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RESEARCH ARTICLE

ASSESSMENT OF THE WATER QUALITY OF LAKE KONGO AND RIVERS IN THE SURROUNDINGS OF SUGAR CANE PLANTATIONS IN THE CITY OF NKAYI (REPUBLIC OF CONGO)

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ABSTRACT

Background: This article focuses on the assessment of the water quality of Lake Kongo and rivers in the vicinity of the sugar cane plantations in Nkayi in the Republic of Congo. **Objective:** The physico-chemical study is based on the determination of the contents of the various parameters. The samples taken in the field were subjected to physico-chemical analyzes. The levels were determined by several methods: in situ and in the laboratory. **Methods:** The results of the chemical analyzes were processed by hydrochemical and statistical methods. **Results:** The organoleptic parameters reveal contents of the wastewater higher than the WHO standards (MES: 591 mg / l, turbidity: 806.5 NTU in the rainy season and MES: 469 mg / l, turbidity: 463.98 NTU in season dried). The physico-chemical parameters also show levels higher than WHO standards for certain rivers such as Louadi (bicarbonates: 235.5 mg / l), Livouba (calcium: 89.83 mg / l) in the dry season. The pH is basic, greater than 7, only the wastewater gives an acidic pH with 6.09 in the dry season and 6.4 in the rainy season. Regarding undesirable substances, nitrates have levels higher than WHO standards: 67.59 mg / l for Lake Kongo and 72.6 mg / l for the Mintouyou river in the dry season, 51.59 mg / l for wastewater and 55.38 mg / l for the Louadi river in the rainy season. **Conclusion:** The mineralization of water is mainly caused by the phenomena of dissolution and precipitation of minerals (calcite, dolomite, anhydrite, gypsum and halite). The results obtained by the PCA indicate that the variables which control the salinization of water are Ca^{2+}, Mg^{2+}, Al^{3+}, HCO_3^-, SO_4^{2-} and K^+. Most of these waters are polluted by a permanent source of pollution which remains to be determined in the future.

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INTRODUCTION

Cane is the main export crop and contributes to socio-economic development in the department of Bouenza, in general and, in particular, in the Nkayi watershed. Indeed, it is not only the main source of monetary income for the peasants who cultivate it, but also provides significant foreign currency to the state. In order to increase agricultural yields and incomes, the use of chemical fertilizers and pesticides is essential in agriculture, with as a corollary their residual transfer to water resources. Also, the quantitative and qualitative composition of water in dissolved and suspended matter, of mineral or organic nature, determines its quality (Jain et al., 2005; Mehounou et al., 2016). However, this quality can be altered when external substances come into contact with the aquifer. This is the case with unwanted or even toxic substances which make groundwater and surface water unsuitable and toxic for various uses, including the use of drinking water.

The intensive use of natural resources and the increase in human activities cause serious problems with the quality of groundwater (Foster, 1995). Agriculture releases fertilizers, pesticides and animal wastes into the soil and irrigation water. In countries in development, obtaining safe water for human consumption has become a serious problem due to a lack of environmental protection. Thus, the aim of this study is to determine the state of knowledge of the waters of Lake Kongo and the rivers in the vicinity of the sugar cane plantations in Nkayi by carrying out physicochemical analyzes.

MATERIAL AND METHODS

Presentation of the study area: The city of Nkayi is located in the southwestern part of the Republic of Congo, between latitudes 4 ° 10'0 " and 4 ° 15'0 " South and longitudes 13 ° 7'30 " and 13 °15'50"East (Figure 1).

