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A typological study of the physicochemical quality of water in the Menoua-Cameroon watershed

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Abstract

Cameroon, a country in Central Africa with an outlet to the Atlantic Ocean in the Gulf of Guinea, holds enormous potentialities of water resources. These resources used for the supply of water for human consumption, etc., would be polluted by the intensification of anthropogenic activities, of which the most important recorded in the Menoua watershedof West Cameroon are agriculture and breeding. The objective of this work was to study the spatiotemporal parameters of the physicochemical quality parameters (temperature, pH, electrical conductivity, Turbidity, Nitrates, Ortho Phosphates, Sulphates, Chloride, Potassium and Calcium) the Menoua watershedthrough a main Principal Component Analysis (ACP). The results obtained showed that the pH, turbidity and orthophosphate have levels which are in contradiction with WHO standards. The physicochemical parameters of this water showed significant spatial and seasonal variations, the causes of which probably related to the human activities generating pollutants. The Principal Component Analysis in this study identified four distinct types of human drinking water depending on the movement of surrounding human activities and the seasons. These results show the acuteness of the problem and the urgency to rationalize the codes of good agricultural practice and sanitation in order to combat this pollution effectively.

1. Introduction

Water resources are at the center of all human activities and constitute the lever of a country's economy. Cameroon, a country in Central Africa with an outlet to the Atlantic Ocean in the Gulf of Guinea, has enormous potentialities of water resources as a whole [1]. It thus counts approximately 39600 km^2 of inland water bodies internal and distributed in watershed exploited in the breeding, agriculture, urbanization, the supply of drinking water, etc. These basins are degraded by anthropogenic movements, reflected in strong urbanization, industrialization, agriculture, livestock, fisheries, deforestation, transport and tourism [2]. This problem of strong anthropization varies according to the watersheds and mainly concerns pollution in all its forms. Faced with this problem, which does not leave on the margins, the division of Menoua [3].Dschang, the capital of this division in the western region of Cameroon, is supplied with drinking water by the Menoua watershed, which suffers from a major pollution problem caused by highly developed anthropogenic activities in the region whose origins could be related to the fertilizers and plant protection agents used by farmers and ranchers, on the one hand, and to the proximity of certain points of landfill or the discharge of wastewater into rivers of the basin or their infiltration into the soil. In order to guarantee the water supply essential to the life of the population at all seasons, the quality of the waters of the basin should be monitored and safeguarded [4-6]. Nevertheless, water pollution problems could affect water quality, and subsequently health status, influencing men's morbidity and mortality [7]. In order to mitigate the nuisance of this resource and the health risk associated with its consumption, a study of the water quality assessment of the Menoua watershed is necessary. Numerous similar studies have also addressed the issues related to this water quality, in particular those of [6-9]. In the present state of knowledge, no work has been done on the typology of the physicochemical quality of water resources at the scale of this basin, and it is within this framework that the present work, aims to study the parameters of the physicochemical quality of the water in the Menoua watershed through spatiotemporal monitoring, in order to establish the similarities and distortions that exist between these parameters and to better evaluate the impact of the anthropic dynamics on the water quality of this basin, through a coherent spatiotemporal profile, we have submitted the data set of the different parameters collected to a principal component analysis (ACP) of the information given.

2. Material and Methods

2.1.Presentation of study site

Dschang, which is fed with water by the Menoua watershed, is the chief town of the Menoua division in the West region Cameroon of, which is experiencing rapid spatial and demographic growth and an anarchic development of the habitat. Its status as a university town greatly influences the population growth. The population is estimated at about 182.3 inhabitants per km^2 with a growth rate of 4.7% per year [11]. The city of Dschang is between 5 ° 25 '- 5 ° 30' North Latitude and 10 ° -10 ° 5 'East Longitude and is located 213 km north of Douala and 350 km northwest of Yaoundé [12]. The Menoua watershed has a sub-dendritic hydrographic network of 655 km^2. It is built on the south-eastern slope of the Bamboutos Mountains and opens to the Southwest by the Menouariver flowing towards the Mbo plain. To the east, it is closed by the Bani massif which culminates at more than 1920 m. The mean rainfall is 1900 mm / year for an average temperature of 20.2 ° C (minimum of 13.4 ° C) [13](Figure 1).

