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Influence Of The Seasons On The Physico-Chemical Parameters And Nutrients Favouring The Proliferation Of Cyanobacteria In TheAghien Lagoon (Côte d'Ivoire)

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Abstract:
Background*: In Africa, freshwater ecosystems are subject to increasing anthropogenic pressures that could potentially have an impact on water quality. In Côte d'Ivoire, in the district of Abidjan, it is estimated that the population will reach almost seven and a half million in the next fifteen years, leading to a rapid increase in water consumption. In order to meet the population's drinking water needs, the Aghien lagoon has been identified by the Ivorian authorities as a likely alternative source of drinking water. The aim of this study is to identify the factors that encourage the proliferation of cyanobacteria and to analyse the influence of the seasons on these factors.*
Material and method*: Samples were taken from June 2016 to March 2018 at six stations in the Aghien lagoon. Physico-chemical parameters were measured in situ using the YSI®EXO 2 multi-parameter probe. The water samples used for nutrient research were taken using an integrated sampler. These samples were stored and then sent to the laboratory for the various nutrient assays.*
Results*: The results reveal that the proliferation of Cyanobacteria in the Aghien lagoon is favoured by physico-chemical parameters such as temperature, hydrogen potential, conductivity, turbidity and nutrients containing phosphorus and nitrogen compounds.*
Conclusion*: Analyses show that these factors are influenced by the seasons.*
Keyword*: Seasons, physico-chemical parameters, nutrients, cyanobacteria, Aghien lagoon.*

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I. Introduction

Freshwater is the main source of drinking water for most of the world's human population[1].

In Africa, freshwater ecosystems are subject to increasing anthropogenic pressures that could potentially have an impact on water quality[2]. Similarly, over the past decade, climate change, combined with increasing inputs of nutrients such as phosphates and nitrates from agricultural fertilisers, wastewater and soil run-off, have accelerated the proliferation of cyanobacteria in water bodies around the world[3, 4, 5].

Cyanobacteria are photosynthetic prokaryotic microorganisms naturally present in the aquatic environment (less than 20,000 cells/mL), with no associated problems[6]. However, problems arise when cyanobacteria proliferate[7]. This problem is made all the more serious by the fact that the species responsible for these blooms can produce toxins. Contamination of freshwater by these toxins limits their use, as they are often the cause of fatal poisoning of domestic or wild animals, fish, birds and humans[8, 9, 10]. Studies carried out by several research teams have shown the presence of cyanobacteria in these waterways[11, 12, 13].

In Côte d'Ivoire's Abidjan district, it is estimated that the population will reach almost seven and a half million in the next fifteen years[14], and water consumption is increasing rapidly. In order to meet this population's growing and pressing need for drinking water, the Aghien lagoon, the largest freshwater reserve in the Abidjan district, has been identified by the Ivorian authorities as an alternative source for supplying drinking water[15, 16].

Against this backdrop, this study is being carried out to investigate the physico-chemical parameters and nutrients that encourage the proliferation of cyanobacteria, and to analyse the influence of the seasons on these factor.

II. Material And Methods

Study framework and period

This study was carried out from June 2016 to March 2018 at six (6) stations in the Aghien lagoon (Figure 1)

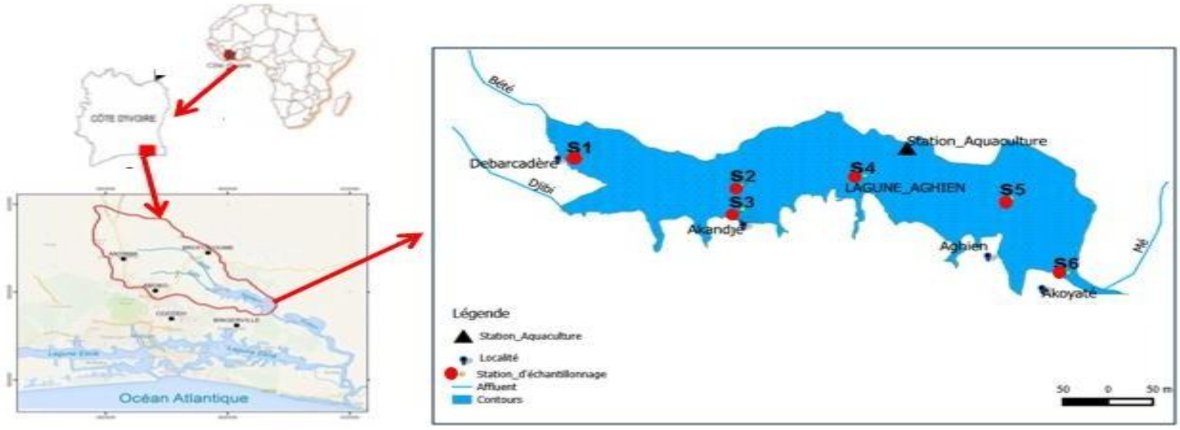

Figure 1: Sampling stations in the Aghien lagoon 17 (modified)