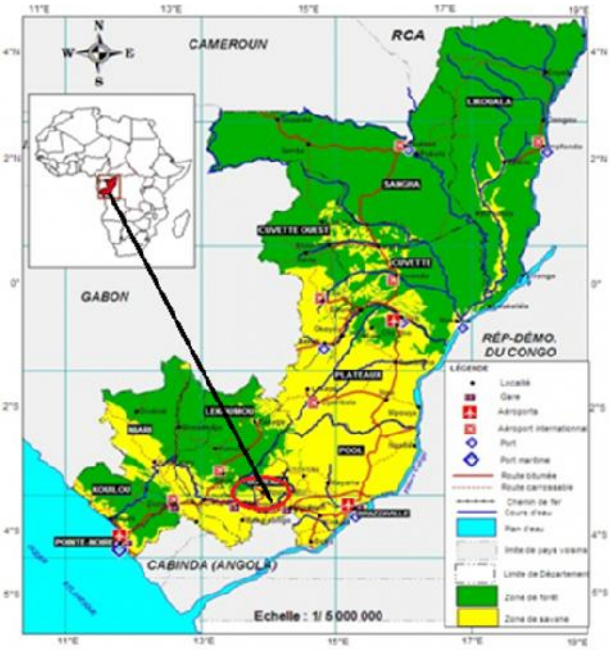

Fig. 1. Location of the study area

This city is part of the Niari basin which constitutes the foreland of the Mayombe chain. It is an area of 42 000 km2. From a geological point of view, the town of Nkayi is entirely made up of schisto-limestone formations subdivided into four groups: Schisto-limestone I (SCI), Schisto-limestone II (SCII), Schisto-limestone III (SCIII) and Schisto-limestone IV (SCIV). The soils of this zone belong to the following three main classes: poorly evolved soils, hydromorphic soils and ferrallitic soils (Brugière, 1953, Mapangui, 1988 and 1992). The town of Nkayi is covered with shrub savannah (Koechlin, 1961) which occupies the more clayey and richer soils of the Niari valley and the Cataractes plateau. It is characterized by a stronger development of the shrub layer and especially by the importance of grassy vegetation. This forms a very dense mat of robust grasses, usually exceeding 2 m in height (Schwartz, 1996). Its climate is characterized by an alternation of seasons: a rainy season (October-December and March-May), with an intrapluvial decline, in January-February, and a dry season (June-September) on which the agricultural calendar is modeled (Samba-Kimbata, 1978).

Experimental procedure: Sampling campaigns were organized between 2019 and 2020 throughout this study to carry out this study. A seasonal monitoring of the water quality assessment parameters of the schisto-limestone aquifer was carried out during the dry season and the rainy season of 2015. The sampling concerned 6 points well distributed over the aquifer. During this campaign, the water samples taken were placed in polyethylene bottles with a capacity of 0.5 liters, previously washed with nitric acid and then with distilled water. Physico-chemical water quality parameters were determined, using the chemical method: pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature were measured in situ using portable devices. HANNA brand. The complete alkalimetric strength (TAC) and the alkalimetric strength (TA) were determined by field titrimetry using 0.01N H2SO4 solution. The analyzes of the water sampled were carried out at the SNDE Brazzaville Water Control and Analysis Laboratory. Consort type C933, Ca2 +, Mg2 +, Al3 +, HCO3-, total water hardness (THt) were determined by volumetric titration with 0.01M EDTA.

The concentrations of orthophosphate ions (PO43-), nitrates (NO3-), and sulphates (SO42-) were determined, respectively by argentometry and by the nephelometric method.

Statistic study: For any geochemical study, the separate study of each of the variables is an important phase in the analysis of chemical behavior, but is often insufficient. It is therefore necessary to analyze the data taking into account their multidimensional nature. To study the sources of water salinization, the statistical method used: Principal Component Analysis (PCA). Principal Component Analysis Principal Component Analysis is a descriptive method whose objective is to present in graphical form the maximum amount of information contained in a database. This base is made up, in rows, of "individuals" (points) on which "quantitative variables" (major elements and trace elements) are measured, arranged in columns.It makes it possible to reduce the number of variables in order to project the point cloud in a two-dimensional subspace generated by pairs of factor axes or factors (Cloutier et al., 2008; Yidana et al., 2008).

RESULTS

The results of the chemical analysis of the water from the various measurement points in this area generally show an instability of their physicochemical properties during all the sampling campaigns. The results are represented in three parts: organoleptic parameters (suspended matter, turbidity), physicochemical parameters (pH, conductivity, complete alkalimetric titer, total dissolved solid, Ca2 +, Mg2 +, HCO3-, SO42- and Al3+) and unwanted substances (PO43- and NO3-).

