



RESEARCH ARTICLE

COMPARATIVE STUDY OF THE PHYSICO-CHEMICAL QUALITY OF THE WATER OF FOUR LAKES OF THE FERKESSEDUGOU DAM (NORTH OF CÔTE D'IVOIRE)

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Abstract

Runoff from the catchment areas of the reservoirs is partly responsible for the chemical quality of the water. The main objective of this study was to compare the physico-chemical quality of the waters of four lakes in the sub-county of Ferkessedougou located in the north of Côte d'Ivoire. After application of the referenced analytical methods, the contents of chemical elements were subjected to statistical processing, mainly principal component analysis (PCA). The study revealed a categorization of the water in the reservoirs. On the whole, the water in the reservoirs is poorly mineralized, thus justifying a low electrical conductivity (66.67 to 138.04 $\mu\text{S}/\text{cm}$). The Bakaryvogo lake, richer in dissolved elements, is opposed to the Korobélékaha and Dékokaha lakes, which have the lowest electrical conductivity, unlike the others. The lake of Sépénédiokaha is distinguished by turbid waters rich in organic matter (COD) and suspended solids (SS). This study provided an overview of the quality of the water, which remains a function of the activities in the catchment areas. Furthermore, the waters of these reservoirs are potentially threatened by the phenomenon of eutrophication given the levels of nutrients measured. Indeed, the concentrations of nitrate, nitrite and phosphorus, although lower than the thresholds allowed by the WHO, are significant. There are also significant levels of phosphorus. In addition, the average Fe^{2+} content measured (0.78 mg/L) is above WHO standards.

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Introduction: -

In West Africa, climatic disturbances characterized by long droughts have become more pronounced since the early 1970s. This long and pronounced climatic deterioration has resulted in a clear break in the average characteristics of the rainfall series and a change in the rainfall regime [1, 2]. This change in precipitation is marked by a decrease in mean annual rainfall of 20% to 40% between 1931-1960 and 1968-1990 [3]. One of the impacts of these climatic changes combined with land use modifications on West African watersheds and their lowlands is the alteration of the availability of water resources as well as their spatiotemporal distribution [4, 5].

One of the responses of the last decades to this strong climatic uncertainty is the control of surface water resources. Thus, many governments and institutions have undertaken large-scale development plans aimed at mobilizing

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freshwater resources through the construction of dams on many rivers [6, 7]. In addition to supplying drinking water, these dams are of vital economic interest because of the development of certain activities such as fishing, livestock and agriculture [8].

In Côte d'Ivoire, about 578 dams have been built and distributed throughout the country to meet the growing water needs of the population. The majority of these dams are located in the northern part of the country, which is an area with low rainfall. 290 dams, including 17 in Ferkessédougou, have been built there. Twenty years ago, the networking of the northern part of Côte d'Ivoire by this infrastructure network was a response to a concern that is no longer relevant. Today, the often effective appropriation of the facilities by other categories of actors has considerably changed the scope of the potentialities associated with them [9]. Studies on small dams in the north of Côte d'Ivoire were essentially carried out in 2009 by the Institut de Recherche pour le Développement (IRD) as part of its "Small Dams in West Africa" program. These studies only concerned a few dams in the sub-prefecture of Ferkessédougou, where the drying up of certain dams during the dry season in recent years has been confirmed.

Water is a necessary resource for all human activity and constitutes the heritage of a nation. It is a determining factor of production in sustainable development. For these reasons, man has learned to master water, however he makes it unsuitable and polluted which is a real threat to life. Indeed, his health is altered if the water at his disposal is of poor quality or if it is polluted by pathogens. Therefore, we are concerned about its quality and its physico-chemical characteristics. The physico-chemical characteristics of the water condition those of the aquatic biocenoses from a structural and functional point of view. Thus the discharges linked to human activities, by modifying the chemical characteristics of water, can also modify the living communities of the receiving aquatic environment. The pressure exerted by this anthropic disturbance will depend on certain characteristics (concentration, amplitude, duration, frequency). The response of the biocenoses will result in changes in their development dynamics [10], biomass [11] and biodiversity [12, 13]. The products of runoff from reservoir watersheds are, in part, responsible for the chemical quality of the water. The main objective of this study was to compare the physico-chemical quality of the waters of four lakes in the sub-prefecture of Ferkessédougou located in the north of Côte d'Ivoire.

In this article, we will first present the methodology used for the collection of water samples and the analyses. We then review the specificity of each parameter studied. Finally, we discuss the interpretation and discussion of the results obtained.

Materials And Methods: -

Presentation of the study area

The sub-prefecture of Ferkessédougou (Figure 1) is located between latitude 9°20' North and latitude 10° North and longitudes 4°50' and 5°40' West. It is located approximately six hundred (600) kilometers from Abidjan. The sub-prefecture is part of the Tchologo region (Savannah administrative district) located in the north of Côte d'Ivoire. It is bordered to the north by the sub-prefecture of Ouangolodougou, to the south by Katiola, to the east by Bouna and to the west by Korhogo. It has a total area of about 3220 km².

