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Contribution to the study of the seasonal variation of the physicochemical and metallic parameters of a reservoir in a tropical environment: Case of Ilauko reservoir at Savè in Benin

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Abstract

This study, that is carried out on, Ilauko dam of the SUCOBE Company, (i.e., Society of Sugar of Savè (SSS)), is the most important drinking water supply for the population of Savè and its surroundings. The objective of this study is to analyze the physico-chemical and metallic quality of Ilauko reservoir water in order to manage this resource rationally in a sustainable way for the benefit of the populations. To achieve this goal, eleven (11) points were followed for one year period. The results from the physicochemical analyses reveal the low oxygen contents dissolved under the effect of the increase of the temperature and the raise of phosphorus and chlorophyll; this characterizes the phenomenon of eutrophication. The values of the nutrients such as nitrogen and phosphorus are largely higher than the limiting values indicated by the system of classification of the Organization for Economic Cooperation and Development (OECD). Water of the dam Ilauko is therefore eutrophic.

Keywords: Eutrophication, Dam Ilauko, Sa Sucobé, Eutrophic water.

Introduction

Nowadays, water constitutes a natural resource which is essential for humanity life, as well as, for the economic growth and social than the ecological balance. Any harmonious and sustainable development is not possible without achieve this. Thus, the quality of water faced various problems because of the uncontrolled industrial wastes, the intensive use of the chemical fertilizers in agriculture, as well as, the overexploitation of the water resources. Indeed, according to Brambati et al[1], Bloundi[2], Bawa et al[3], the coastal hydro-systems such as, the rivers, the lakes, the estuaries, the lagoons, the oceans, the tanks, etc., are subjected to strong anthropogenic pressures, particularly due to urbanization, tourism, agriculture, fishing, the industrial expansion.

However, we can notice that the anthropogenic disturbances have a very strong effect on the aquatic biodiversity[4]. Thus, the degradation of the water resources comes primarily from specific and diffuse pollutions and also from the modification of the physicochemical characteristics[5].

In Benin, the Oueme basin at Savè, through the tank of Ilauko, present strong potential in terms of water resources which contribute to the satisfaction of the needs of the population. However, the strong pressure of the anthropogenic activity carried on the water, by the users on the site, can be the source of various pollutions. Also, the reserve of Ilauko is subjected to a daily pollution due to the significant amounts of waste resulting from the industrial water wastes, as well as, the pollution from the chemical inputs or the fishing, and the invasion by the undesirable aquatic plants.

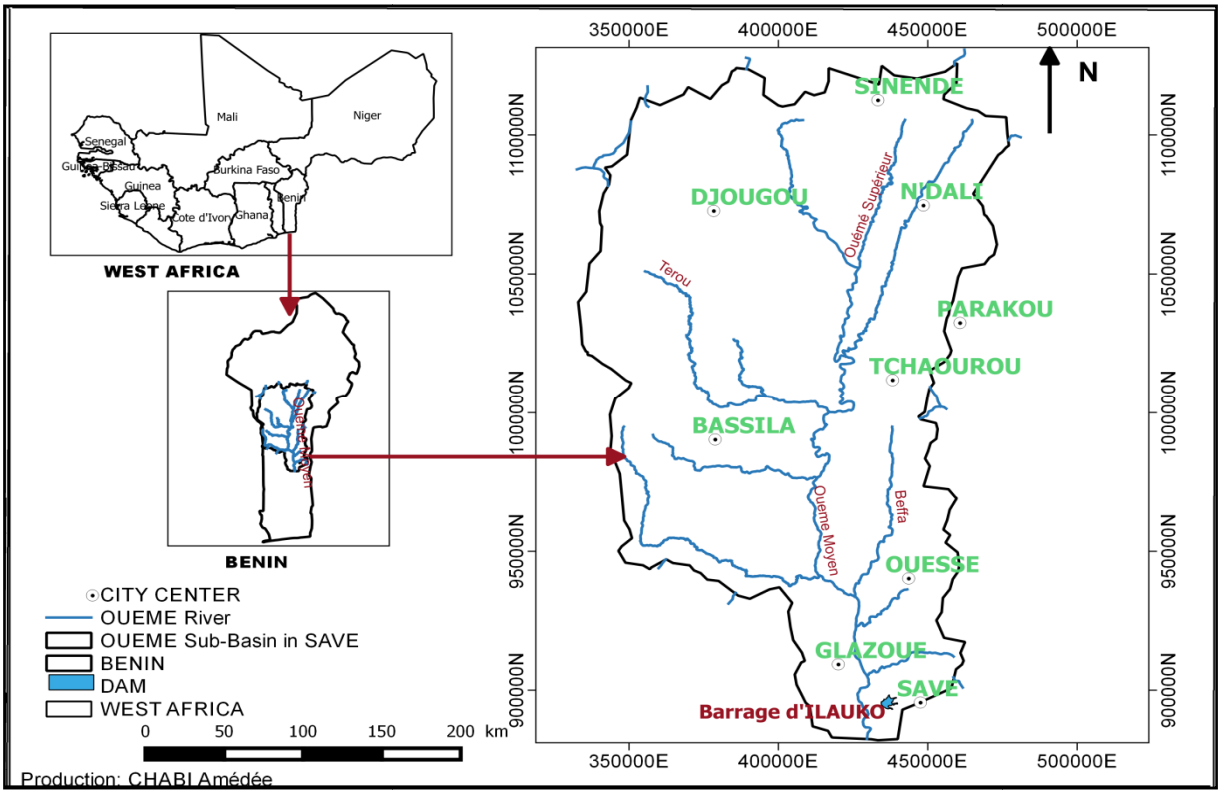
Faced with this it becomes indispensable to take appropriate measures to improve the protection of the water resource. This requires a rational and sustainable management of the reservoir.

This study is therefore, aims to investigate the physicochemical parameters of this tank, for an efficient use and an equitable access of all the stakeholders.

Materials and methods

Study area: The dam Ilauko (Figure-1), is localized in the Oueme basin at SAVE (Benin, West Africa). This dam is located in an area with difficult hydrogeological access. It is fed by the Ouémé River which is approximately at 500 m from the dam. The dam Covers an area of 445 ha and extends between the latitude 8°0'0" and 8°7'30" north and longitude 2°19'30" and 2°25'0' East.

The tank was built between the years 1978-1980 by a French company, named GTE under the control of HHS (Han Howard Humphleys and sounds) BABA - MOUSSA[6].



Source: Data from NGI of Benin, 1992.

Figure-1: Location of the dam Ilauko in the Oueme basin at Savè.

Sampling collection: After investigation on the field, the water sampling has been carried out during the following periods: i. April 2016 corresponding to rainy season; ii. October 2016 for dry season.