Organoleptic parameters

Suspended matter: Figure 2 represents the variation of suspended matter as a function of the different measurement points during two seasons.The samples analyzed show levels above the WHO standard, with the exception of Louadi (0 mg / L) in the dry season and Livouba, in the rainy season, with a content of 0.5 mg / L.Wastewater from agricultural companies shows suspended solids content of 469 mg / L in the dry season and 591 mg / L in the rainy season. This water degradation can be explained by the presence of vegetation, the debris of which is brought in by runoff.

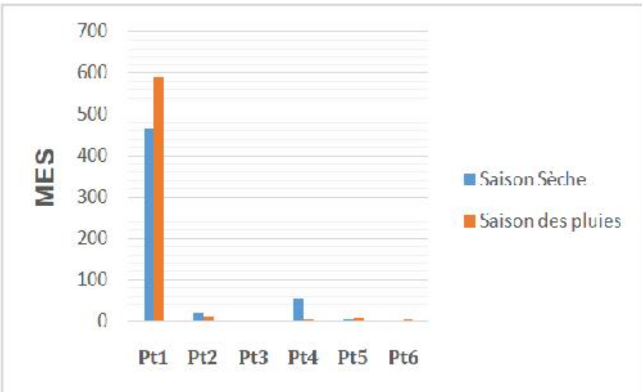

Fig. 2. Variation of suspended matter in the water studied

Turbidity: The turbidity of the water is an important parameter because the clogging of the membranes depends on it.A correction factor is therefore applied tending to increase the filtration surfaces in order to limit the rate of clogging.

Table 1. Results of chemical analyzes of the waters of Lake Kongo and rivers in the town of Nkayi

	MES	Turb.	pH	CE	TAC	TDS	Ca2+	Mg2+	SO42-	HCO3-	Al3+	NO3-	PO43-
Saison sèche													
Pt1	469	463,98	6,09	200	74,68	12	21,3	17,58	35,5	90,95	0,87	38,5	1,34
Pt2	21,5	9,5	7,53	27	19,92	12	52,47	0,44	0	24,3	0,003	67,59	0,26
Pt3	1	0,3	8,18	102,5	192,56	43,16	89,83	0,58	1	235,42	0,003	18,26	0,11
Pt4	57	41,7	7,9	65	128	29,27	28,38	0,71	0	156,16	0,21	28,66	0,12
Pt5	6	3,1	8,7	179	306	106,7	66,7	0,67	1	42	0,012	72,6	0,05
Pt6	0	2,1	8,85	104	174,2	46,84	95,85	0,59	1	212,5	0,01	35,95	0,4
Saison des pluies													
Pt1	591	806,5	6,4	745	112	345,5	46,78	0,74	90	136,6	0,045	51,54	0,8
Pt2	12	10,45	7,75	36,6	16	16,86	4,18	0,26	0,5	19,52	0,04	2,35	0,085
Pt3	0,5	1,1	8,5	513,5	242	241,12	66,13	0,23	0,5	276,94	0,01	40,1	0,1
Pt4	5,5	2,95	8,73	289,5	103	137,27	22,77	0,37	9,5	183,77	0,026	55,38	0,095
Pt5	10,5	5,35	8,67	194	97	89,52	28,34	0,18	0,5	115,9	0,005	13,45	0,7
Pt6	5	1,75	8,41	397	113	179,76	46,38	0,16	0	124,44	0,02	12,08	0,03

The man-made watercourse where the wastewater of the agricultural society flows has the highest rates of 806.5 NTU in the rainy season and 463.98 NTU in the dry season. The other rivers have rates below the WHO standard of 5 NTU.This turbidity (806.5 NTU) can be explained by the filling of waste from the factory, industrial waste and plants carried by runoff.