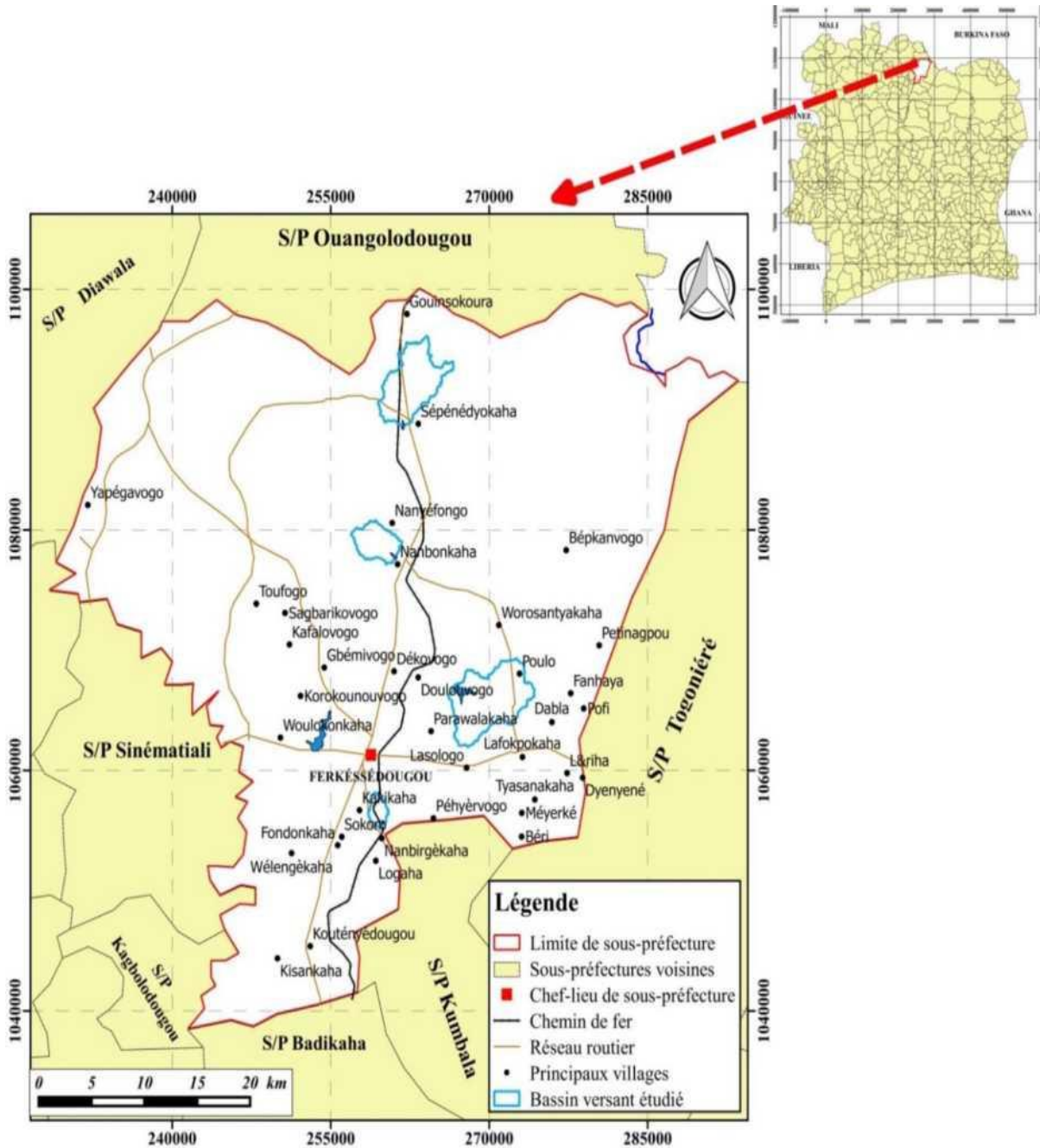


Figure 1:- Location of the Ferkessédougou sub-prefecture and the study watersheds.

Sampling

To better assess the pollution in each reservoir, sampling was done according to a spatial distribution that takes into account the entire surface of the reservoir (Figure 2). Thus, five (5) points were identified on the Bakaryvogo and Dékokaha reservoirs and 3 points on each of the other dams. For each point identified, water and sediment samples were collected. A total of 16 water samples were collected.

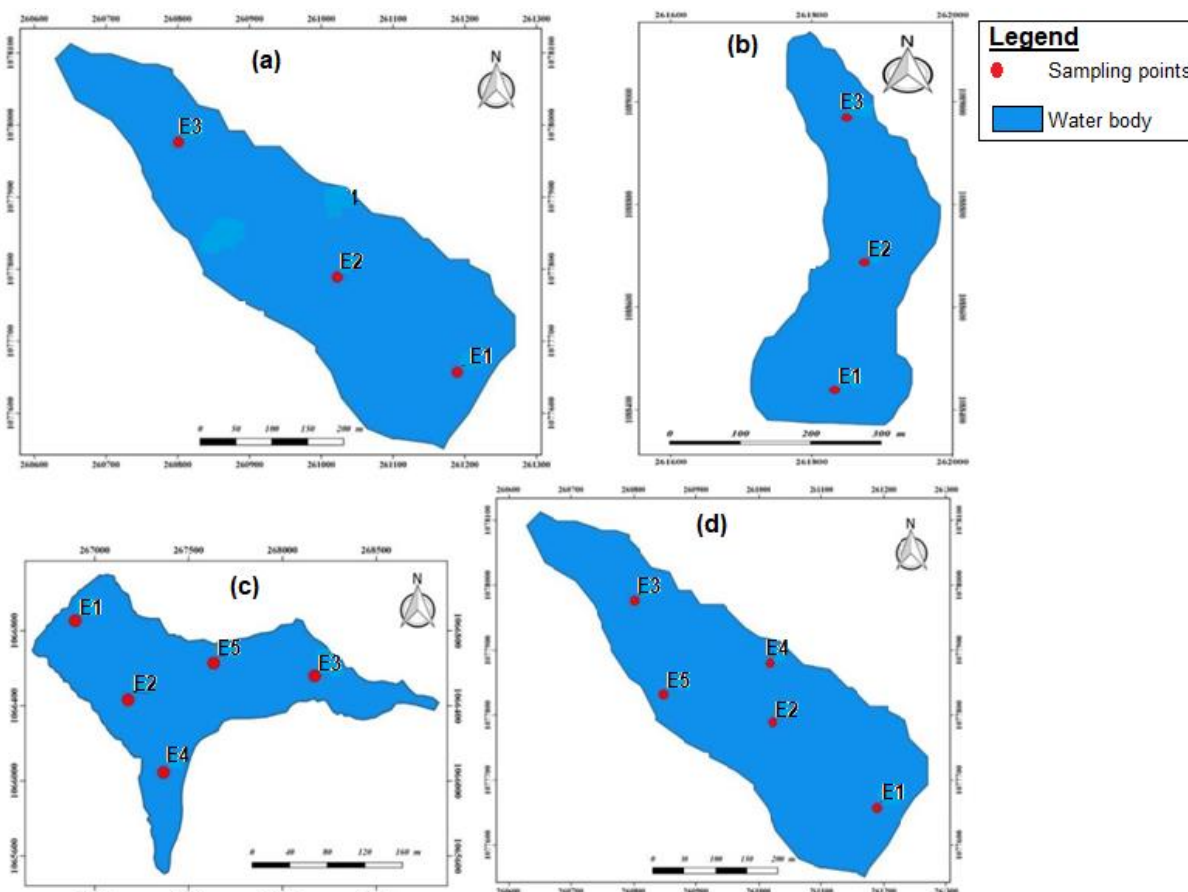


Figure 2:- Spatial distribution of sampling points on the reservoirs studied: a-Korobélékaha; b-Sepnediokaha; c-Dékokaha and d-Bakaryvogo.

Analytical Methods:-

Some (physical) parameters were measured in situ and the chemical parameters of the water samples were determined in the laboratory of the Ferké 1 sugar complex.