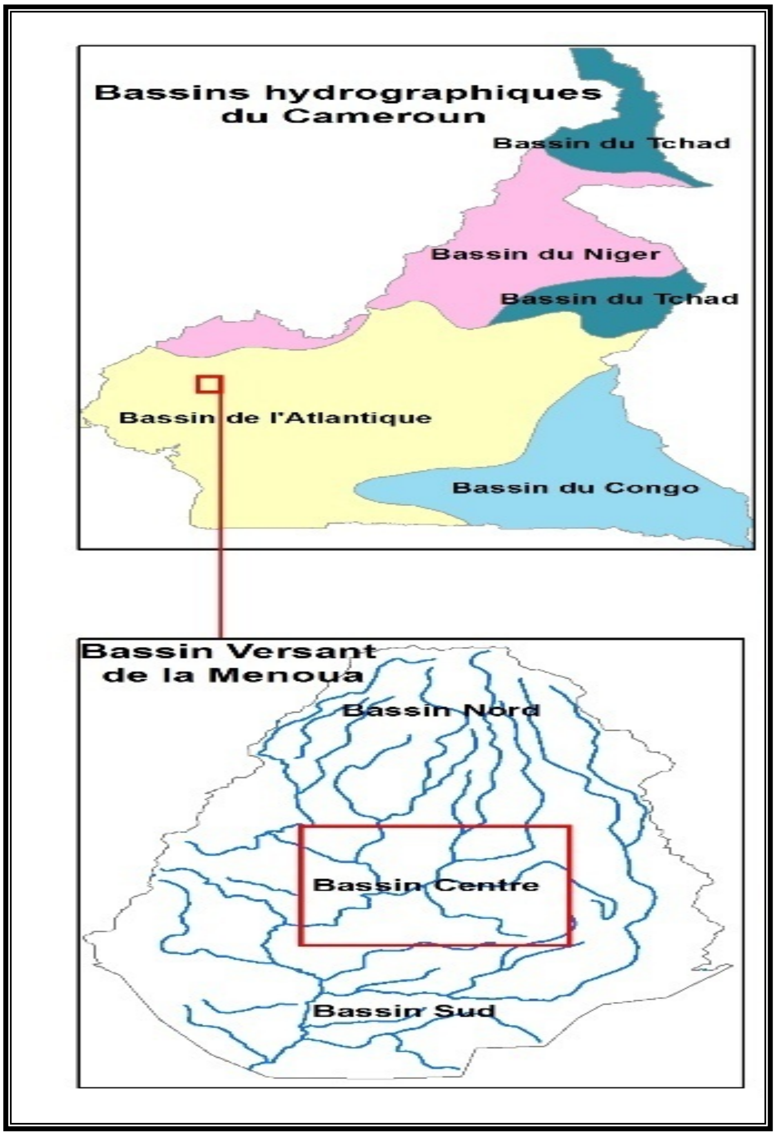

Figure 1: Hydrographic map of the Menouawatershed

2.2. Study sites
In order to carry out this work, the choice of the sampling sites for the different water samples was done taking into account the various anthropogenic activities identified: e = breeding, a = agriculture, d = waste dumping, b = building. The geographic coordinates of each site were taken into account using the GPS device. To this end, 33 sites were selected and distributed as follows: Source water 15 sites; Drilling water 7 sites; Well water 11 sites. Thus, a map of the location of the study sites was made with the Quantum GIS software (Figure 2). Four (4) sampling campaigns were conducted at the 33 sites, two of which in dry seasons (December and February 2014/2015) and the others in the rainy season (May and August 2015).

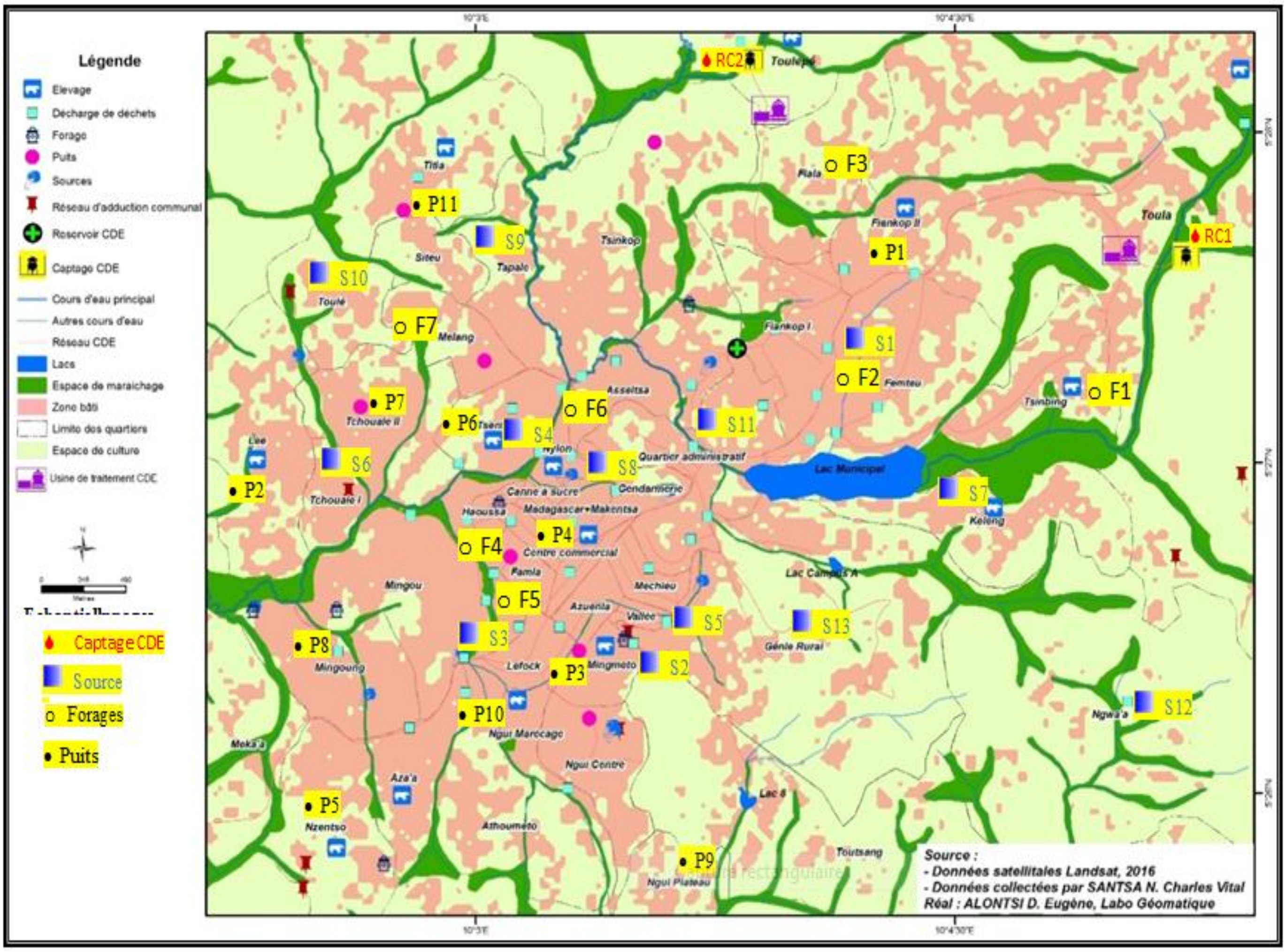

Figure 2: sampling sites

2.3. Sampling, transport and Measurement of physicochemical parameters of water
Samples were taken from 500 ml sterile vials according to the procedures described by Rodier [14]. The analyzes were carried out according to the methods described by Rodier [14] and the temperature was measured using a Digital Thermometer electronic thermometer, pH measurements were carried out using a pH -Meter of the mark SUNTEX TS-2, the electrical conductivity measurements were carried out using a YSI type conductivity meter (Model 33); S.C.T Meter, the Turbidity measurements were carried out using the conductivity /TDS multimeter of the HACH brand. Nitrates, Ortho phosphates, and Sulfates were performed using the DR/2000 spectrophotometer. The volumetric method allowed the measurement of chloride, potassium and calcium. The ACP-based statistical study was conducted with the XL-STAT software.

3. Results and discussion

Temperature
The results in Figure 3 show similar time-space-temperature variations for the entire study period. The amplitude of the variation between the countryside does not in any case exceed 25,50^{o}C. The maximum temperature (25.20 ° C) was recorded during the dry season (February 2014) at the P8 site and the minimum

temperature (20.70 ° C) was obtained during the rainy season (August 2015). This reflects the influence of local temperature. As for spatial variations, no significant differences were found. The discrepancies recorded are in fact due only to the daily time difference between the different sampling sites, which is why the spatial profile does not show any significant difference between the different sites. Indeed, water temperature is one of the important factors controlling almost all the microbiological reactions of aquatic environments [15]. It is acceptable in comparison to the WHO standard.