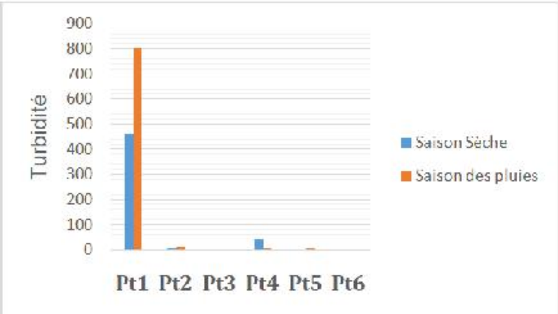

Fig. 3. Variation in turbidity

Physicochemical parameters

Hydrogen potential (pH) : The pH of natural waters is linked to the geological nature of the terrain crossed.The waters studied have an average pH of 7. The Livouba has a pH of 8.18 in the dry season. And 8.5, in the rainy season. These results are close to those found by Moukolo in 1992. In comparison with the WHO standard (6.5 to 9), the samples taken all have a basic pH, except the wastewater from the artificial river at the level. The national road n ° 1 which have an acidic pH with an average of 6.

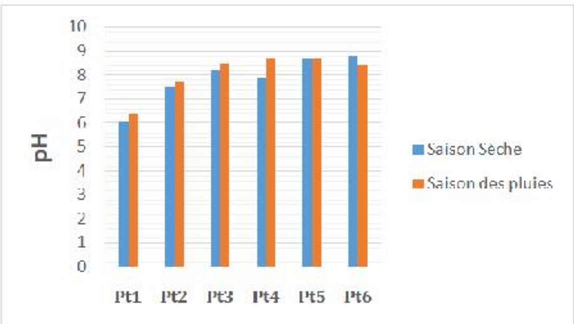

Fig. 4. Variation of hydrogen potential

Conductivity : The measurement of the electrical conductivity gives an overview of the mineralization of the waters of this zone.It increases with increasing dissolved salt content in water.The conductivity contents are quite high.

In the dry season, the wastewater gives an average content of 200 μS / cm and the average is 745 μS/cm in the rainy season.

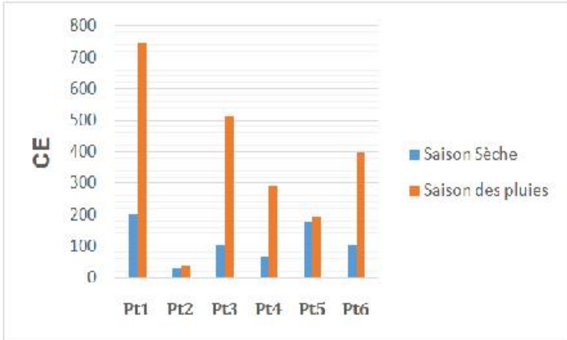

Fig. 5. Change in conductivity

Complete alkalimetric title (TAC): The complete alkalimetric content (TAC) of the waters studied in this geographical area is higher than the WHO standard (100mg / L of CaCO3), in most rivers.In the dry season, the wastewater from the artificial river and Lake Kongo present, respectively, levels of 74.68 mg / L and 19.9 mg / L of CaCO3.

In the rainy season, Lake Kongo with (16 mg / L of CaCO3) and Louadi (97 mg / L of CaCO3) have levels below WHO standards. The total dissolved solids of the waters of this geographical area have values varying between 12 and 106.7 mg / L, in the dry season, and 16.86 and 345.5 mg / L, in the rainy season.

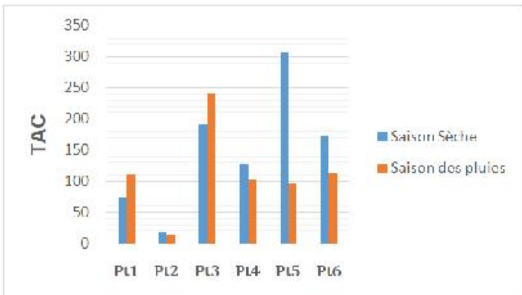

Fig. 6. Variation of the complete alkalimetric strength

The TDS values are within the acceptable limits of the WHO, for drinking water;because they are less than 500 mg / L (WHO, 2011).The low values of electrical conductivity and total dissolved solids are explained by the nature of the dominant aquifer throughout the Nkayi area.