Thus, to underline the evolution of Ilauko dam water physico-chemical quality, eleven (11) points were selected for the test sample selection, at a rate of 01 sample per point and for two seasons (flood period and low water period), (Figure-2): i. 09 points on the dam; ii. 01 point (station N°3), installed in Oueme river, where water is pumped in the direction of the dam, and is located at about 500 m; iii. 01 point at SONEB station (National Company of Water Distribution).

Moreover, the reasons of the sampling sites choice are the following: i. geographical space coverage of the dam, for better characterize of the spatial evolution of physicochemical parameters; ii. Knowledge of the influence of wastewaters coming from industrialist SUCOBE society and those of human actions on the dam;

Research methods: The methodology used for this study consisted, to make direct measures of in situ parameters such as conductivity, pH, salinity, temperature, total dissolved solids.

From the collected water samples, several parameters were analyzed in the laboratory.

Thus, on different points of measurements, distant in majority by 500 m the ones from the others, the sampling were carried out about 5 cm of surface water, without catching the air using the polyethylene plastics, of 1,5L volume and which is tightly closed. Some parameters were measured in situ, where as the others were measured at the laboratory.

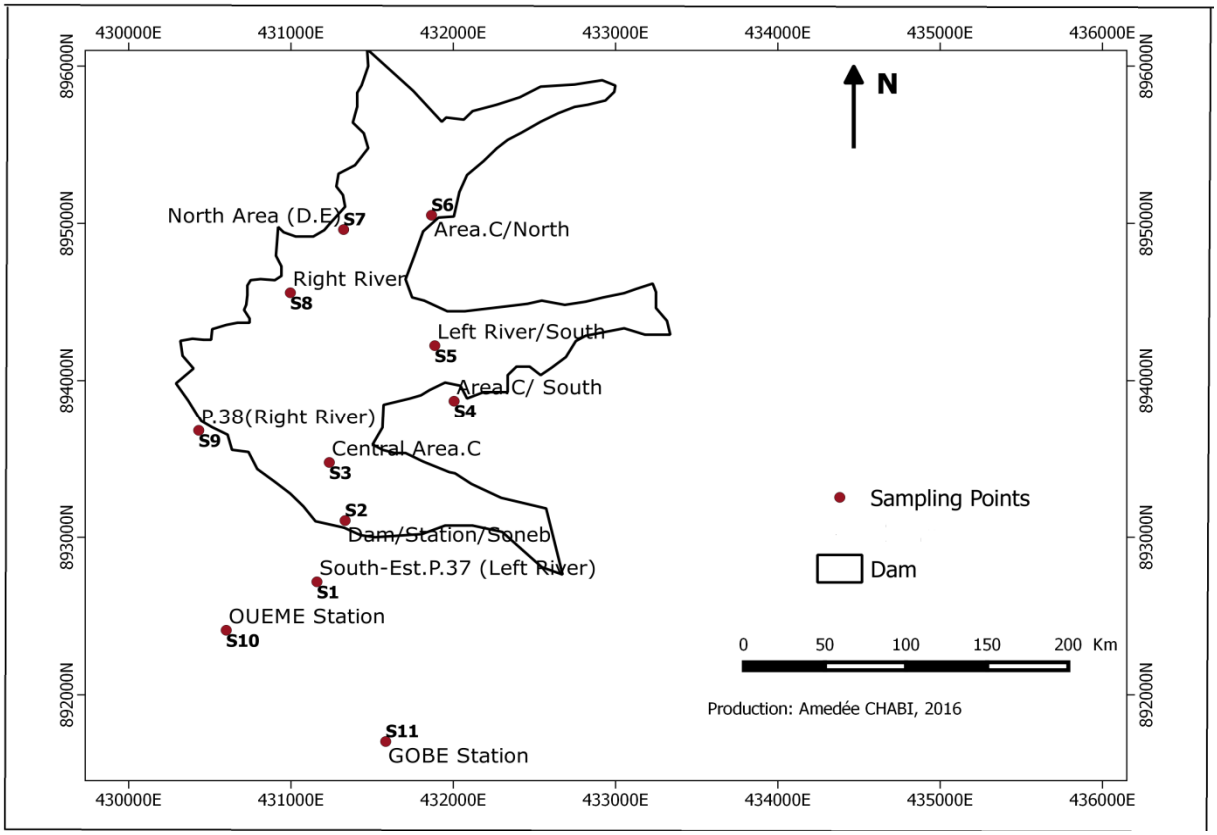
The in situ parameter measures are about: i. coordinated of the sampling points by using a GPS, Garmin 72; ii. dissolved oxygen, with anoxyo-meter of the type WTW 340i, TDS and the temperature of water, salinity, conductivity, the transparency and pH of water. The pH is measured with a pH – meter (HACH WTW 340i).

The water sampling was preserved in a cooler and was transported to the laboratory for analysis.

Methods of analysis at the laboratory: The different methods that we use were summarized in Table-1.

Statistical analysis of the data: The statistical analysis of the data was carried out using the software "R" for the Principal Component Analysis (PCA) and Mini tab for the correlations.

The PCA, enabled us to classify the groups that show the seasonal dynamics of the physicochemical parameters from one site to another.



Source: Area data, 2016

Figure-2: Location of the sampling points.

Table-1: Laboratory analysis methods.

Parameters	Devices used	Method for the analysis
pH, Temperature, Dissolved oxygen, conductivity, Salinity	Multi-paramètre de type WTW340i	Direct measurement in site
Suspended solids (SS), Turbidity, color	Colorimeters HACH DR/890	Method 8025
Total phosphorus and Ortho-Phosphates, NTK	Spectrophotometers DR 2800	Method of ascorbicacid
Chlorophyll a	Spectrophotometers DR2800	Scor-UNESCO method NF T 90-117

Source: Area data laboratory, 2016.

Results and discussion

Results of the physico-chemical parameters: Potentiel of Hydrogen (pH): The pH measures the concentration of the hydronium ions in a solution. In an aquatic environment, it indicates the balance between the acids and bases of water[7]. The analysis of the values of the pH on the site of Ilauko, shows a seasonal variation with the lowest values in rainy season and strongest values in dry season. We also notice that the median value of the pH is about 7.46 for all the study period, with the minimum (6.39) observed in the site 9 (P.38 Right river) and the maximum (8.03) in the site 6 (C/North) (Figure-3).

Temperature: The temperature of Ilauko dam water, vary between 32,3°C and 36.7°C with an average of 34 and 32°C. According to the directives of the World Health Organization[8], the temperature of a drinking water should not exceeded 25°C (Figure-4).

Dissolved oxygen: The increase in the temperature of water is accompanied by a reduction in dissolved oxygen. The recorded values range between 0.92 mg /L on site 9, during the rainy season and 4.2 mg /L, on site 6 in dry season, with an average of 2.31 mg/L (Figure-5).