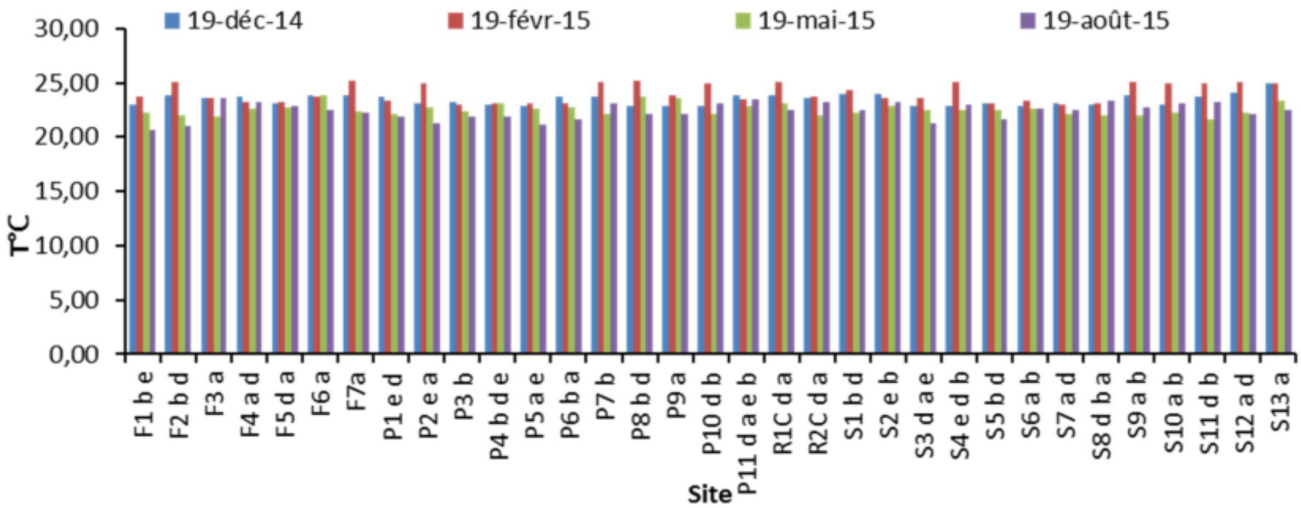

Figure 3: Spatiotemporal evolution of the water temperature of theMenoua watershed

pH (hydrogen potential)

Water pH values along the Menoua watershed recorded during the study period ranged from 7.96 recorded in the RC1 site and 4.22 recorded at the P4 and P9 sites in the month December 2014. The time evolution of the pH does not generally exceed one unit. However, as illustrated in Figure 4, the shape of the curves of the spatiotemporal variation of the pH for the 33 sites is very variable and does not follow a regular law. The spatial evolution of the pH in the different sites studied shows a remarkable difference (1.50), the maximum value (6.38) being recorded in the site F3 and the minimum value (5.09) recorded in the P11 site. The temporal evolution of the pH of the waters of the Menoua watershed shows a variable pH, but with an acidic tendency and does not comply with the WHO standard. This difference in pH is related to probable fluctuations in agropastoral activities, points of point discharges located near the water points or in the watercourses of the basin [16-17]. It is noteworthy that the domestic wastewater would be found in the rivers of the basin without undergoing any previous treatment.

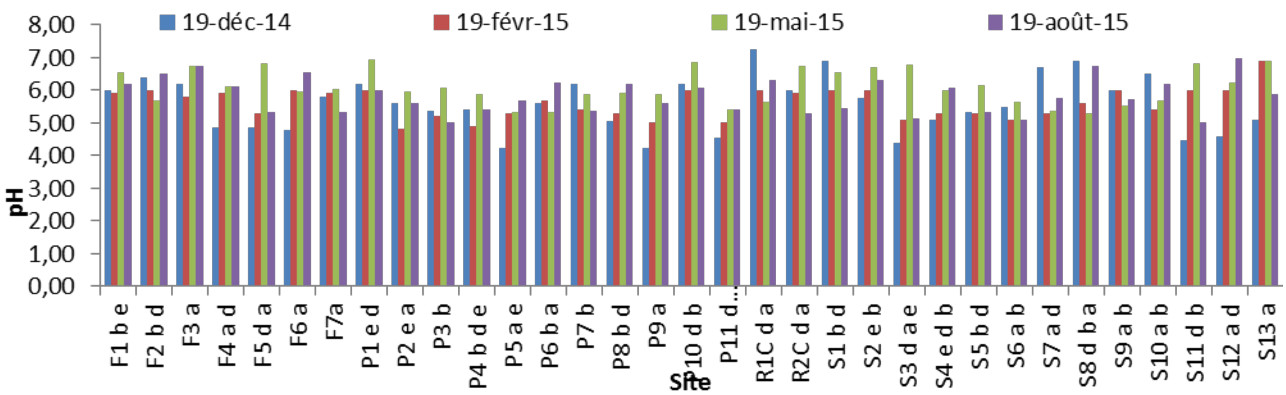

Figure 4: Spatiotemporal evolution of the pH of the Menoua watershed

Electrical conductivity (Ce)

The results presented (Figure 5) in our study show that the recorded conductivity values oscillate between 693 µS / cm (site S6) in August 2015 and 12 µS / cm (site S7) in May of the same year. The spatial evolution has a maximum value (459.75 µS / cm) at the P4 site and a minimum value (39.50 µS / cm) at the S2 site. The temporal profile shows that the water in the Menoua watershed is very weakly mineralized (12.44 µS / cm) at the beginning of the dry season (December), weakly mineralized (37.1 µS / cm) in the middle of the season (May) and decreases towards the end of the rainy season (August). ANOVA reveals a very highly significant effect (Pr<0.0001). These values are low compared to the potability standard and give this water a low mineralization [18].