Determination of major ions

The chemical parameters were determined using different reagents that were added to the samples according to their correspondence (NitriVer 3 for nitrite; 1Sulfa Ver 4 for sulphate; 1 Ferrous for iron). In fact, after adding the reagents to the different samples, they were shaken and left to rest for a certain time depending on the parameter (e.g.: 5 min for nitrate; 2 min for phosphate; 3 min for chlorine; etc.). In the presence of the reagents, the ions of the different chemical parameters present in the samples react to give precipitates (e.g. sulphate ions which give an insoluble barium sulphate precipitate) for some and colorations (e.g. nitrite ions react with their reagent to give a pink colored complex whose coloring is proportional to the quantity of nitrite present) for others. The determination of the concentrations of the ions was made, for the majority of the parameters, by the method of spectrophotometry also called colorimetry. The model used at SUCAF is the DR/2500 HACH spectrophotometer.

Determination of metallic trace elements

The objective of the trace metal element assay is to determine the quantities of trace metal elements and other major constituents in the sediment. In this study, Pb, Zn, Ni, Mn, Fe, Cu, were determined. These data allow us to determine the initial quantities of these elements in the sediment. The AFNOR NF X 31-151 standard was used for the determination of metallic elements.

Statistical method of data analysis

The main methodology is based on statistical processing through basic descriptive statistics and a multivariate approach that is principal component analysis.

Principal Component Analysis

Principal Component Analysis (PCA) synthesizes the information into only a few new variables called principal components. These new variables correspond to a linear combination of the original variables. The number of principal components is less than or equal to the number of original variables. The information contained in a data set is the total variance or inertia it contains. The objective of PCA is to identify the directions (i.e., principal axes or principal components) along which the variation in the data is greatest. In other words, PCA reduces the dimensions of a multivariate data to two or three principal components, which can be visualized graphically, losing as little information as possible [14].

Technically speaking, the amount of variance explained by each principal component is measured by the so-called eigenvalue. Subsequently, the correlation between a variable and a principal component (PC) is used as the coordinates of the variable on the principal component. The representation of variables differs from that of observations: observations are represented by their projections, but variables are represented by their correlations [15]. The correlation graph of the variables shows the relationships between all variables. It can be interpreted as follows [14]:

- Positively correlated variables are grouped together.
- Negatively correlated variables are positioned on opposite sides of the origin of the graph (opposite quadrants).
- The distance between the variables and the origin measures the quality of representation of the variables. Variables that are far from the origin are well represented by the PCA.

The objective of the principal component analysis in this study is to assess in a synthetic way the similarities or dissimilarities between the withheld variables on the basis of the 17 physico-chemical parameters analyzed. Also, it would allow to describe the existing correlations between some parameters.

Normalization of data

In principal component analysis, variables are often normalized. This is especially recommended when the variables are measured in different units. Otherwise, the result of the PCA obtained will be strongly affected. The objective is to make the variables comparable. Generally, the variables are normalized so that they finally have i) a standard deviation equal to one and ii) a mean equal to zero. At the end of this transformation, the data obtained are called centered-reduced data. The PCA applied to these transformed data is called standardized PCA. The standardized value of the variable is noted Z_i and is written according to equation (1):

$$Z_i = \frac{x_i - x_m}{S_i} \quad \text{Eq. 1}$$

Where x_m is the mean of the values of x , and S_i is the standard deviation.

Results and discussion: -

Descriptive statistics of physical parameters

The determination of the physico-chemical composition of the four water reservoirs allowed us to assess the quality of these waters. The statistical description of the physico-chemical parameters makes it possible to appreciate their distribution by dam and also to make a comparison between the different dams. The statistical processing of the data from the different dams shows more or less homogeneous values for the physical data, most of which are marked by small standard deviations (Figure 3).

Figure 3a shows the variation of pH in the different dams. The pH values of the dam samples are homogeneous with standard deviations ranging from 0.01 to 0.24. The pH is 6.3 at S ep enediokaha (E1). The waters of the S ep enediokaha and Korob el ekaha reservoirs are acidic, with average pH values of 6.31 and 6.96 respectively. These waters have a corrosive character. The waters of the other dams are basic; their pH values are between 7.17 and 7.85.

The temperatures of the dam samples are homogeneous with standard deviations ranging from 0.16 to 0.99 (Figure 3b). Temperatures range from 23 C to 32.4 C for all dams. Temperature values for all four impoundments are above

15°C. Temperature is a parameter that is generally used to monitor water quality. High values ($T > 15^{\circ}\text{C}$) promote the growth and nuisance of microorganisms, thus causing taste and color problems in the water. However, temperatures below 15°C decrease the effectiveness of water treatment.

Figure 3c shows the content of electrical conductivity in water reservoirs. The electrical conductivity of a water is related to its mineralization. The conductivity measured in all the reservoirs varies between $138.7\ \mu\text{S}/\text{cm}$ and $62.7\ \mu\text{S}/\text{cm}$. The highest values are observed in the Bakaryvogo and Sépénédiokaha dams, where the average values are $138.04\ \mu\text{S}/\text{cm}$ and $89.37\ \mu\text{S}/\text{cm}$ respectively. Low values are observed in the Dékokaha $74.82\ \mu\text{S}/\text{cm}$ and Korobélékaha $66.67\ \mu\text{S}/\text{cm}$ dams. These low values show that these reservoirs are low in dissolved salts.

Figure 3d shows the concentration of suspended solids in the dams. Suspended solids (SS) levels determined for the four dams range from $14.67\ \text{mg}/\text{L}$ to $123.67\ \text{mg}/\text{L}$. The average value is $43.56\ \text{mg}/\text{L}$.