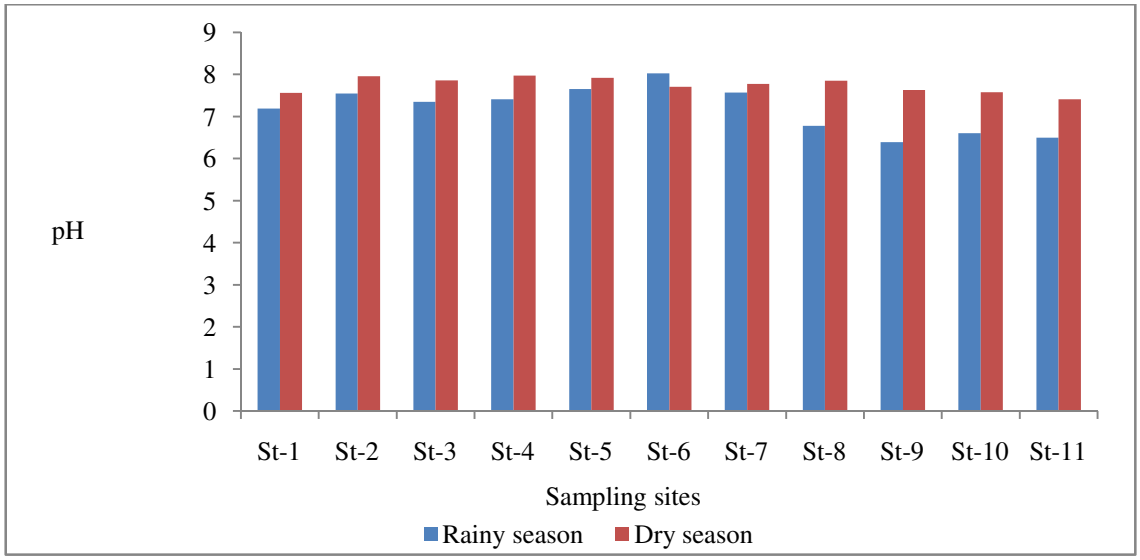


Figure-3: Seasonal variation of the pH of water of the Ilauko dam at Savè.

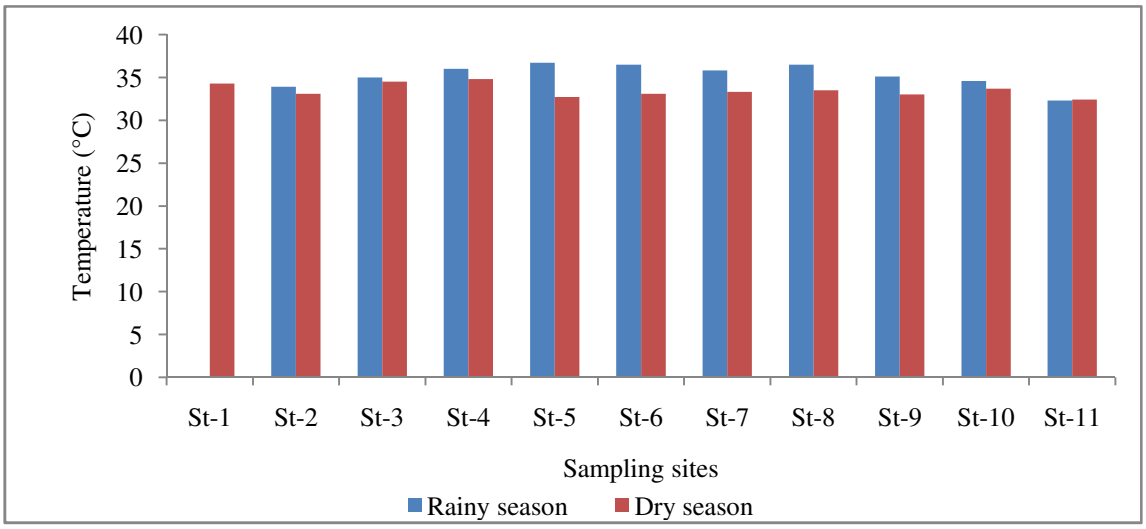


Figure 4: Seasonal variation of the temperature of water of the Ilauko dam at Savè.

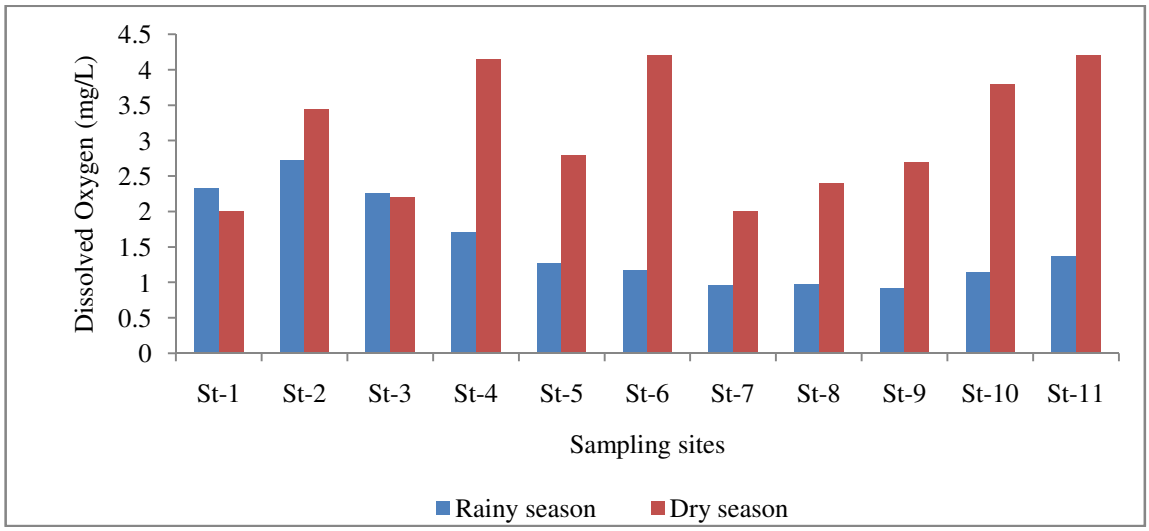


Figure-5: Seasonal variation of the dissolved oxygen of water of the Ilauko dam at Savè.

Salinity: The values of salinity observed during the dry and rainy seasons reveal that they are all lower than 0, 1%, which is the limit of detection of the device.

Color, turbidity and suspended solids: The color is an important parameter of appreciation of the organoleptic quality of water. The various values recorded for water of the Ilauko dam for the two study periods, vary between 16.30 and 138 Pt-Co with an average of 39.89 Pt-Co. The greatest value is observed on the site1 (South-Est/P.37) in rainy season, while the smallest value is observed on site 11 in dry season, SONEB station (National Company of Water Distribution). This strong value can be justified by the strong values of turbidity and suspended matter observed on the same site (Figure-6).