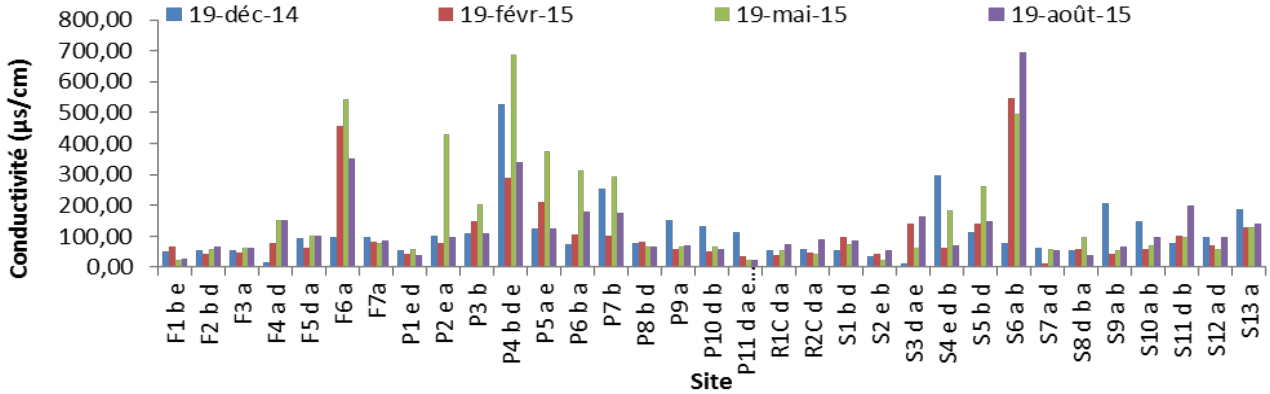

Figure 5: Spatiotemporal evolution of the electrical conductivity of the Menoua watershed

Turbidity

The seasonal evolution of turbidity (Figure 6) shows similar spatial variations. Maximum turbidity (2, 01TFU) was recorded at the R2C site during the rainy season (August 2015) and minimal turbidity (0.27 TFU) was obtained at site F5 during the same season (May 2015). This reflects the specificity of each site and the anthropogenic activities encountered. Spatial values are maximum (1.6TFU) at site R2C and minimal (0.33TFU) at site F2. The R2C site is a basin watercourse open to torrential waters, domestic wastewater and agropastoral inputs. The temporal evolution shows the turbidity values are higher in rainy season and low in the dry season. ANOVA reveals a very highly significant effect of turbidity (Pr<0.0001). The high values of the turbidity from one point to another in the water of the Menoua catchment area would come from the torrential waters carrying with them debris of all natures [14]. These values are not consistent with the WHO standard.

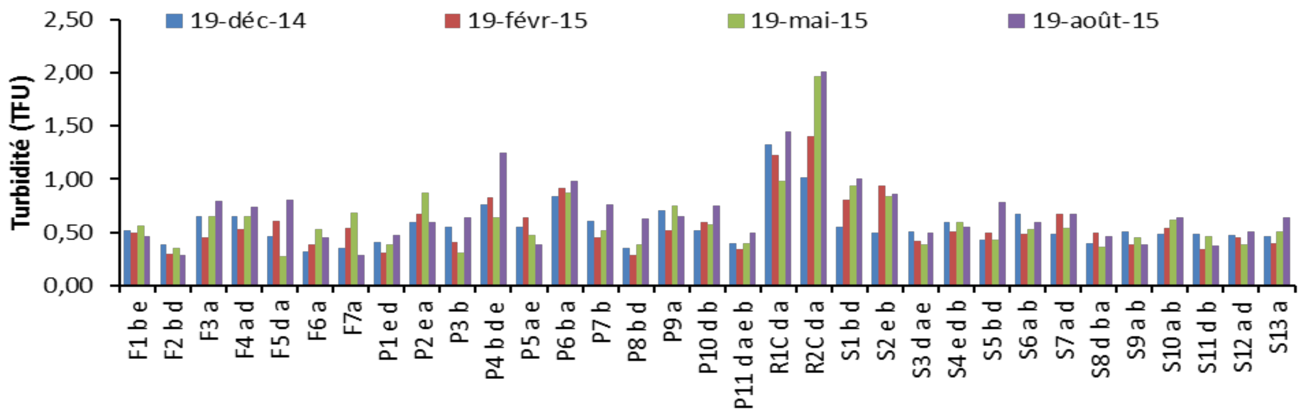

Figure 6: Spatiotemporal evolution of the turbidity of the Menoua watershed

Nitrate (NO_3^-)

The evolution of nitrate in space and time (Figure 7) shows the maximum values (67mg / l) in the R2C and P11 sites and the minimum values (2,26mg / l) in the P4 site in the rainy season (August 2015). The R2C site is a waterway not only opens to torrential waters but also located in a marshy area of the basin where agricultural activities are more intense in this season. The same applies to site P11. The spatial values of the nitrate show a curve with a serrated appearance in which the maximum (59.22mg / l) is recorded at the P11 site and the minimum (6.64mg / l) at the P4 site. As for the temporal evolution, the high values are recorded in the rainy season and low in the dry season. This enrichment of nitrate along the basin is due to a very active nitrification during this period (rainy season) of reoxygenation of the medium. The inputs of nitrate through leaching of agro-pastoral lands that are very heavily loaded into this element are very important. The increase in nitrate levels can be explained by crops (use of agricultural nitrogen inputs), the flow of domestic wastewater and sometimes even by landfill points in the vicinity or in the rivers of the basin [19]. These results show a pollution by nutrients whose origins are probably related to the fertilizers used in the region in order to fertilize the soil as much as possible and, on the other hand, to the oxidation of the nitrites by the bacteria of nitrification following sewage infiltration [20-21]. ANOVA reveals a very highly significant effect of nitrates between the different sites (Pr<0.0001). These values are acceptable in relation to the WHO standard.