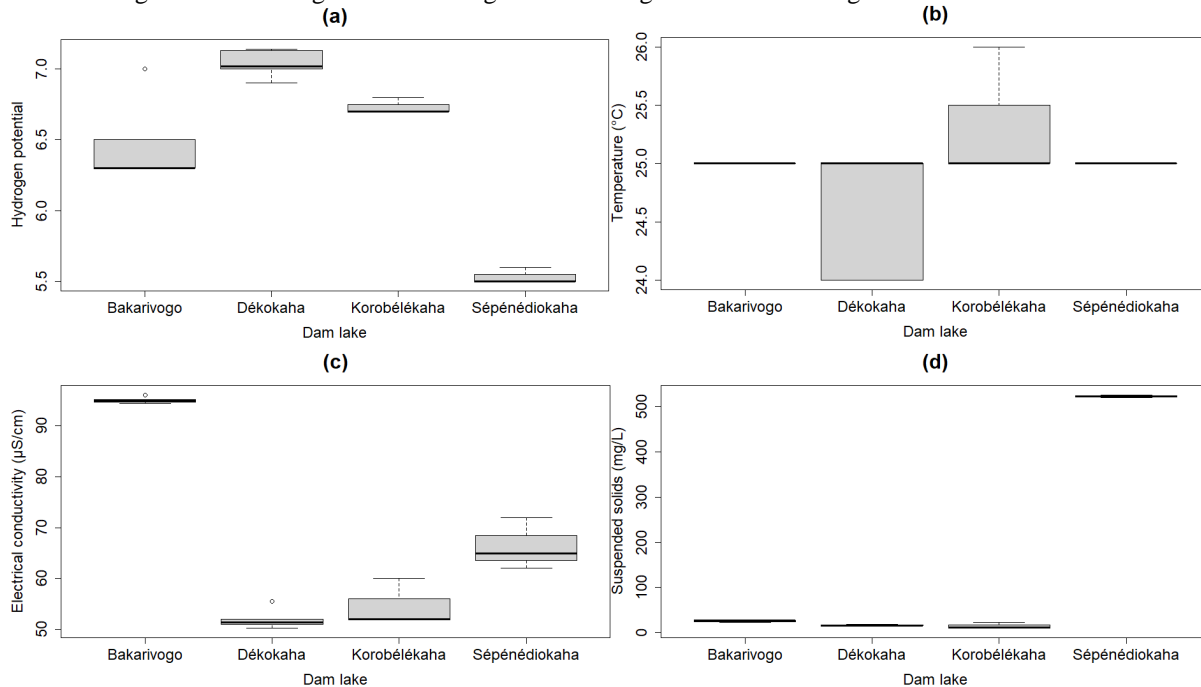


Figure 3:- Physical parameters of the reservoirs: a-pH; b-Temperature; c-Electrical conductivity and d-Suspended solids.

Mineral composition of the reservoirs

Cations

Figure 4 shows the values of the major cations. Potassium levels are very low, ranging from $2\ \text{mg}/\text{L}$ to $3.6\ \text{mg}/\text{L}$. They are all lower than $4\ \text{mg}/\text{L}$, which is the WHO standard. Manganese levels are variable. They are low in Dékokaha and below the WHO standard of $0.5\ \text{mg}/\text{L}$. The levels in the other reservoirs are higher than $0.5\ \text{mg}/\text{L}$. The aluminum values obtained are $0.02\ \text{mg}/\text{L}$ in Dékokaha and Sépénédiokaha. The total hydrotimetric titre (THT= $\text{Ca}^{2+} + \text{Mg}^{2+}$) has a high value of $23.55\ \text{mg}/\text{L}$ at Bakaryvogo. The dams at Dékokaha and Korobelekaha have values of $8.96\ \text{mg}/\text{L}$ and Sépénédiokaha has a value of $4.90\ \text{mg}/\text{L}$. Ferrous ion (Fe^{2+}) levels range from $0.2\ \text{mg}/\text{L}$ to $2.06\ \text{mg}/\text{L}$. All of these waters sampled in the Dékokaha, Sépénédiokaha and Bakaryvogo dams have levels above $0.3\ \text{mg}/\text{L}$, which is the WHO standard. Only the Korobélékaha dam has a value below $0.3\ \text{mg}/\text{L}$. However, although these ions are not harmful to humans, they cause discomfort for consumers. They give a reddish or blackish color and a bad taste to the drinking water.

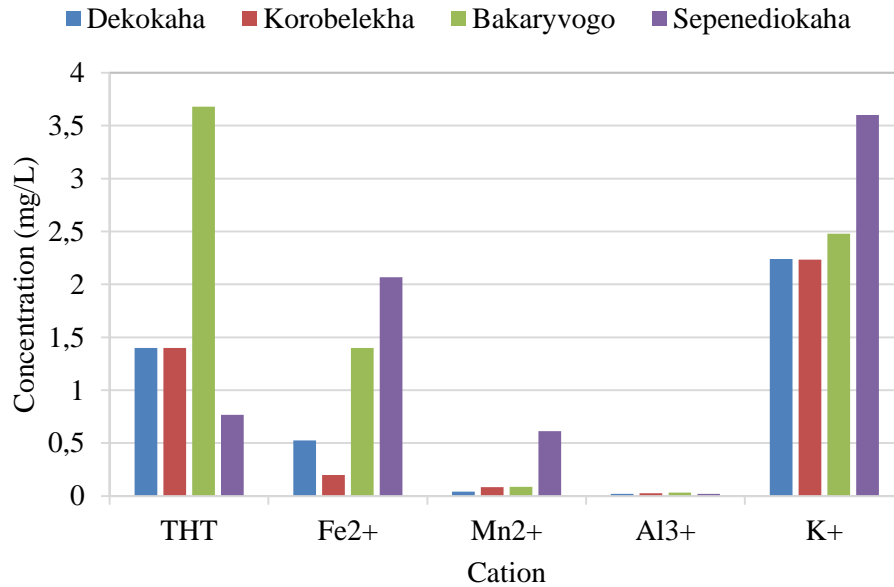


Figure 4:- Cation concentrations of water from the study dams.

Anions

Like cations, anions exist at highly variable levels (Figure 5). The full alkalimetric titer (CO₃⁻+CO₃²⁻+OH⁻) shows levels ranging from 53.44 mg/L to 14.23 mg/L. The sulfate levels recorded are very low and range from 1.6 mg/L to 1.9 mg/L. Nitrate values are very low for all dams with an average of 0.03 mg/L. Nitrite levels are also zero for all dams. Finally, phosphate levels are very high and vary between 6.36 mg/L and 1.74 mg/L. Fluoride values vary between 0.28 mg/L and 0.03 mg/L.

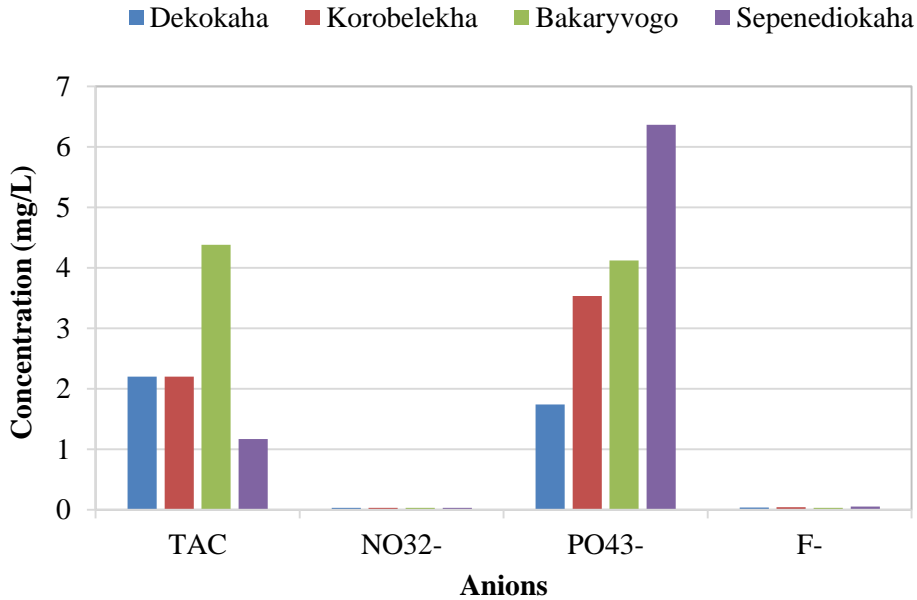


Figure 5:- Concentrations of anions in the waters of the dams studied.