Sampling techniques

Water samples for nutrient analysis were collected using an integrated sampler based on the technique employed by Laplace-Treyture18. This sampler was used to collect water samples from the surface down to a depth of one meter. The contents of the sampler were transferred into sterile one-liter glass vials. The water samples collected for the various assays were stored in a cooler containing cold accumulators to prevent contamination, and then transported to the laboratory.

On-site measurements of water physico-chemical parameters

Parameters such as temperature, turbidity, conductivity and pH were measured in situ using the YSI®EXO 2 multi-parameter probe. At each sampling station, physico-chemical parameters were measured from zero to 1 meter depth using the YSI® EXO 2 multi-parameter probe. The probe was immersed in the water and the values of the various parameters selected were recorded. The data collected by the probe was then exported to the computer's hard disk.

Nutrient measurements

Nutrient parameters such as nitrites, nitrates, phosphorus, and phosphates were measured according to Blottière19

Statistical analysis

The results obtained per station during the different sampling months were entered into Excel 2016. The averages of the various results obtained were calculated according to the different seasons. Statistical analyses of the physico-chemical parameter data were carried out in Past 3.12. The non-parametric Kruskall-Wallis test was used to test the variance of the physico-chemical parameters between the different sampling stations and between the different seasons. These tests are significant for a probability value of less than 0.05 ($p < 0.05$).

III. Result

Physico-chemical parameters

Hydrogen potential

The results of this study indicate a significant difference in pH values between months ($p < 0.05$). On the other hand, the results show that there is no significant variation ($p > 0.05$) in this parameter between stations. The minimum pH of the water in the Aghien lagoon was 5.92, recorded at station 3 in August 2016, while the maximum pH of 9.82 was measured at station 4 in September 2017. The average pH of the lagoon was 7.74 ± 0.89 (Figure 2).

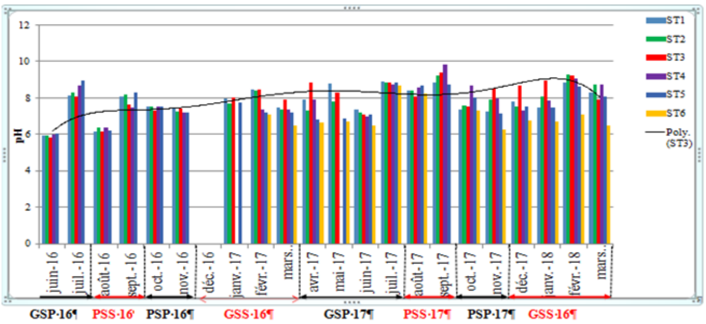

***Figure 2**:* Spatial and temporal variations in the pH of water in the Aghien lagoon
GSS: Great Dry Season; GSP: Great Rainy Season; PSS: Little Dry Season; PSP: Little Rainy Season; ST1: Station 1, ST2: Station 2, ST3: Station 3, ST4: Station 4, ST5: Station 5, ST6: Station 6.

Temperature

The results of this study show that the average temperature of the water in the Aghien lagoon is 28.61 ± 1.70°C. The minimum (23.10°C) and maximum (31.9°C) temperature values were recorded at station 3 in June 2016 and March 2018 respectively (**Figure 3**). The analyses indicate a significant variation in temperature values between the months ($p < 0.05$). A fluctuation in temperature was also observed throughout the campaign. A successive increase in temperature was noted from June to September 2016, followed by a slight drop in October 2016 and then another increase between November 2016 and April 2017.