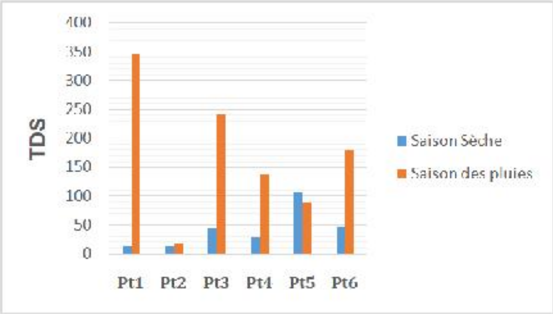

Fig. 7. Change in Total Dissolved Solids (TDS)

Calcium: The statistics of the concentrations of Ca2 + ions show that no river is beyond the value required by the WHO (40 to 160 mg / L) during the rainy season, because the average values obtained for calcium are insufficient..No calcium pollution during this season is observed.On the other hand, Livouba (89.83 mg / L) and Louadi (95.85 mg / L) have levels higher than the WHO standard, in the dry season. Therefore, they present calcium pollution during this period. The found calcium contents are very close to each other.

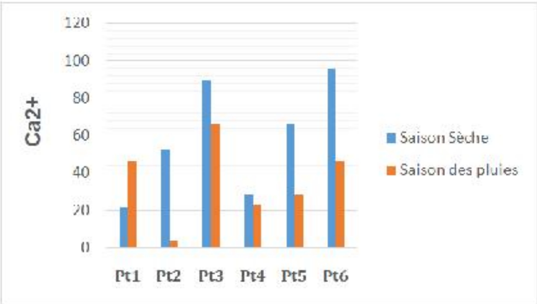

Fig.8. Calcium variation

Magnesium: During this analysis, insufficient amounts of magnesium were recorded in all the rivers studied, compared to the WHO standard (50 mg / L), during the rainy season.No magnesium pollution is observed and the levels do not exceed 1 mg / L.During the dry season, magnesium levels are very low in all rivers.In the rainy season, the wastewater from the artificial river from the agro-industrial company indicates 17.58 mg / L. However, no magnesium pollution exists and these results meet WHO standards.

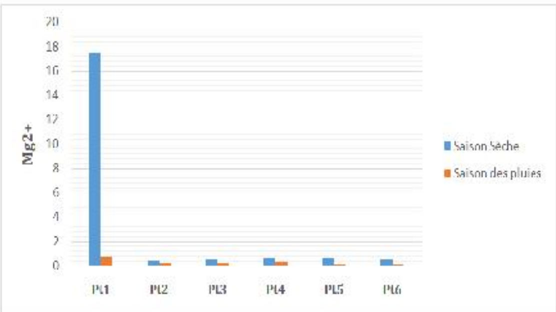

Fig. 9. Variation of magnesium

Sulphate: Sulphates naturally present in water can bind to many cations (calcium, magnesium, sodium, lead, barium, strontium, aluminum, etc.).The origin of these sulphates can also be human: pollution of paper, textile, mining industries or treatment for the purification of water (aluminum and iron sulphates used for flocculation). Sulphate ions are non-existent in the waters of rivers and lakes in this area.During the two seasons, no river presents a pollution. The levels obtained are lower than the standard accepted by the WHO (250 mg / L).Lake Kongo has sulphate contents equivalent to 0 mg / L, in the dry season.The Louadi, Livouba and Mintouyouet rivers have a content equal to 1 mg / L.