Hydrochemicalfacies of reservoir waters

The Piper diagram (Figure 6) is one of the most classical representations to compare the chemical compositions of natural waters. It allows a representation of cations and anions on two specific triangles whose sides show the relative contents of each of the major ions in relation to the total ions. The relative position of an analytical result on each of these triangles makes it possible to specify first the cationic and anionic dominance. Figure 6 shows the projection on

the Piper diagram of the analyses of the waters of the reservoirs. The Piper diagram makes it possible to distinguish: the calcic bicarbonate waters, the most important (83%) of the waters studied. The waters of the Dékokaha, Bakaryvogo and Korobélékaha reservoirs have a very homogeneous bicarbonate-calcium facies. In the region, the waters are therefore characterized by a predominance of bicarbonate ions over sulfate and chloride ions. Calcium is the most important cation, followed by sodium. The waters of the Sépénédiokaha dam are calcic and magnesian bicarbonate. Overall, the waters of the study dams are calcic-magnesian bicarbonate.

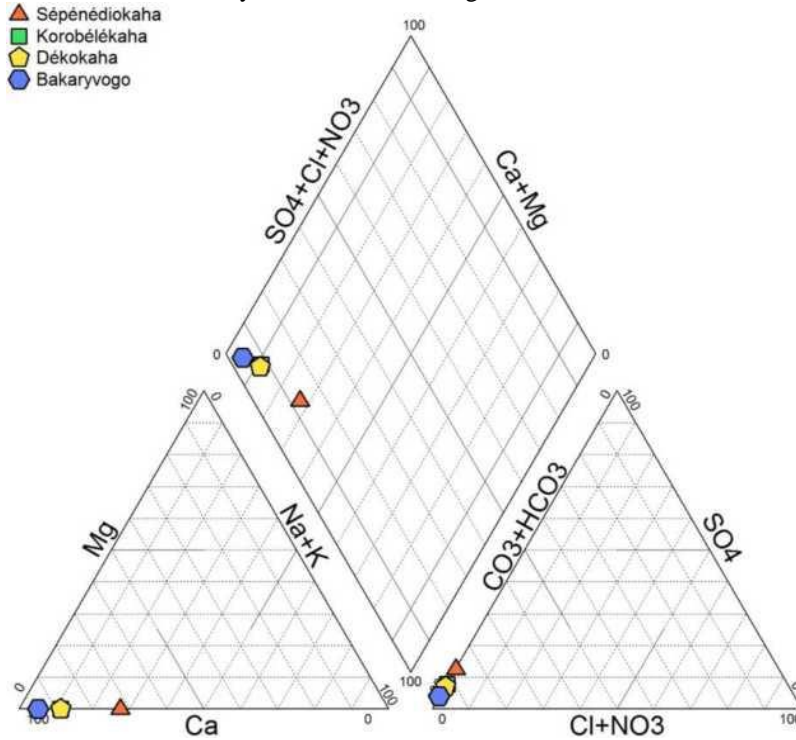


Figure 6:- Piper diagram of water analyses for the four reservoirs.

Principal composition analysis of the chemical parameters of the reservoirs

Variations explained by the principal components

An eigenvalue > 1 indicates that the principal component (PC) concerned represents more variance than a single original variable, when the data are standardized. This is generally used as a threshold at which PCs are retained. Thus, principal components 1 through 4 could be retained (Figure 7). However, components 1 and 2 alone retain 86% of the information (variances) in the data. They will be used for the rest of the study.

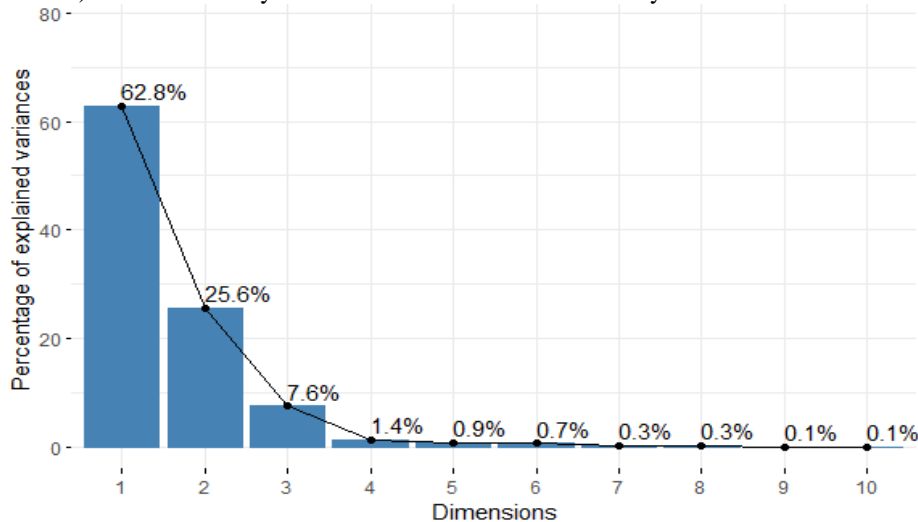


Figure 7:- Percentage of variances explained by the principal components (Dimensions).

Correlation circle

Quality of representation

The correlation circle with the color gradient (Figure 8) allows us to describe the quality of representation of the variables with respect to the principal components considered. This produces a color gradient, for which variables with low \cos^2 values will be colored white, variables with medium \cos^2 values will be colored blue and variables with high \cos^2 values will be colored red. On this basis, almost all of the variables under study, except for nitrate and temperature, are best represented on the PCA map (orange to red in color because close to the circumference of the correlation circle). These variables are the most important for interpreting principal components 1 and 2.