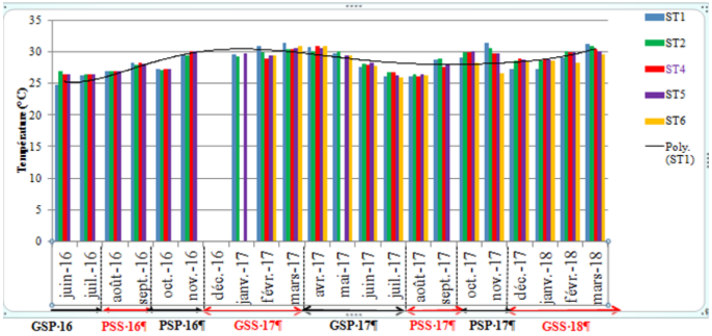

Figure 3: Spatial and temporal variations in temperature
GSS: Great Dry Season; GSP: Great Rainy Season; PSS: Little Dry Season; PSP: Little Rainy Season; ST1: Station 1, ST2: Station 2, ST3: Station 3, ST4: Station 4, ST5: Station 5, ST6: Station 6

Conductivity

Conductivity values fluctuated between a minimum of 5.23 µS/cm recorded in November 2016 at station 3 and a maximum of 233.12 µS/cm measured at station 5 in April 2017. The average conductivity of the water in the Aghien lagoon was 68.98 ± 12.28 µS/cm (**Figure 4**). The analyses indicate that there is a significant variation ($p < 0.05$) in this parameter between the months of sampling.

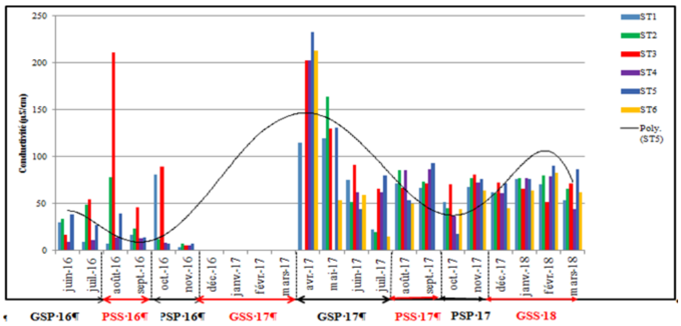

Figure 4: Space-time variation in Conductivity
GSS: Great Dry Season; GSP: Great Rainy Season; PSS: Little Dry Season; PSP: Little Rainy Season; ST1: Station 1, ST2: Station 2, ST3: Station 3, ST4: Station 4, ST5: Station 5, ST6: Station 6

Turbidity

Turbidity values in the lagoon fluctuated between 7.51 and 404.95 NTU. The minimum and maximum were observed respectively at station 3 in January 2017 and station 5 in September 2017. Average turbidity was 67.18 ± 7.24 NTU (**Figure 5**). The results of the analyses of this parameter indicate a significant difference ($p < 0.05$) between the months.

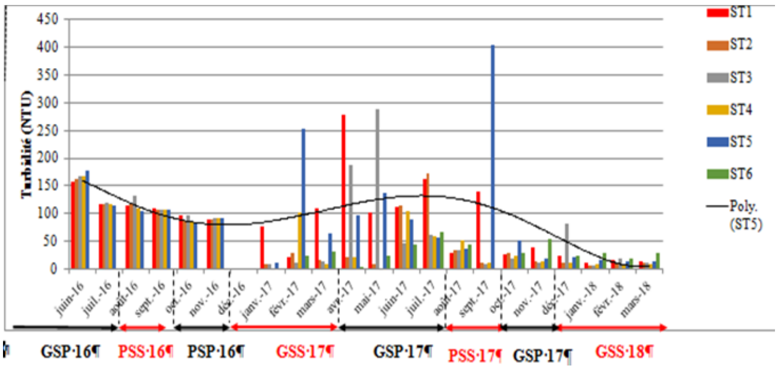

Figure 5: Spatial and temporal variation in Turbidity
GSS: Great Dry Season; GSP: Great Rainy Season; PSS: Little Dry Season; PSP: Little Rainy Season; ST1: Station 1, ST2: Station 2, ST3: Station 3, ST4: Station 4, ST5: Station 5, ST6: Station 6.

Nutrients

Phosphor

The average phosphor concentration was 0.2 ± 0.043 mg/L, with values ranging from 0.102 mg/L to 1.11 mg/L. The lowest phosphor value was obtained in November 2016 at station 4 and the maximum value at station 6 in June 2017 (**Figure 6**). Phosphor levels showed significant variation $p < 0.05$ between months.