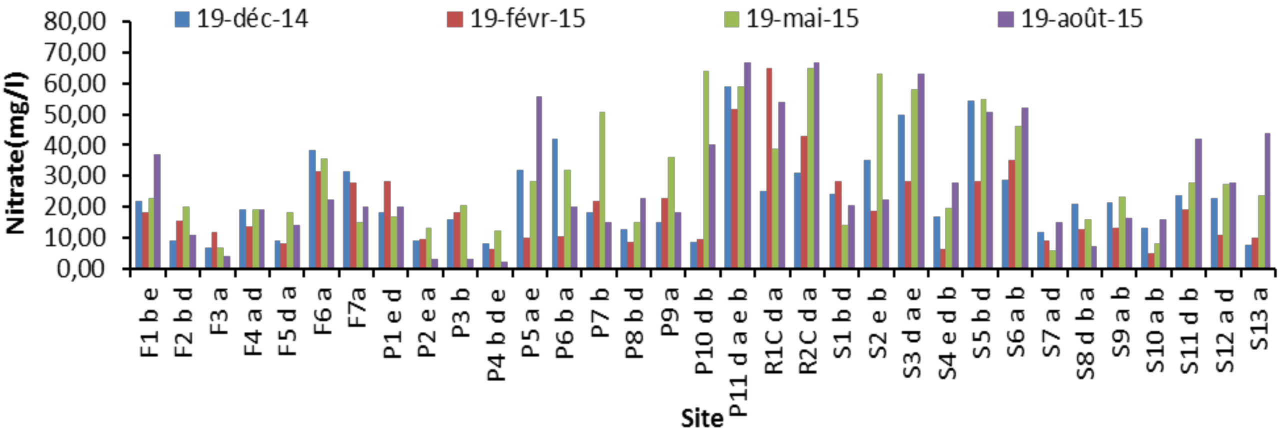

Figure 7: Spatiotemporal evolution of water nitrate of theMenoua watershed

Phosphorus (PO_4^{3-})

Spatiotemporal analysis (Figure 8) shows that the concentration of orthophosphates in the waters of the Menouawatershed varies from 7.08mg / l (December 2014) to the P8 site and 0.04mg / l recorded at site F7 (February 2015). The orthophosphate profile shows a relatively marked variation in a tendency to increase in the sites located at the marshy areas (use of phosphate fertilizers for fruiting) and points of discharges. This increase is also due to the drainage of domestic waste water into the watercourses along the basin. The time variation of phosphorus showed a maximum (2.17 mg / l) recorded in May and a minimum (1.61 mg / l) in February. The high levels recorded during the rainy season are the result of climatic factors (wind and rain) [22]. Ortho phosphates are part of the anions easily fixed by the soil. Their presence in natural waters is linked to the nature of the lands traversed and to the decomposition of organic matter [23]. The result is a real degradation that can become irreversible [24]. ANOVA shows that there is a significant variation for the orthophosphates between the different sites, because Pr<0.0001. These values are not consistent with the WHO standard.

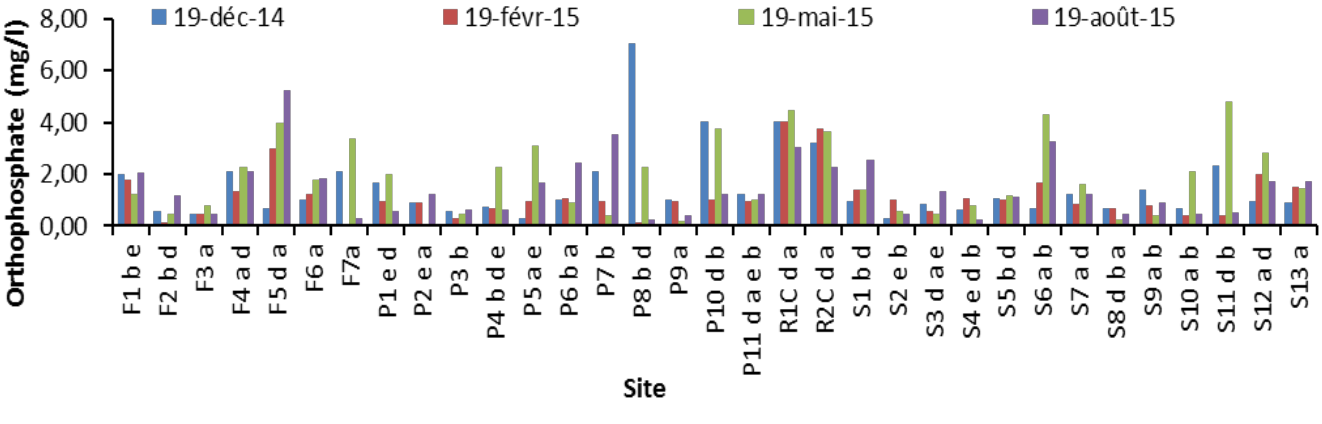

Figure 8: Spatiotemporal evolution of phosphorus of theMenoua watershed

Sulfates (SO_4^{2-})

The spatiotemporal profile of the sulfates (Figure 9) allows to detect differences in significant and irregular contents along the basin and during different sampling periods, the lowest value (0.2mg / l) recorded in the site F2 , is noted in May 2015 and the largest (9,60mg / l) recorded in the S5 site is recorded in December 2014. The spatial evolution of the sulfates along the basin shows a sheared profile, the maximum sulfate contents (8, 68mg / l) are recorded in site S5 and minimal (0.57mg / l) at site F2. Generally, the most important sulfate values observed at the different sites could be due to agricultural activities, but also to the leaching of triassic salt formations in the form of gypsum (CaSO4) which exists in the basin [25]. The temporal evolution of the sulfates has a profile in which the high grades are recorded in the rainy season with the maximum (3.71 mg / l) in May 2015. The low dry season levels with a minimum of 3.50 mg / l in February of the same year. These high values in the rainy season can be explained by the presence of acid rain (rich in sulfuric acid) in the environment on the one hand and on the other hand by the use of sulfated agricultural inputs by the riparian populations along the courtyards of water in the basin [25]. ANOVA reveals a very highly significant effect of sulfates between the different sites because Pr<0.0001). These values are consistent with the WHO standard.

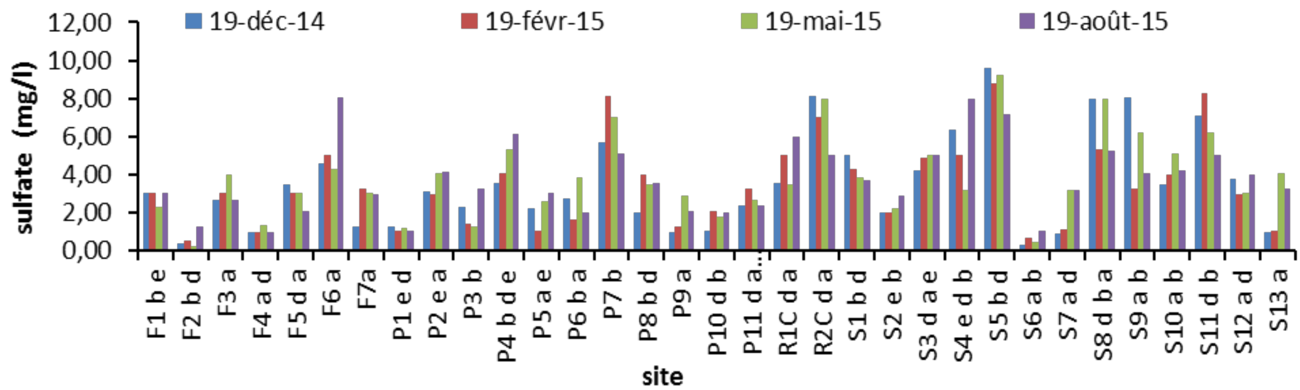

Figure 9: Spatiotemporal evolution of sulfate of the Menoua watershed

Chloride (Cl^-)