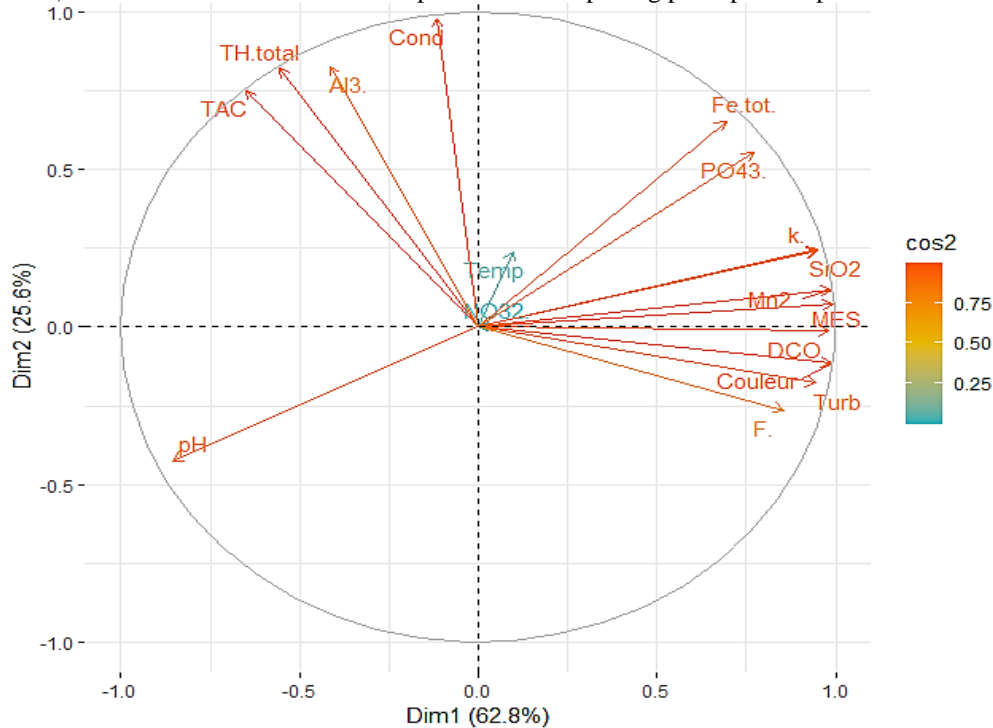


Figure 8:- Quality of representation of the variables according to the principal components.

Contributions of the variables to the principal axes

The contributions of the variables in the definition of a given principal axis are expressed in percentage. The variables correlated with PC1 (i.e., Dim.1) and PC2 (i.e., Dim.2) are the most important to explain the variability in the data set. Table 1, shows us the variables most significantly associated with the principal components PC1 and PC2. The variables suspended solids, Manganese, COD, silica, potassium, turbidity, fluorine and to a lesser degree phosphorus and total iron are positively correlated to the PC1 component, while pH and TAC are strongly negatively correlated to this axis. Concerning the PC2 component, only the variables conductivity, aluminium, THT, TAC are strongly positively correlated to this axis.

On the basis of the quality of representation and the contribution of the variables, only :

- Suspended solids, Manganese, COD, Silica, Potassium, Turbidity, Fluorine, Phosphorus, Total Iron and pH variables are used to characterize the PC1 component;
- And the variables Conductivities, Aluminum, THT, TAC are used for the component PC2.

Table 1:- Significance of the contribution of the variables to the principal components.

Statistique	Composante Principale 1 (PC1)						
	MES	Mn ²⁺	Coul.	DCO	SiO ₂	K ⁺	Turb.
Corrélation	0,99	0,99	0,99	0,98	0,95	0,95	0,95
p. value	3.10 ⁻¹⁴	4.10 ⁻¹³	4.10 ⁻¹³	3.10 ⁻¹¹	2.10 ⁻⁸	2.10 ⁻⁸	3.10 ⁻⁰⁸
Statistique	Composante Principale 2 (PC2)						
	Fluor	PO ₄ ³⁻	Fe _{tot}	THT	TAC	pH	
Corrélation	0,86	0,77	0,69	-0,55	-0,65	-0,85	
p. value	2.10 ⁻⁵	4.10 ⁻⁴	2.10 ⁻³	2.10 ⁻²	6.10 ⁻³	2.10 ⁻⁵	
Statistique	Composante Principale 2 (PC2)						
	Cond.	Al ³⁺	THT	TAC	Fe _{tot}	PO ₄ ³⁻	
Corrélation	0,98	0,83	0,82	0,75	0,65	0,55	
p. value	4.10 ⁻¹¹	7.10 ⁻⁵	9.10 ⁻⁵	8.10 ⁻⁴	6.10 ⁻³	2.10 ⁻²	

Quality of representation and contribution of individuals to the principal components

With the exception of sample 1 from Korobélékaha (KE1), the individuals are perfectly represented on the projection circle, with cos2 between 0.8 and 1 (Figure 9). This is reflected in the color taken by these samples on the graph (orange to red color). The samples from the Sépénédiokaha reservoir contribute strongly to axis 1 (PC1). The other samples, on the other hand, contribute better to the explanation of principal component 2 (Figure 9).

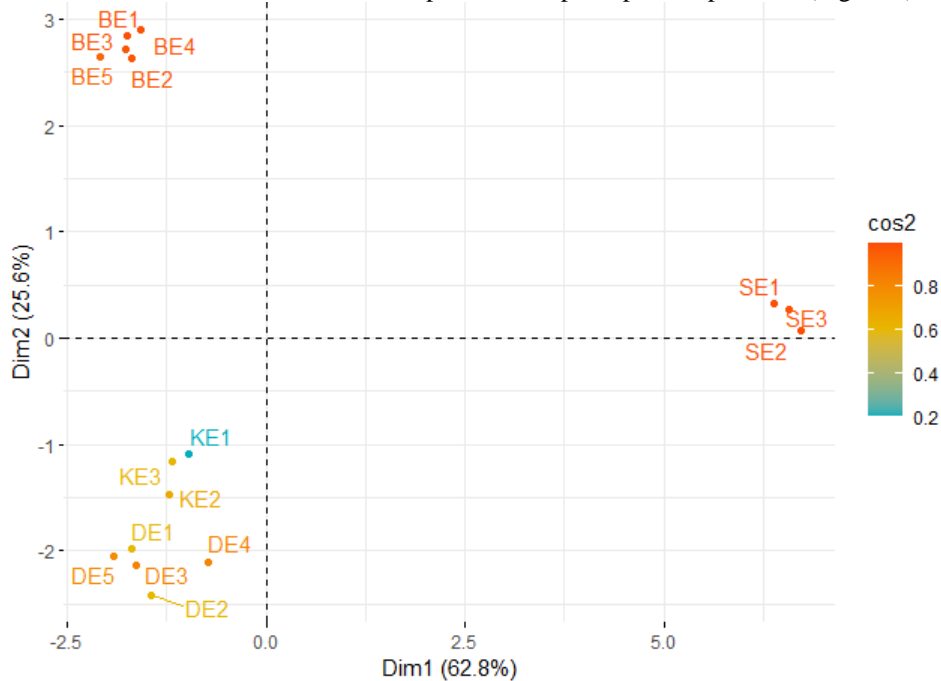


Figure 9:- Quality of representation of individuals (lakes) on the principal components.