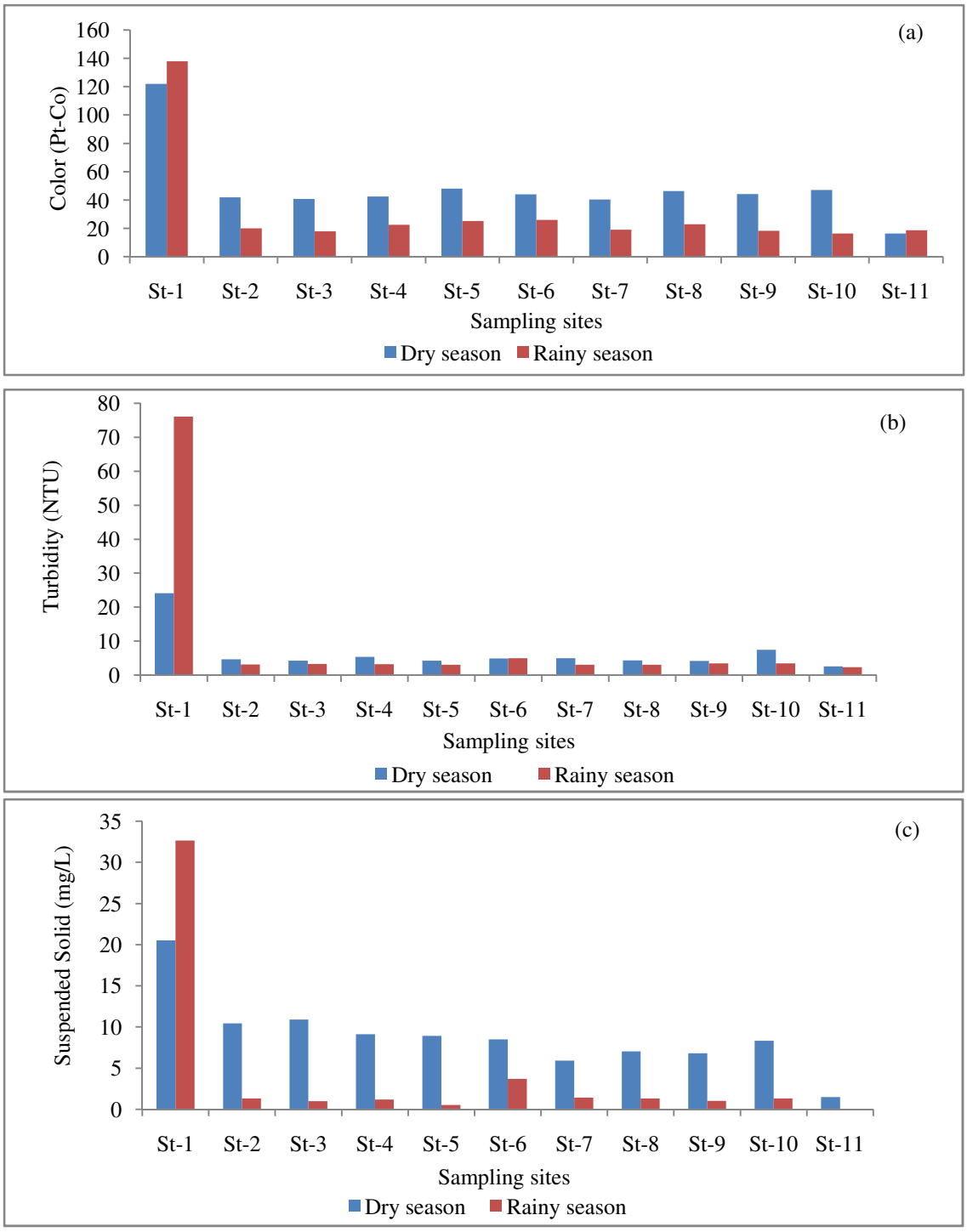


Figure-6: Seasonal variation of the color (a), turbidity (b) and suspended solid (c) of water in the Ilauko dam at Savè.

Electric conductivity: In the natural aquatic environments, the increase in the temperature of the medium implies also the increase of electric conductivity. The results of measurements on the field show that the minimal value of electric conductivity is observed in rainy season (73.5 µS/cm) on site 1 (C/North), whereas a maximum value of electric conductivity is observed in dry season (1651) µS/cm) on site 11, with an average value of 180.88 µS/cm (Figure-7).

Total dissolved solids: The total dissolved solids vary between 31mg/L (rainy season) and 580 mg/L (dry season dries) for water of the Ilauko dam with an average value of 69.82 mg/L. The maximum value is observed on the site 11 (Station of treatment) (Figure-8).

Iron and manganese: The variation of the concentrations of iron and manganese in the water of the Ilauko dam show a seasonal dynamics. The values of the iron concentrations vary from 1.92 mg/L (dry season) and 6.71 mg/L (rainy season). On the other hand, those of manganese vary between 0.048 mg/L and 0.21 mg/L. These two values are all observed in rainy season on sites 11 and site 1 respectively. On site 1, iron and manganese are in strong proportion; whereas on site 3, site8 and site 9, manganese is in strong proportion during the rainy season (Figure-9).

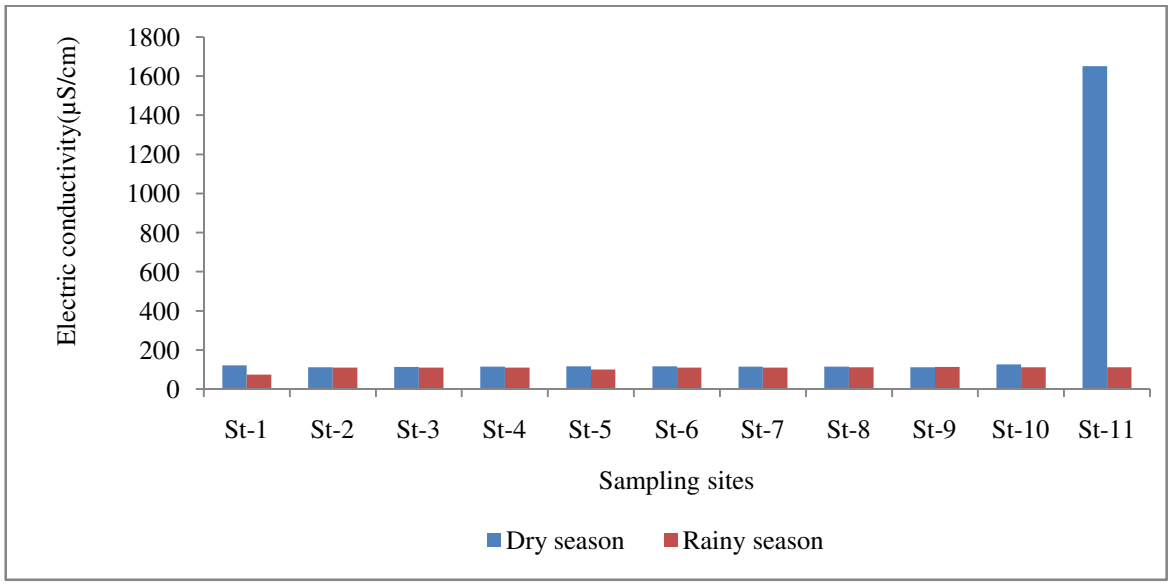


Figure-7: Seasonal variation of the electric conductivity of water of the Ilauko dam at Savè.