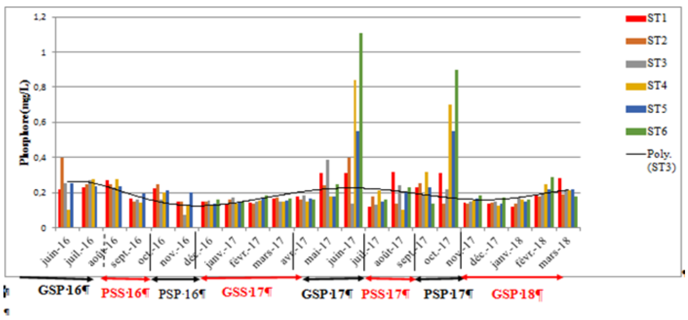

Figure 6: Spatial and temporal variations in phosphor
GSS: Great Dry Season; GSP: Great Rainy Season; PSS: Little Dry Season; PSP: Little Rainy Season; ST1: Station 1, ST2: Station 2, ST3: Station 3, ST4: Station 4, ST5: Station 5, ST6: Station 6

Orthophosphate

The average orthophosphate concentration was 0.08 ± 0.014 mg/L with extreme values of 0.003 and 0.18 mg/L. The minimum recorded in September 2016 at station 5 and the maximum measured at station 4 during February and November 2017 (**Figure 7**). Analyses of orthophosphate levels show significant variation ($p < 0.05$) between months.

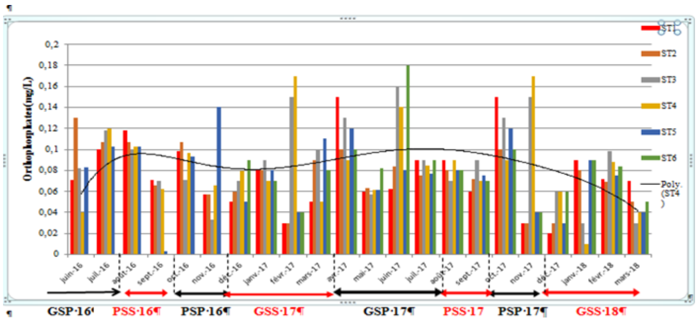

Figure 7: Variationspatio-temporelledes orthophosphates

GSS: GrandeSaisonsèche;GSP:GrandeSaisondespluies;PSS:PetiteSaisonsèche;PSP:PetiteSaison desPluies ; ST1 : Station 1, ST2 : Station 2, ST3 : Station 3, ST4 : Station 4,ST5 : Station 5 ST6 : Station 6.

Nitrate

Nitrate levels range from 0.21 mg/L to 3.8 mg/L, with a minimum value observed at station 4 in March 2017. The maximum value was obtained at station 3 in July 2016 and at station 1 in August 2018. The average was 0.82 ± 0.38 mg/L (**Figure 8**). Analyses of nutrient levels showed significant differences ($p < 0.05$) between months.

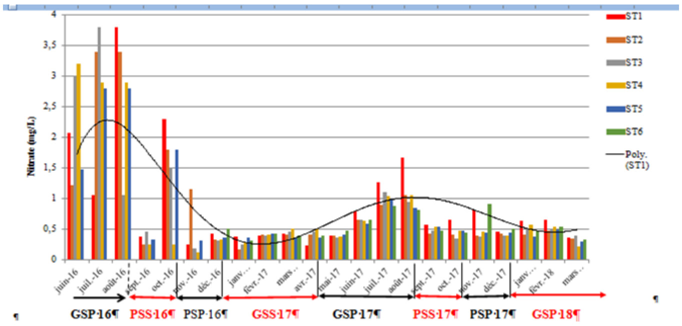

Figure 8: Spatial and temporal variations in nitrates

GSS: GrandeSaisonsèche;GSP:GrandeSaisondespluies;PSS:PetiteSaisonsèche;PSP:PetiteSaison desPluies ; ST1 : Station 1, ST2 : Station 2, ST3 : Station 3, ST4 : Station 4,ST5 : Station 5 ST6 : Station 6.

Nitrite

The results show that nitrite concentrations ranged from 0.0015 mg/L in October 2016 (stations 1, 2, 3 and 4) to 1.5 mg/L at station 4 (July and August 2016), with an average of 0.125 ± 0.0195 mg/L. (**Figure 9**). The analyses also showed significant differences ($p < 0.05$) in nitrite levels between months.