The spatial and temporal evolution (Figure 10) shows that chloride levels are high in May 2015 (131.07mg / l) recorded at site F1 and low (1.59mg / l) recorded at the site in December 2014 at site F7. The spatial profile observed along the basin shows high values at sites F1, F2, P1 and S5, the maximum level of which is recorded at site F1. This high content indicates the contribution of anthropogenic input, which may be of agricultural origin as well as domestic wastewater or landfills near the watershed of the basin [26]. The temporal evolution of the averages is marked by a lowering of the chloride contents during the rainy season compared to the dry one. The minimum value (38.43mg / l) is recorded in August 2015 and the maximum value (44.81mg / l) in December 2014. This decrease in rainy season results from the dilution of the basin's water by precipitation [27]. ANOVA shows a very highly significant effect of chlorides between the different sites because Pr<0.0001. These values are consistent with the WHO standard.

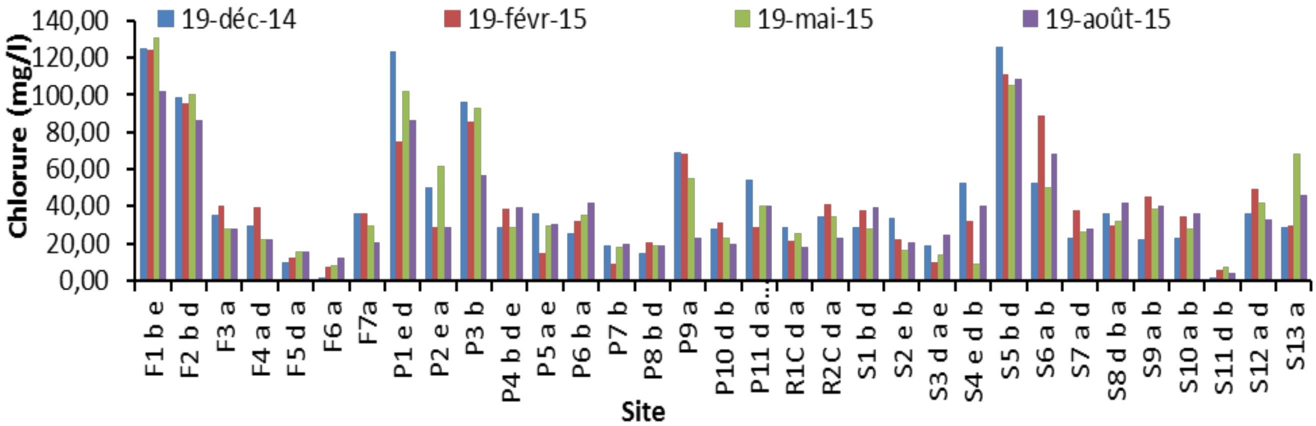

Figure 10: Spatiotemporal evolution of chloride of theMenoua watershed

Calcium (Ca^{++})

The spatial and temporal evolution of calcium (Figure 11) along the basin varies little in the majority of sites. The values observed in the F1 site (61.80 mg / l) throughout the study period show high inflation in the others and could be explained by the use of calcium hypochlorite in the treatment of water. The spatial and spatiotemporal variation has a similar profile. The extreme maximum (48.88mg / l) is recorded in the S1 site and the minimum (9.34mg / l) in the S5 site. The temporal profile shows high values during the rainy season, the maximum (27.97 mg / l) recorded in May 2015. The low values are recorded in the dry season and the minimum (26.08 mg / l) recorded in February 2015 Changes in water levels along the calcium basin would be a direct result of the geological nature of the lands traversed by the waters as a result of attack by carbon dioxide-laden water, calcareous rocks or the simple dissolution of gypses [28]. It exists mainly in the form of hydrogencarbonates and in lesser amount in sulfate, chloride, etc. [14]. Analysis of the variance shows a very highly significant effect of calcium in water at the different sites (Pr<0.0001). These values are consistent with the WHO standard.

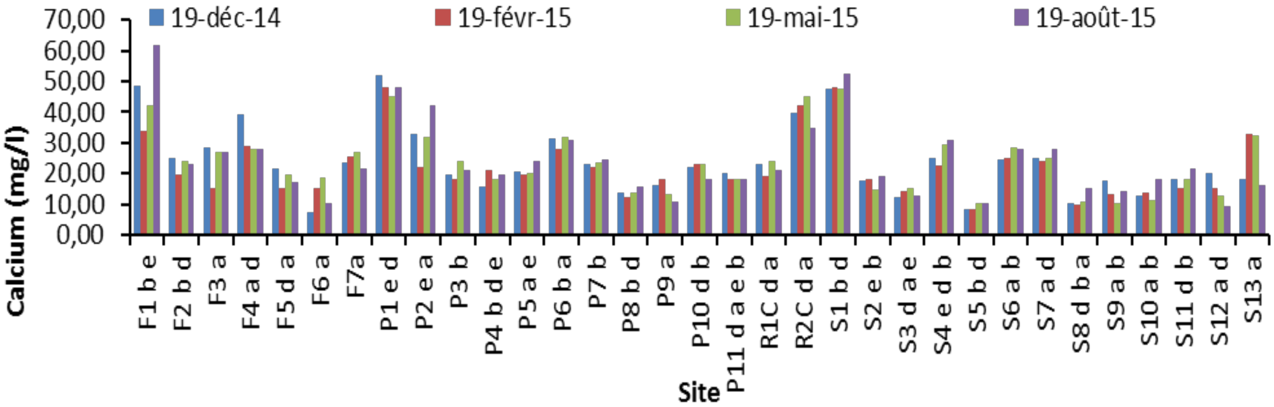

Figure 11: Spatiotemporal evolution of calcium of theMenoua watershed

Potassium (K^+)

The spatial and temporal evolution of potassium (Figure 12) shows almost similar fluctuations, with minimal values (0.56mg / l) recorded at the F4 site in August 2015, while the maximum values (10,80mg / l) are observed at the S5 site in February 2015. The spatial profile shows the levels fluctuating between 0.69 mg / L (F4 sites) and 9.91 mg / L at the S5 site. The temporal range shows a slight oscillation between 3.85 mg / l and 3.11 mg / l. High levels are recorded in the dry season. Potassium is an essential element in life and especially in the growth of plants. In agriculture, it is used as fertilizer in the form of potassium sulfate, potassium chloride, or potassium nitrate. Although in igneous rocks the potassium content is almost as great as that of sodium [14], with the nature of the soil, it is quite the opposite, where potassium is minor compared to sodium. The analysis of the variance shows a very highly significant effect of potassium in the water of the different sites since Pr<0.0001. These values are consistent with the WHO standard.