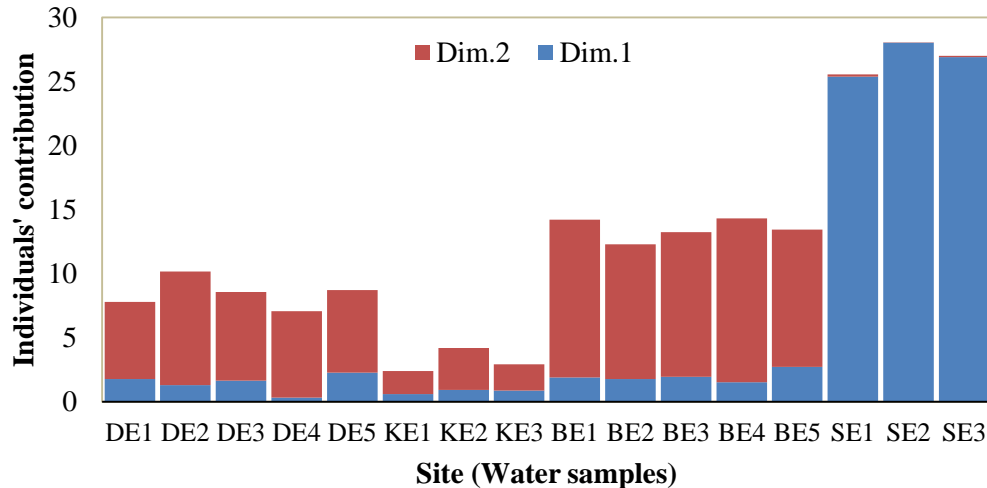


Figure 10: - Contribution of individuals to the principal components.

Summary of the principal component analysis

Figure 11 shows a categorization of the water reservoirs. The samples from Bakaryvogo are opposite in chemical composition to those from Korobélékaha and Dékokaha. While those of Sépénédiokaha are distinguished from the others by a physico-chemical singularity. The interpretation of the results begins with an examination of the correlation circle (Figure 8); we note that the variables TSS, Manganese, COD, Silica, Potassium, Turbidity, Fluorine and Phosphorus are very strongly positively related to component 1, while pH is strongly related to this axis, but negatively. In terms of correlation between variables, this means that the correlation coefficient between these parameters is close to 1, and the coefficient between pH and the above mentioned parameters is close to -1.

Thus, the first axis opposes the pH to the parameters characteristic of solid inputs (runoff products) such as TSS, organic matter (COD), turbidity, silica, etc. We deduce that the presence of suspended solids would be negatively related to an increase in pH. The catchment area of the Sépénédiokaha reservoir would be the most exposed to runoff phenomena with these corollaries. The waters of the reservoir are therefore rich in suspended matter, silica and very turbid with low pH, unlike the other reservoirs.

The second component is positively related to the variables conductivity, aluminium, total hydrometric title and total alkalimetric title. From the point of view of the physico-chemical quality of the reservoirs, this axis contrasts the Bakaryvogo reservoir with the Korobélékaha and Dékokaha reservoirs. The Bakaryvogo reservoir is rich in dissolved elements with a good correlation between the electrical conductivity and the hydrometric and alkalimetric titres. While the Korobélékaha and Dékokaha reservoirs' watersheds drain less chemical elements towards these dam lakes, resulting in water that is less rich in dissolved elements.

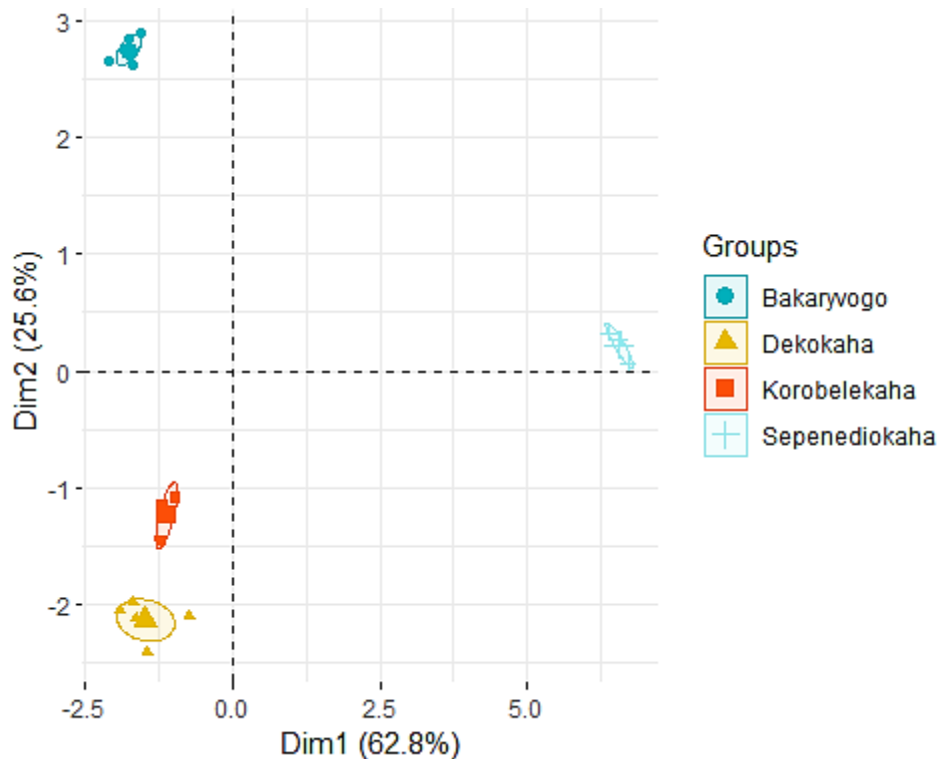


Figure 11:- Proximity map between individuals (Reservoir water samples).

Discussion:-

Surface water quality is characterized by the various substances it contains, their quantities and their effects on aquatic ecosystems and human health. These substances can be of natural origin (bicarbonates, sulfates, sodium, calcium, magnesium, potassium, nitrogen, phosphorus...), or anthropic (wastewater or industrial and agricultural activities). It is the concentration of these different elements that determines the quality of a water and whether it is suitable for a particular use [16]. From the various physico-chemical parameters studied for the characterization of the water reservoirs in the sub-prefecture of Ferkessédougou, it appears that the iron content is very high in the four reservoirs. Studies conducted in Africa on surface waters have shown that the degradation of the physico-chemical quality of water is sometimes marked by the sudden appearance of exceptional levels of soluble iron and manganese [17].