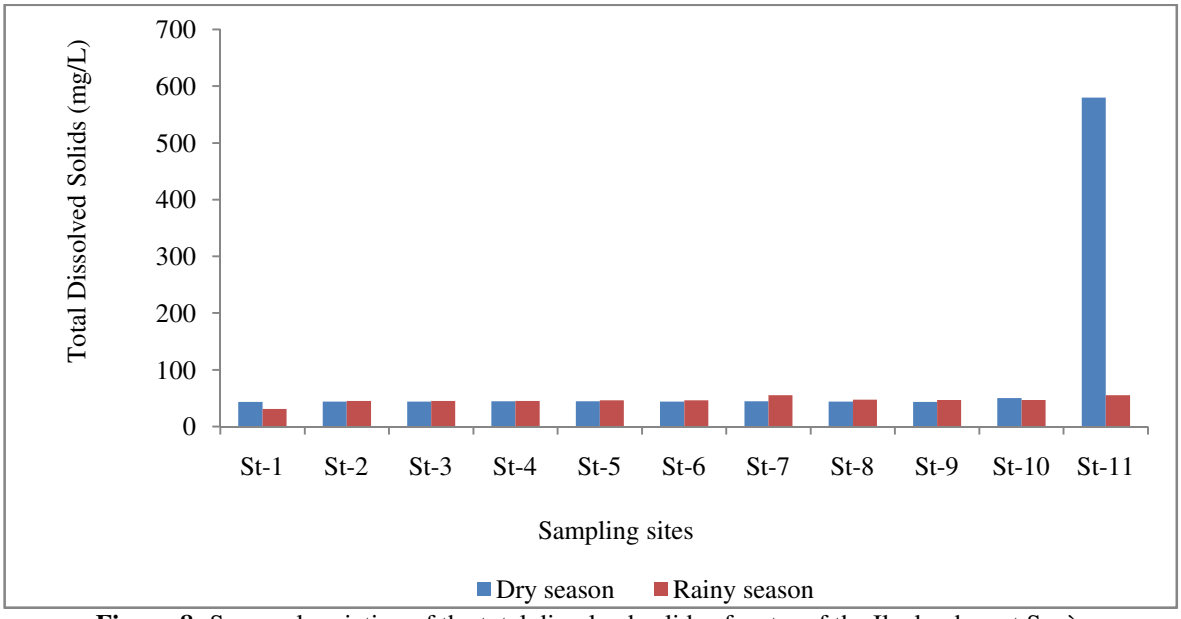


Figure-8: Seasonal variation of the total dissolved solids of water of the Ilauko dam at Savè.

Results of pollution parameters: Total Nitrogen Kjeldahl (TNK): The analysis of the variation of the contents of TNK shows that in rainy season the measured values are clearly higher than those measured in dry season, except for sites 3,4,5, and 6. The minimal value of the total nitrogen Kjeldahl, observed for these periods is of 0,1mg/L (site 11), against a maximum value of 7.7 mg/L is obtained on site 8 and all values are obtained in rainy season, with an average value of 2.8 mg/L (Figure-10).

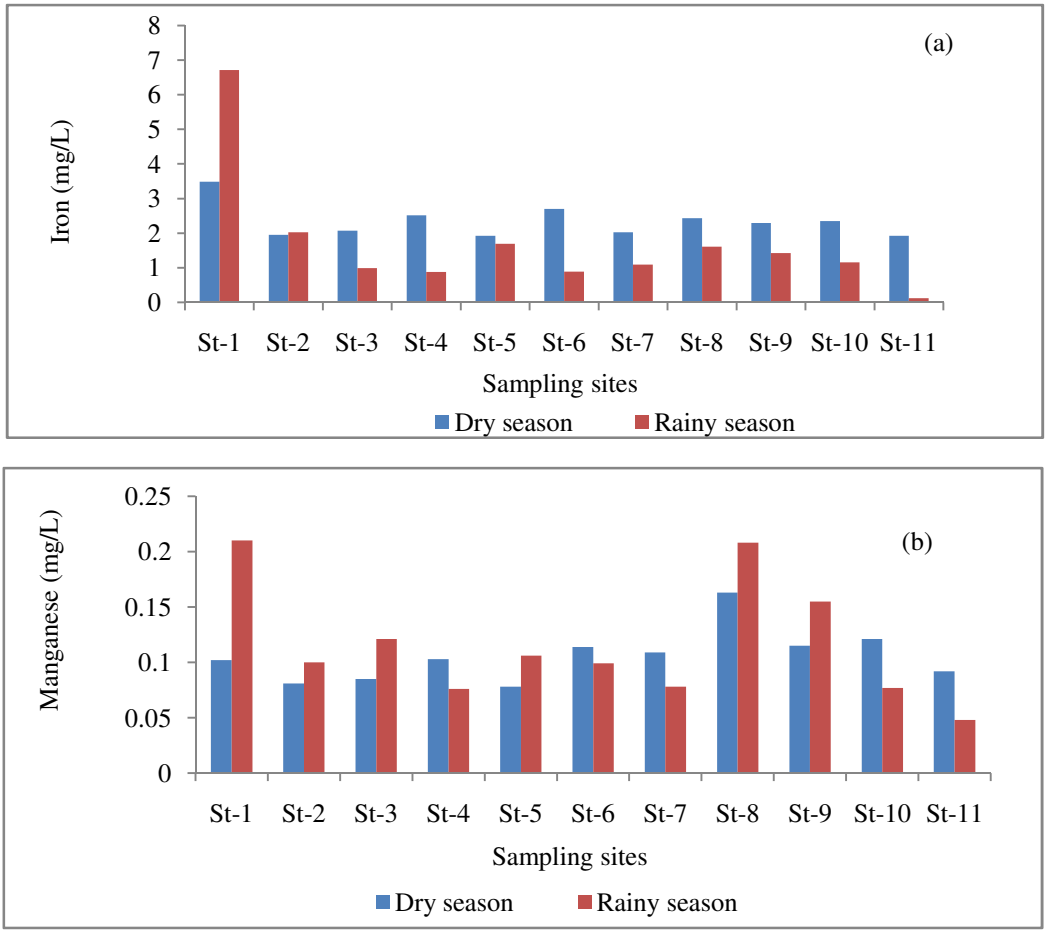


Figure-9: Seasonal variation of iron (a) and manganese (b) in water of the Ilauko dam at Savè.