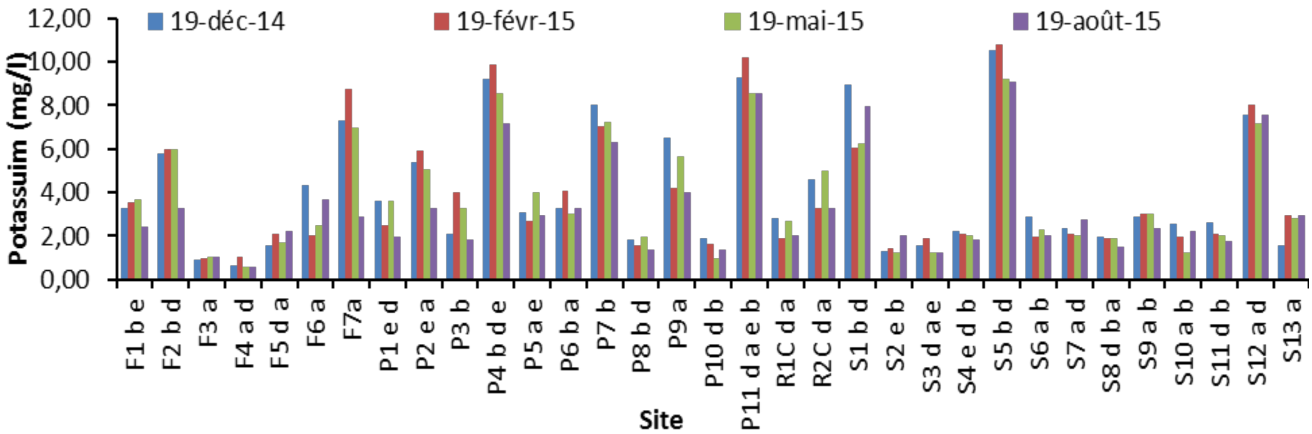

Figure 12: Spatiotemporal evolution of potassium of the Menoua watershed

ACP is a factorial method that allows the simplified description of a measure that is difficult to manipulate, composed of variables with quantitative aspects derived from a space-time observation plan [29]. The synthesized information is based on the reduction of the number of the character and on the simultaneous construction of a new synthetic character [30]. The latter form the main components which are obtained by linear combination of the initial characters. The ACP particularly illustrates the correlations between the variables. The synthetic characters or components thus formed each contain a part of the starting information. The first will contribute as much information as possible to similarities or differences between variables and will therefore be an original character of the data table, and then the information for each variable or statement will be analyzed and processed at the level of each component. Depending on the experimental objectives, a number of basic calculations can be carried out, leading to some graphical representations [31].The data processing carried out by (ACP) made it possible to classify and process the information relative to the physicochemical parameters carried out during the period of study in order to identify the relations of the physicochemical variables studied with each other, study the spatial distribution of study sites as a function of spatiotemporal dynamics. This ACP was carried out on a matrix of 132 samples (33 sites X 4 campaigns), in which the variables (pH, temperature, electrical conductivity, turbidity, nitrate, orthophosphate, sulfate, chloride, potassium and calcium) been measured.Analysis of the factor plane F1 and F2 (Table 1a and Figure 13) shows that more than 33.80% are expressed.

Table 1: (a) factor plane F1 and F2 and (b) correlation matrix

(a)	F1	F2
pH	0,353	-0,250
T	-0,327	0,035
Ce	-0,044	0,298
turbidité	0,516	0,209
NO_3^-	0,289	0,398
PO_4^{3-}	0,473	0,120
SO_4^{2-}	0,054	0,536
Cl^-	-0,001	-0,315
Ca^{++}	0,427	-0,399
K^+	-0,087	0,294

(b)	pH	T	Ce	turbidité	NO_3^-	PO_4^{3-}	SO_4^{2-}	Cl^-	Ca^{++}	K^+
pH	1									
T oc	-0,127	1								
Ce	-0,146	-0,089	1							
turbidité	0,091	-0,072	-0,008	1						
NO^{3-}	-0,032	-0,146	0,032	**0,227**	1					
PO_4^{3-}	0,138	-0,132	0,078	**0,290**	**0,174**	1				
SO_4^{2-}	0,032	-0,022	0,075	**0,171**	**0,209**	-0,019	1			
Cl^-	0,042	-0,144	-0,029	-0,164	0,009	-0,159	-0,163	1		
Ca^{++}	**0,232**	-0,129	-0,103	**0,282**	-0,037	0,141	**-0,222**	**0,297**	1	
K^+	-0,150	0,072	0,147	0,012	0,158	-0,075	**0,229**	**0,280**	-0,025	1