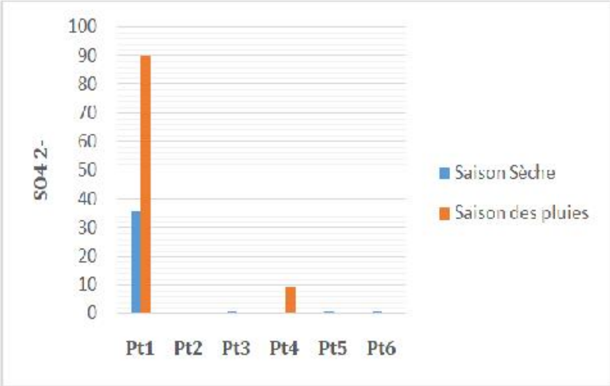

Fig. 10. Variation of sulphate

Bicarbonate : The bicarbonate values in the study area are symmetrical with the pH. They are significant. This could be a mark of the chemistry of waters in a schisto-limestone environment. Indeed, the water being saturated or supersaturated with respect to calcite, a decrease in pH leads to an increase in bicarbonate. In the rainy season, Livouba (276.96 mg / L) is the only river studied which has pollution in bicarbonates and others have insufficient quantities, compared to the WHO standard (200 mg / L). In the dry season, there is pollution of this element in certain rivers, the Livouba (235.42 mg / L) and the Louadi (212.5 mg / L). The results found in Livouba, in the dry season and in the rainy season (276.94 mg / L), are close to those obtained by Moukolo (1992) (298.8 mg / L). Regarding Lake Kongo, it appears that in the rainy season, the value obtained is 19.52 mg / L and 24.3 mg / L, in the dry season, while Moukolo and Cheikh (2003) find 21.35 mg / L. These results are very close.

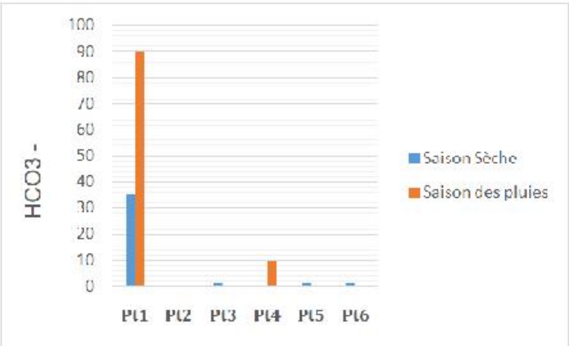

Fig. 11. Bicarbonate variation

Aluminum: The presence of aluminum in water can be of human origin or of natural origin in the soil.Aluminum can present encephalopathy dangers to people with chronic kidney disease.The aluminum contents of the water studied do not exceed 1 mg / L.The permitted limit is 0.2 mg / L.This wastewater from the agro-industrial company has a high aluminum content.By way of illustration, this is the case for Livouba which presents 0.21 mg / L in the dry season. In the rainy season, the contents are very low.These aluminum contents are very close to the lithology of the land.

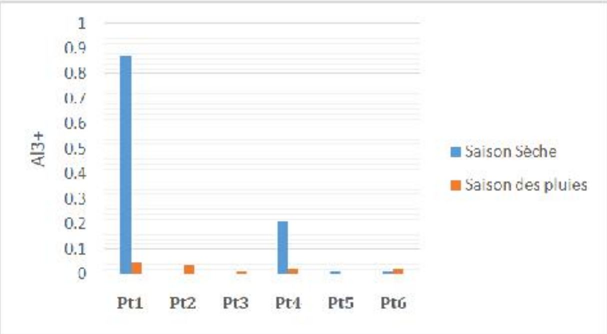

Fig. 12. Aluminum variation

Unwanted substances

Nitrates (NO3-): Nitrates are naturally found in low concentrations in water. They can have an artificial origin due to their use as fertilizers for crops (mineral and organic fertilizers, animal droppings ...). Excesses not absorbed by plants are washed away by the rains and join the groundwater and surface water. They can also be provided by food: some vegetables are indeed very "concentrators" (zucchini, spinach, etc.). Nitrates are not dangerous for health, but it is their transformation into nitrites in the digestive system that is problematic. In excess, they contribute to the eutrophication of surface water (in relation to phosphates). In the whole of this zone, there is a nitrate pollution, at the level of wastewater (51.54 mg / L) of the agro-industrial company and at the level of the Louadi river, with a content of 55.38 mg / L, in the rainy season. In the dry season, Lake Kongo and the Mintouyou river have, respectively, the contents of 67.56 and 72.6 mg / L while the other rivers do not present any pollution; they are in insufficient quantity and in dose, limit compared to that required by WHO.