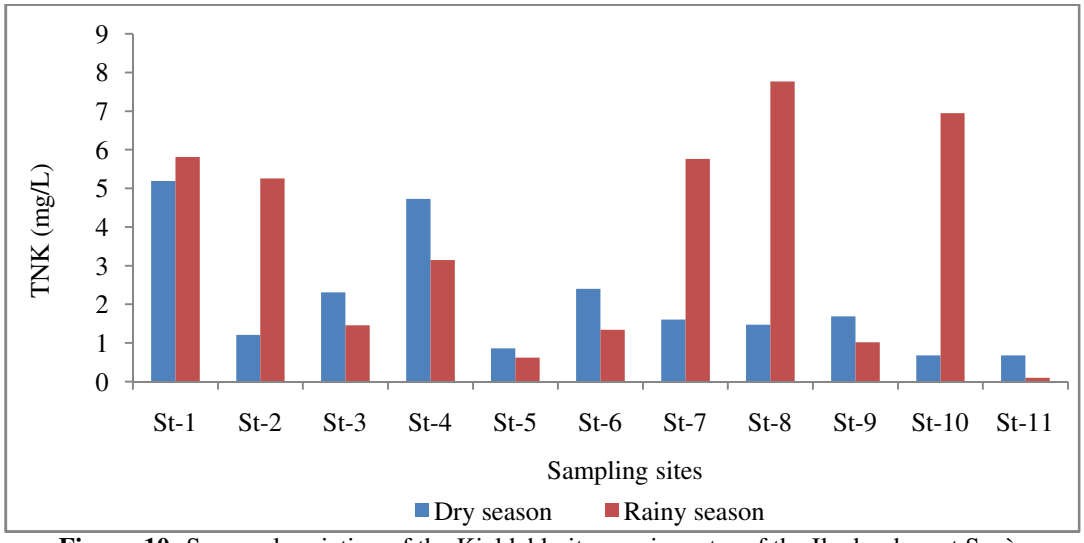


Figure-10: Seasonal variation of the Kjeldahl nitrogen in water of the Ilauko dam at Savè.

On the overall sites of measurement of the physicochemical parameters, the total phosphorus values, in dry season, are higher than those obtained in rainy season, with an average value equal to 2.56 mg/L obtained in this period. This indicates that water of the Ilauko dam is rich in nitrogen and phosphorus elements respectively during the rainy and dry seasons.

Total Organic carbon (TOC): Analysis of the Figure-11 indicates a large variation in total organic carbon from one season to another. The highest values are observed in dry season, except for the sites 1, 2 and 9.

Chlorophyll a (chl a): The values of chlorophyll aranges between 4.64 and 85.91 µg/L, with an average of 22.54µg/L. The dry season is the season that recorded the strongest values of the phytoplanktonic biomass.

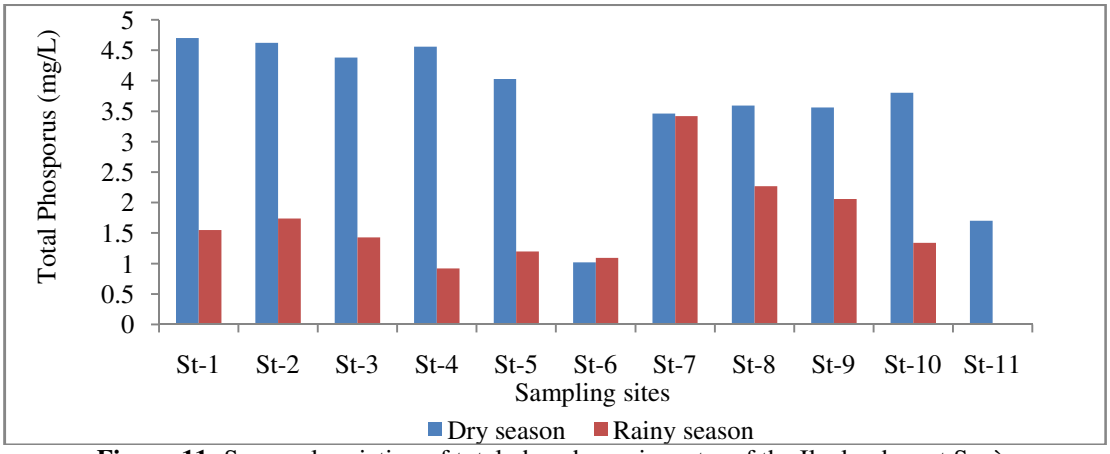


Figure-11: Seasonal variation of total phosphorus in water of the Ilauko dam at Savè.

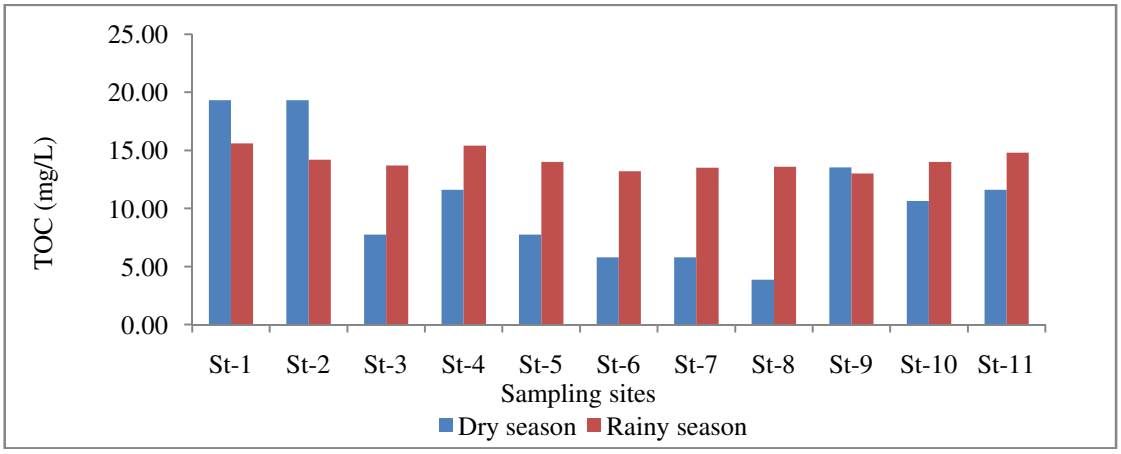


Figure-12: Seasonal variation of Total Organic Carbon in water of the Ilauko dam at Savè.