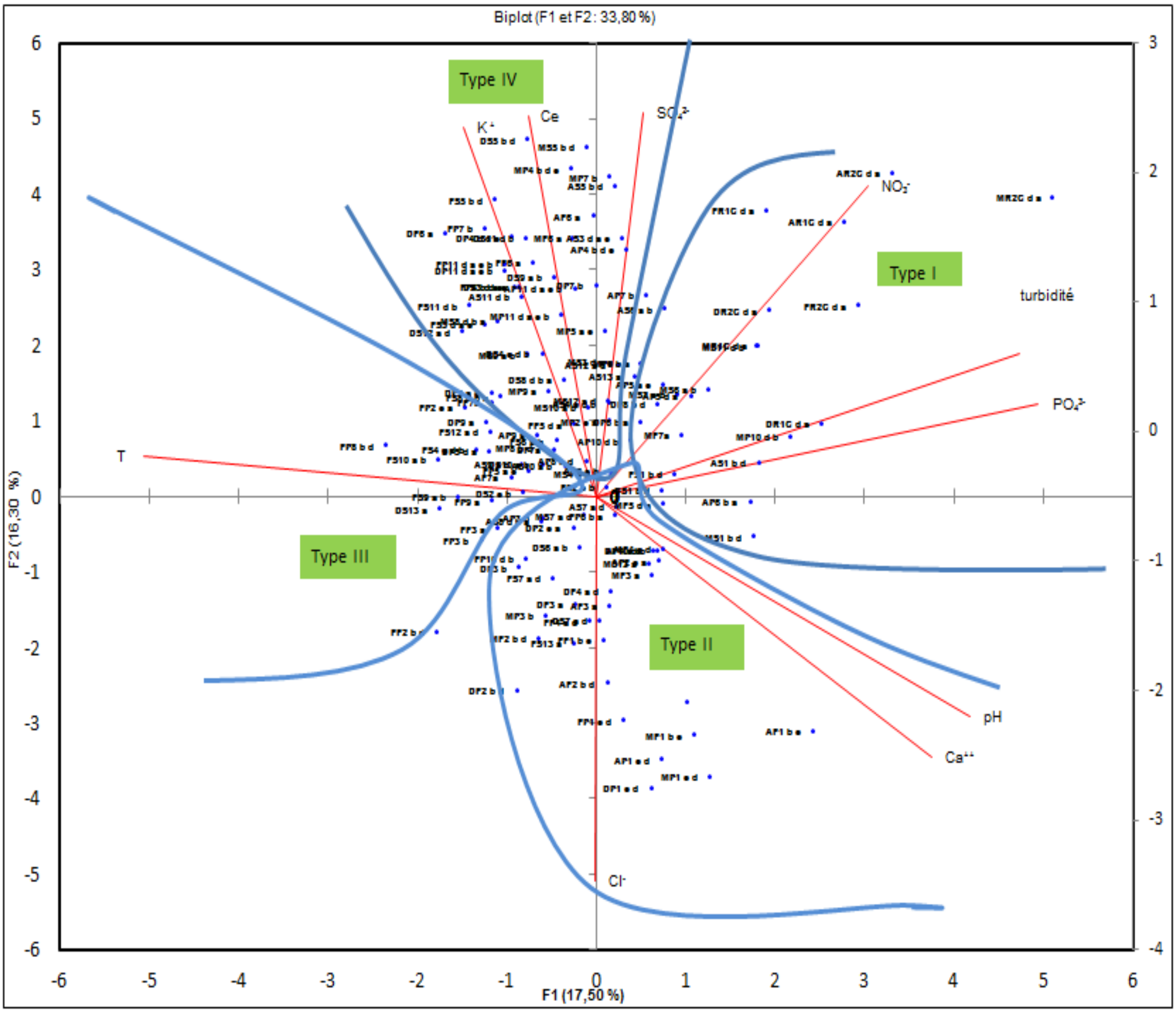

Figure 13: Factor map of the water of theMenoua watershed

The F1 axis has a variance of 17.50% and contributes positively to pH, turbidity, nitrates, orthophosphates and calcium and negatively by temperature. The axis F2 has a variance equal to 16.30% contributes positively by electrical conductivity, turbidity, nitrates, sulfates, potassium and negatively by calcium and chloride. The correlation matrix has the following correlations: pH/Ca^{++} (0.232), turbidity/NO_3^- (0.227), turbidity/PO_4^{3-} (0.290), turbidity/SO_4^{2-} (0.171), turbidity/PO_4^{3-} (0.174), NO_3^-/SO_4^{2-} (0.209), SO_4^{2-}/Ca^{++}(-0.222) and Cl^-/Ca^{++} (0.297) (Table 1b). The application of statistical methods (PCA) on the physicochemical data of the water of the Menoua watershed reveals the presence of four types of water (Figure 13):

Type I mostly collects the waters of spring and rivers, which are highly polluted in the dry season and in the rainy season. This pollution is characterized by high levels of nitrate and orthophosphate all correlated with high turbidity. This variety of water is located near landfills, agricultural areas and built-up areas, which would certainly be the potential source of pollution. Indeed, the pollutants deposited during periods of drought on the ground and at the level of the unsaturated zone are driven by the rains [32].

Type II containing well water and some boreholes is moderately contaminated by chloride, calcium correlated with acidic pH and this pollution would result from the use by the owners of these wells and boreholes of the not recommended quantities of disinfectants in the optics to clean up their water such as: calcium / sodium hypochlorite or to the geological profile of the soil.

The type III represented by the drilling waters has a high temperature. This could be explained by the geothermal phenomenon.

Type IV collects well water and some sources. They present an acceptable mineralization but are highly polluted during the rainy season and this pollution is materialized by high levels of sulfate which would certainly come from breeding, agriculture and buildings because they are located in the vicinity of these zones.

The principal component analysis confirmed the origin of certain pollutants degrading the quality of the water used for human consumption in the Menoua watershed. In other words, the environment is locally rich in leaching elements from agropastoral activities and landfill sites in the vicinity or in the rivers of the basin. The origin of pollution and variations in time and space remain an enigma and are probably multiple (natural and anthropogenic). It results from this multi-varied analysis a certain typology of water materialized by their degree of pollution in different elements varying according to the space, seasons discriminated by different origins.

Conclusion

This study was carried out on the spatiotemporal monitoring of the physicochemical quality of water in the Menoua watershed and the typology of these waters as a function of anthropogenic dynamics and seasons main Principal Component Analysis that:

Some physicochemical parameters such as pH, turbidity and orthophosphate have grades that are in contradiction with WHO standards.

The physicochemical characteristics of the waters of the Menoua watershed showed quite marked spatial and seasonal variations. During their evolution, these waters showed significant differences between the different sampling sites, through ANOVA. This evolution is the consequence of the highly developed anthropogenic activities in the basin. However, this pollution is not constant; it fluctuates in time and space. The Principal Component Analysis in this study identified four distinct types of human drinking water depending on the movement of surrounding human activities and the seasons.

The results of this study are perfectly consistent with the issues raised in the problem and show the acuity of the problem and the need to limit its effects. There is also an urgent need to rationalize the codes of good agricultural practice and sanitation in order to combat this pollution effectively. A more complete diagnosis ofthe current situation of the pollution of this water and a rigorous follow-up of its evolution proves to be of great necessity for its safeguarding.

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