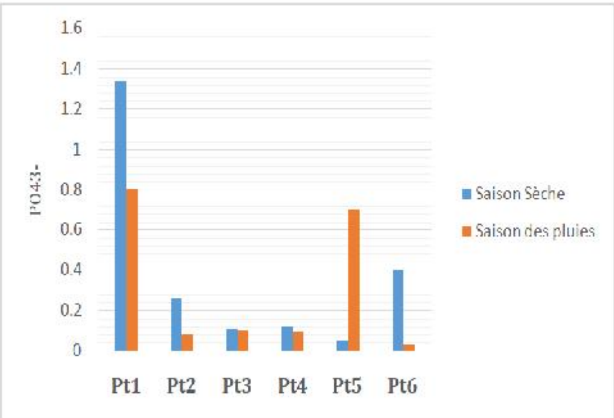

Fig. 13. Nitrate variation

Phosphate (PO43-): Phosphate can be found in various oxidized forms (meta HPO3, pyro H4P2O7 and ortho H3PO4) in aqueous medium, the meta and pyro forms tending towards the ortho form for pHs from 5 to 8. This chemical element is often found inaquatic environment under the effect of urban, industrial and agricultural discharges and also under the effect of biological reactions.Various chemical and biological factors can react on the mobilization of phosphate and on the evolution of nitrogen compounds at the water / sediment interface: temperature, dissolved oxygen (O2), redox potential (Eh) and pH(Boers, 1991; Jensen and Andersen, 1992).

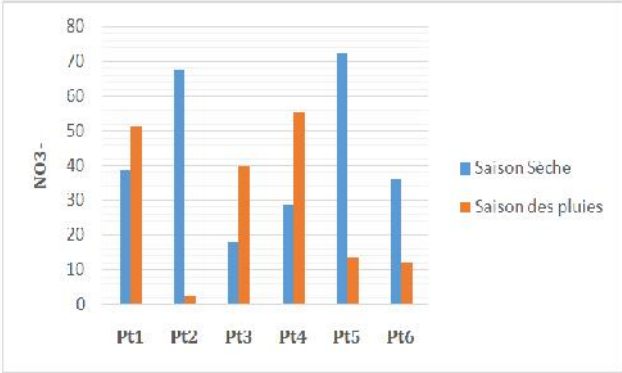

Fig. 14. Nitrate variation

During the two sampling seasons, Lake Kongo and the rivers do not present levels of phosphates exceeding the WHO standard (5 mg / L);which allows us to say that these rivers are not polluted with phosphates. The wastewater of the agro-food company has the highest content equivalent to 1.34 mg / L, in the dry season and the lowest is that of the Louadi river in the same dry season, with a content of 0.05 mg./ L.

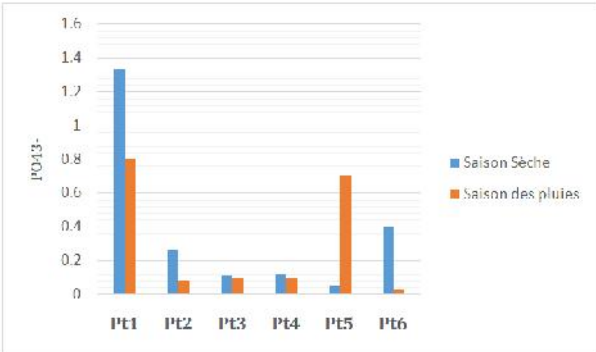

Fig. 15. Change in phosphates

Principal Component Analysis (PCA) : The Principal Component Analysis (PCA), applied to the standardized parameters, confirms the results relating to the source of mineralization obtained previously. The available results were subjected to principal component analyzes. The first takes into account some major elements and parameters in the samples taken in the dry season, the second was made in the rainy season.