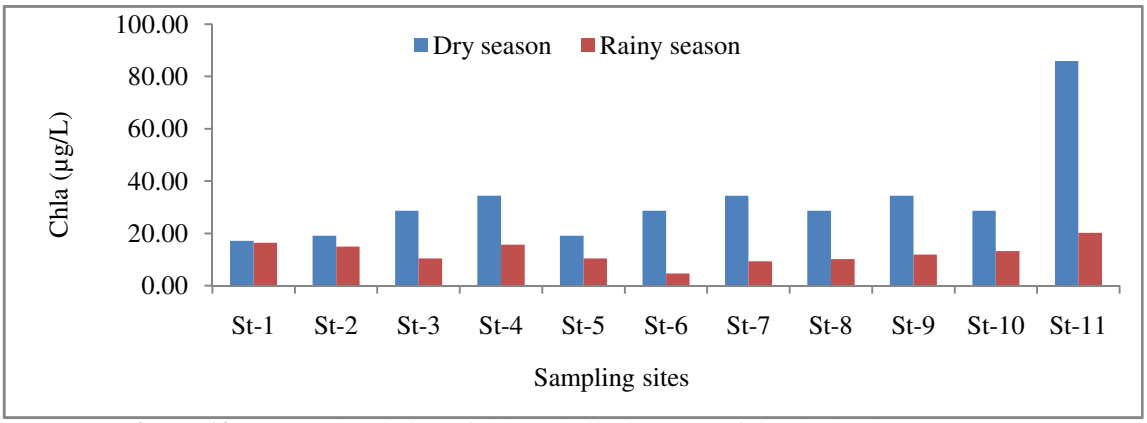


Figure-13: Seasonal variation of chlorophyll a in water of the Ilauko dam at Savè.

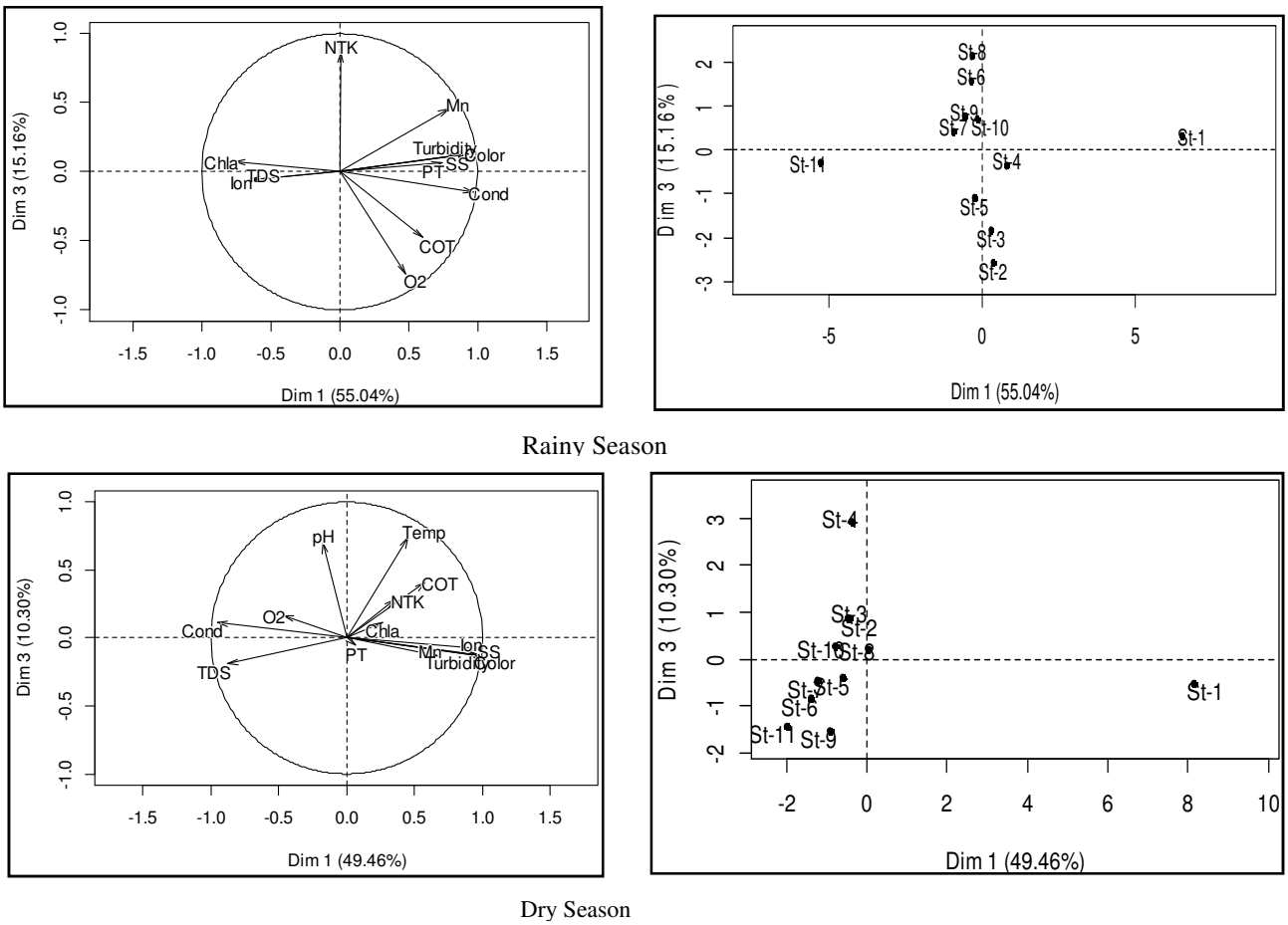
Results of correlation between the parameters: The analysis of the matrix of correlation achieved on the physicochemical data, reveals a positive correlation between the pH and the temperature. On the other hand, it presents a negative correlation with the conductivity, the total dissolved solids and chlorophylla. A negative correlation is also noted between the conductivity, the TDS and the temperature. A perfect correlation was found between the color, turbidity and the suspended solids. In addition, the color, turbidity and the suspended solid influence positively on the content of iron of the dam water. Thus, manganese is positively correlated with the iron and negatively correlated with the dissolved oxygen content. Total phosphorus, which is the element responsible for eutrophication is negatively correlated with conductivity and the TDS, but is positively correlated with the TNK. A very close correlation between color, turbidity, suspended solids and iron is noted. The temperature, which is a very determining element in the synthesis of chlorophylla, is positively correlated with the conductivity and the TDS, but negatively correlated with the PT.

The Principal Component Analysis (PCA), enabled us to distinguish two groups, according to the seasonal variation of the physicochemical parameters of the reservoir water. The first group is composed of the sites (St-8, St-6, St-9, St-7 and St-10) and shows the same affinity for the physicochemical parameters such as: TNK, Mn, turbidity and color. The second group is composed of (St-1, St-2, St-3, St-4 and St-5) and presents the same variations of suspended solids, total phosphorus, total organic carbon, conductivity and dissolved oxygen. In dry season, the two groups are distinguished as follows: a first classification constitutes by the sites (St-2, St-3, St-4, St 8 and St-10) that have the same variations of conductivity, dissolved oxygen and pH. The second classification takes into account the sites (St-5, St-6, St-7, St-9 and St-11) and these sites have the same values of TDS.