The other values obtained are for the most part lower than the standards prescribed by the WHO. Nevertheless, although lower than the various standard values, these concentrations constitute sources of pollution for the water reservoirs, because their presence is linked to the various activities carried out around them. The temperature values obtained in these reservoirs are between 24.6°C and 26.30°C in the dry season. In addition, the average value obtained at this time of year (25.3°C) follows the same order of magnitude as those found in several large lakes in the country at the same time. These include Taabo Lake (28.37°C) by Kouassi (2007), Kossou Lake (28.62°C) by Brunel and Bouron (1992), Buyo Lake (between 26.00 and 32.00°C) [18] and Ayamé Lake (between 26.45 and 29.45°C) by Diomandé (2001). These $T > 15^{\circ}\text{C}$ values favor the growth and nuisance of microorganisms, thus posing problems of taste and color to the water.

The waters of the Sépénédiokaha and Korobélékaha dams are acidic, with average pH values of 6.31 and 6.96 respectively. The waters of the other dams are basic; their pH values are between 7.17 and 7.85. The pH values obtained in the reservoirs are close to neutrality. The average of 6.55 is similar to the value found by Cecchi et al. (2009) on the small dams of Brobo, Nambègué and Tiné. The pH values are low with a slight tendency towards acidity. Also these pH values are lower than most of the values obtained in the large lakes of Taabo (pH= 7.39; Kouassi, 2007), Ayamé (pH= 8.00; Diomandé, 2001 and Buyo (pH= 8.60) [18]. The average conductivity values in the Sépénédiokaha (66.4 pS/cm) and Bakaryvogo (95 pS/cm) dams are generally higher than those in the other environments studied by Iltis and Levêque (1982) in the Bandama (59 pS/cm) and Comoé (51.4 pS/cm). However, the values observed in the

Dékokaha (52.1 pS/cm) and Korobélékaha (54.6 pS/cm) reservoirs are close to the values of the above-mentioned work. In the three northern reservoirs (Nambegué, Brobo, Tiné) [9], the conductivities are always below 200 pS/cm. These high values of conductivity in the reservoirs can be explained by the geological formation of the study area, which favors the release of a certain number of ions such as iron.

NO₃⁻, NO₂⁻ ions are marked by very low values in the 4 dams. The average is 0.03 mg/L for nitrates and 0.01 mg/L for nitrites. Nitrates are natural compounds of the nitrogen cycle, an element essential to life and particularly to the development of plants. They are naturally present in the soil in the form of residues necessary for the life of plants, animals and humans. They come from their decomposition or from their dejections. Nitrates can reach surface water resources by runoff. These average values are lower than those obtained by Doumbia (2003) in Lake Ayamé for nitrate (0.3 mg/L) and nitrite (0.003 mg/L). Ahoussi obtained higher levels of nitrate (2.75 mg/L) and nitrite (1.48 mg/L) in the surface water of Agboville [19]. Although these concentrations are low overall, they constitute pollution that could be due to the drainage of mineral and organic fertilizer into the reservoirs. In fact, the immediate surroundings and edges of the reservoirs are used for market gardening and rice cultivation, which require fertilizer for growth. The average Mn²⁺ content varies according to the reservoirs. They are higher than the WHO standard (0.3 mg/L of Fe²⁺ and 0.05 mg/L of Mn²⁺) in all dams except Dékokaha. These concentrations are higher than those obtained by Yao et al. (2010), in the Buyo (0.0007 mg/L Mn²⁺), Lobo (0.005 mg/L Mn²⁺) and Sou (0.002 mg/L Mn²⁺), and by Ahoussi in the surface waters of Agboville (0.06 mg/L Mn²⁺) [19]. The water in the reservoirs is soft with an average total hardness of 1.44°F.

Phosphate levels are very high. The average is 3.52 mg/L. All of the impoundments are experiencing phosphate pollution. Phosphate is not harmful to human health, but it induces abnormal development of algae in the rivers, which reduces their biological and fish farming qualities [20]. The risk of eutrophication by phosphorus appears at low doses for thresholds close to 0.035 to 0.1 mg/L in total phosphorus [21], while the guide value for raw water for drinking water treatment is 0.7 mg/L. Phosphorus applied to the soil by synthetic fertilizers or animal manure is rapidly adsorbed on the surface of clays and organic matter (adsorption is a reversible electrostatic fixation). Unlike nitrate, it is not easily leached, but stored in the first few centimeters of soil on the surface of particles. Ferkessédougou is an agricultural area. Agricultural activity strongly modifies the quality and dynamics of water in the environment. Also by the transformation of the vegetation cover, the work of the ground, the contribution of fertilizers and pesticides, agriculture alters the cycle of water as of its compounds. The impact of anthropogenic activities on water quality is a major global problem and is the subject of several studies [22-24].

In addition, many boreholes drilled under former programs are now abandoned because they have dried up, and people are forced to consume water from traditional wells, rivers or directly from lakes [25]. Also, Yapo (1997) considers that water from lakes should first undergo organic and microbiological treatment before consumption [26]

Conclusion: -

The results obtained from the physico-chemical analysis of the water reservoirs in the sub-prefecture of Ferkessédougou reveal that the waters of the four reservoirs have an average temperature that varies between 23 and 32°C. They are more or less neutral, and the water is more or less stable. They are more or less neutral, with a pH that varies between 6.31 and 7.85. These waters are weakly mineralized, thus justifying a low electrical conductivity (66.67 to 138.04 μS/cm). Also, the concentrations of nitrate and nitrite, although lower than the thresholds admitted by the WHO, are important. They constitute tracers of pollution of diverse origin. The risk of eutrophication is high because of the very high levels of phosphate. In addition, the average Fe²⁺ content measured (0.78 mg/L) is above WHO standards. In this study, the physico-chemical characteristics of 4 dam lakes were synthesized by 2 principal components; the variances between the reservoirs and the correlations between the variables are then described by these 2 components. The study revealed a categorization of the water in the reservoirs. The Bakaryogo lake, richer in dissolved elements, is opposed to the Korobélékaha and Dékokaha lakes, which have the lowest electrical conductivities, unlike the others. The lake of Sépénédiokaha is distinguished by turbid waters rich in organic matter (COD) and suspended solids (SS). The analysis also showed the presence of trace metallic elements. The results suggest that an important part of these metals may come from the inputs used (chemical fertilizers, insecticides or fungicides). A control of fertilizers and pesticides intended for agriculture is necessary.

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