (redox potential, magnesium, calcium, sodium). There is a chemical species evolution of the anionic triangle as well as in the diamond from one season to another. The analysis of correlation circles allow to differentiate: i. Elements positively correlated without seasonal effect (calcium, magnesium, electrical conductivity, chloride) and with seasonal effect (nitrate and redox potential); ii. Items that are not correlated and without seasonal effect (temperature, bicarbonate and potassium) and the variables that are uncorrelated and with seasonal effect (sodium and redox potential); iii. The elements with negative correlations without seasonal effect (pH) and the variables that have negative correlations with seasonal effect (sodium nitrate). Comparing piezometry of the pre-monsoon season and the monsoon season, there is fluctuation of the water table for which changes can be low, medium or high.

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