Table-2: Matrix of correlation between the various physicochemical parameters

	pH	Temp	O_2	Color	Turb	MES	Cond	TDS	Iron	Mn	TNK	PT	TOC	Chla
pH	1													
Temp	0,551	1												
O_2	0,158	-0,312	1											
Color	0,003	0,125	-0,126	1										
Turb	-0,07	0,02	-0,081	0,99	1									
SS	0,047	0,11	-0,037	0,99	0,986	1								
Cond	-0,51	-0,786	0,302	-0,264	-0,156	-0,269	1							
TDS	-0,51	-0,786	0,292	-0,277	-0,169	-0,282	-0,329	1						
Iron	0,002	0,133	-0,124	0,99	0,972	0,98	-0,329	-0,34	1					
Mn	-0,21	0,363	-0,536	0,5	0,442	0,445	-0,405	-0,41	0,56	1				
TNK	-0,05	0,229	-0,227	0,306	0,287	0,286	-0,409	-0,41	0,38	0,495	1			
PT	0,181	0,411	-0,449	0,286	0,23	0,275	-0,681	-0,68	0,35	0,35	0,58	1		
TOC	-0,17	-0,425	0,483	0,541	0,584	0,582	0,085	0,072	0,57	-0,07	0,08	0,19	1	
Chla	-0,59	-0,707	0,263	-0,329	-0,215	-0,336	0,959	0,96	-0,39	-0,4	-0,37	-0,59	0,073	1

Source: Area data, 2016. Legend: Temp=temperature, Turb= Turbidity, SS= Suspended solids, Cond= conductivity, TDS= Total dissolved solids, NTK= Azote Kjeldahl, PT= Total phosphorus, TOC= Total Organiccarbon, Chla= Chlorophyll a, O_2= dissolved oxygen, Mn = manganese.



Source; Area data, 2016

Figure-14: Results of the principal component analysis of the physicochemical parameters.

Discussion: The monitoring of the various parameters for assessing the water quality of the Ilauko dam vary in time and space.

The potential hydrogen is one of the parameters that influences the behavior and the distribution of the chemical elements in the hydrosystems[9]. Indeed, the values of the pH almost supposed basics, got during these periods could be explained on the one hand, by the rise of water with for effects, the dilution and also by the water coming from Ouémé river.

In addition, this could also be explained by the presence of phytoplankton which releases the oxygen and increases by this way its concentration and thus would consume the carbon dioxide (CO_2) and lead to the rising of the pH[10]. These observations, are confirmed by the work of AWO-AFFOUDA[11] where, the values of the pH, obtained on the site of Ilauko are higher than 7.

The observed temperature values are similar to those obtained by Dèdjiho[12] and Pouomogne[13] who showed that the temperatures ranging between 24°C and 35°C are favorable to a good growth of the usually high piscicultural species in aquiculture. Thus, the obtained temperatures are characteristic of those of water of the tropical lagoons which vary between the average of 25°C and 30°C[14,15,16]. Overall, the temperature of the reservoir water is directly influenced by the climatic conditions. This influence is at the origin of cold waters observed during the flood period.

Dissolved oxygen is one of a parameter that participates in photosynthetic activity, to oxidation and to atmospheric oxygen.

The dissolved oxygen decreases due to the increase of the temperature in the dam area. The very low dissolved oxygen values observed at site 9 during the flood indicate poor water quality.

Indeed, when the oxygen level is less than 2mg / L, many aquatic organisms perish, result of decomposition processes that reduce dissolved oxygen[17].

The low value of dissolved oxygen obtained, are due to the lack of continuous flows of water, to the Lack of water flows, industrial wastewater discharges from SUCCOBE Company at downstream.

Moreover, the observed salinity values are less than 0.1%. This could be explained by the fact that the dam is fed by fresh water from Ouémé and is not subject to any other source of saline contamination.

Statistical analysis of the color measured data does not show any significant difference between the colors of water from one site to another during the same period. Nevertheless, a significant difference of the color can be seen between the seasons. This situation could be explained by the contribution of the inorganic matter (sand, clay. etc), as well as by suspending organic matter of the reservoir and other mineral matters (iron and manganese) by the surface water currents coming from the catchment during the rainy season.It could also be due to the anthropic activities which are unrolled near the site1 (fishery, the fish sellers, Garbage dumpsand Industrial waste water from SUCCOBE).

Turbidity is an important ecological factor, because it permit to evaluate the quantity of suspended matter in the water. It is produced in natural water by the sediments and other suspended matter[18]. The strong values obtained at site1 would be due to bringing of sediments in the tank, from Ouémé River, and to the suspension particles at the bottom by the water strong agitations due to the winds.

On the other hand, the significant difference between the minimum and maximum of turbidity and the total dissolved solids values observed at sites 1 and 11 during both periods could be explained by: the effect of dilution produced by the supply of water, the runoff from the dam basin, by the pumping of the river Ouémé towards the retention of Ilauko or by the leaks sometimes observed on the pipeline.

The concentration of iron and manganese, in high proportion on site 1, is due to industrial discharges and anaerobic conditions, resulting in adverse effects such as their suspension.

Then, the strong concentrations of TNK and TOC, recorded during the rainy season would be due to the industrial and the direct domestic waste water contributions produced by SUCOBE SA in the dam. The low contents of nitrogen Kjeldahl obtained in dry season could be related to the hydrology of the dam, which induces a dilution of the nitrogen contributions which constitutes the waste waters rejected directly into reservoir.

Moreover, the average content of phosphorus, which is about 2.56 mg/L, is largely higher than the one of the majority of natural water, where the contents oscillate between 0.005 and 0.02 mg/L [9]. It is also lower than the European standards toxicity value fixed at 6.1 mg/L. In effect, the problems of eutrophication in water start from the contents of about 0.34 to 0.70 mg/L. Thus, the contributions of phosphorus in the reservoir can then be associated with mineral particles, by adsorption on clays and co-precipitation with calcium. They do not appear in the dissolved phase, but remain partially accessible for the assimilation by the phytoplankton.

From the analysis of the chlorophyll a values observed on the reservoir and according to the classification table of OECD[19], Ilauko dam can be classified in the category of the eutrophic reservoir; Concentrations sometimes exceeding 25.00 µg /L.

This situation can create a deficit of oxygenation of the aquatic environment, and involves the asphyxiation of aquatic species and an unbalance of the trophic chain[20].

Conclusion

The present study which is based on the parameters of pollution of the Ilauko tank of the SUCOBE Company, enabled us to apprehend the level of pollution in the dam, because of the anthropogenic activities which are carried out, and also the contributions of the input water. Based on the obtained results during this study, we can conclude that the reservoir of Ilauko was disturbed by the anthropogenic activities which are carried out on this catchment and by the use of water for multiple purposes. The quality of water of the reservoir is damaged and leads to the eutrophication, which causes a lot of consequences on the aquatic life. Therefore, it is urging to give a special attention to this dam in order to sustainable exploitation.

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