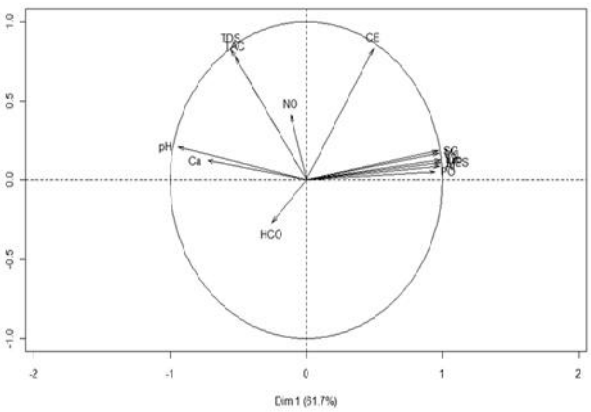

Fig. 16. Principal Component Analysis of the waters of Nkayi town in the F1- F2 factorial plane in the dry season

In the dry season : The study of the spectrum of eigenvalues shows that there are two axes to be retained for the interpretation of the results since they hold 80.05% of the total variance. , the factor 1 expresses 61.7% of the variance of the parameters TDS, TAC, CE and NO3- and shows an opposition with HCO3-. This first interpretation shows a double origin of salinity: a first caused by geology, in particular by the dissolution of the surrounding area, the second originally characterized by high values of a few parameters such as bicarbonate. The factor 2 expresses 18.35% of the variance of the data.Note that the observed mineralization is generated by all the elements, except calcium, whose pH is negatively correlated with this axis.

In the rainy season: The statistical study, from the PCA gives numerous results which are presented in Table I. In Table 2 are recorded the eigenvalues, the variances expressed for each factor and their accumulations. The observation of the circle formed by the two axes F1F2 (86.92%) of the information shows, along the axis F1 (55.87%), an inverse evolution between the pollution indicators, particularly, the elements coming from the fertilizer (NO3, PO4 and Al).This evolution characterizes the redox phenomena.We deduce that the positive part of the axis shows an oxidation state.However, the negative part corresponds to a reduction. The F2 axis (31.05%) shows an opposition between phosphates and pH and oxygen;this indicates that the phosphates have another origin which would be waste water. The interpretation of the results provided by the ACP showed that the waters of the region had some pollution, we will try to highlight these forms of pollution (natural or anthropogenic, mineral or organic) detected after treatment of the analyzes carried out.

DISCUSSION

The potability of water is defined by physicochemical parameters, but above all according to its use. With regard to drinking water, in the absence of national standards, reference is made to the WHO guideline values given according to the quality guidelines for drinking water (Faillat, 1984). By these standards, which are highly turbid, the water in the study area is of poor quality, all the more so that; the majority of the concentrations of physicochemical elements measured do not meet the criteria for the quality of drinking water. This indicates the openness of the aquifer system, and therefore its vulnerability to pollution. These waters are aggressive, with a variation in pH. This observation for the waters of this zone was made at several measurement points. The results of the chemical analysis of the waters of this geographical area generally show an instability of the physicochemical properties during the two seasons of the year (Table I).

The surface water of this zone has a relatively strong mineralization, compared to that of the water of other neighboring water tables (the water table of the Loémé watershed presented by Ngouala Mabonzo in 2008 and 2016). Chemical analyzes show that the total mineralization of the water logically increases from point to point in the direction of flow. The lower values characterize the upstream zone of the water table which is captured at shallower depths and benefits from surface infiltration through the river beds. On the other hand, the maximum of mineralization was identified to the south and to the east of the aquifer due to the burial of the aquifer, in the downstream zone, under a thick series of clay which constitutes a limiting impermeable screen. The infiltration of surface water, and therefore the renewal of water.

CONCLUSION

The physicochemical analyzes carried out on the water samples taken have shown that the organoleptic parameters of the wastewater from the agro-food company are polluted with SS and turbidity during both seasons. Lake Kongo, the Louadi and Mintouyou rivers also present SS pollution in the dry season. In the rainy season, on the other hand, the rivers are less polluted in organoleptic parameters. Chemical analyzes show no pollution in aluminum, magnesium and calcium. Only the Livouba and Louadi rivers present pollution in the dry season. The pH values obtained are within the range of WHO standards. Apart from the wastewater of the agro-food company which has an acidic pH, in the dry season and in the rainy season, the other rivers have a basic pH. Regarding undesirable substances, only nitrates have levels above WHO standards. The waters studied can be considered as hard because of the high levels of THt, TAC and TDS.

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