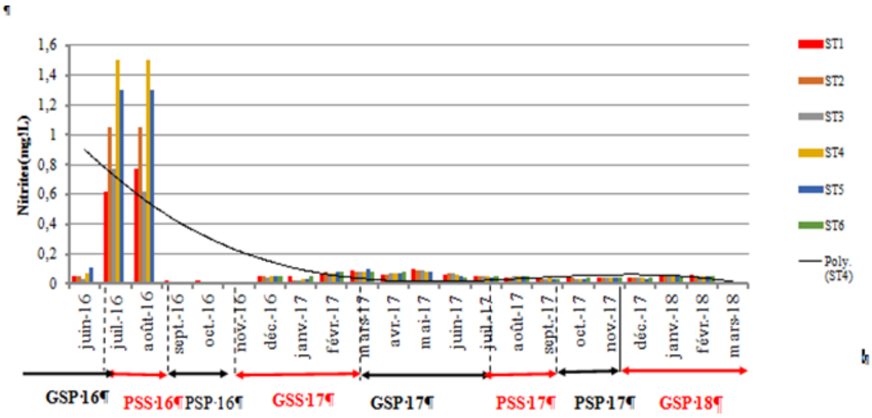

Figure 9: Spatial and temporal variations in nitrites

GSS: GrandeSaisonsèche;GSP:GrandeSaisondespluies;PSS:PetiteSaisonsèche;PSP:PetiteSaison desPluies ; ST1 : Station 1, ST2 : Station 2, ST3 : Station 3, ST4 : Station 4,ST5 : Station 5 ST6 : Station 6.

IV. Discussion

In this study carried out on the Aghien lagoon, the aim was to highlight the influence of the seasons on the physico-chemical parameters and nutrients involved in the proliferation of cyanobacteria in this watercourse.

The results show that the temperature of the water in the Aghien lagoon is high (25.89°C to 30.30°C). These results corroborate those of Konan et al.[20] in the Grand-Lahou lagoon and Traoré et al.[21] in the Aghien lagoon. These results confirm the hypothesis that the maximum temperature values in the Ivorian lagoons are recorded (30 to 32°C) in the dry season. According to Traoré et al.[21], during hot periods, rainfall is low and the inflow of water from the Djibi, Bété and Mé rivers is almost nil (low-water periods). These increases in temperature recorded during the dry seasons lead to intense evaporation, which could explain the basic state of the water reported by the results of the hydrogen potential (pH) measurements. The basic nature of the water is thought to be due to the physico-chemical and biological reactions of aquatic plants. According to Kosten et al.[22], temperature is an important factor in the growth of cyanobacteria. This growth accelerates with the warming of the water and the availability of dissolved oxygen.

An increase in temperature is accompanied by a decrease in dissolved oxygen, as a result of photosynthesis. Photosynthesis tends to raise the pH, while respiration tends to lower it. The pH values of the water in the Aghien lagoon recorded during the study period ranged from 5.92 to 9.82. These values are in the same order as those measured in the Potou lagoon, which varied between 6 and 923. However, the values reported in this study are higher than those obtained by Traoré et al.[21] and Niamien-Ebrottié et al.[24] in the Aghien lagoon. This result may be due to very intense biological activity in the lagoon. The presence of phytoplankton, including cyanobacteria, is responsible for the increase in pH in the water. In addition, work by Amon *et* al.[16] and Konan et al.[25] has also shown that the high temperature values during this period favour the self-purification phenomenon and increase the rate of sedimentation of suspended matter.

With regard to conductivity, the highest value was recorded during the main rainy season. This result corroborates those of Amon et al.[16] and Niamien-Ebrottié et al.[24], which found high conductivity during the rainy season. These high values indicate that the water in this lagoon is highly mineralised. This could be attributed to the inflow of water from the Djibi and Bété rivers, on the one hand, and to human pressures from the surrounding villages, on the other.

As for turbidity, the analyses showed a significant difference in this parameter between the months of the study. The highest values were observed during the rainy season. These results corroborate those obtained Seu-Anoi et al.[26] in the Grand-Lahou lagoon, and in the Aghien lagoon [24]. In fact, rain washes away more suspended matter due to the transport of organic and mineral particles in the lagoons.

As for nutrients, the results of this study reveal a variation in the content of these compounds depending on the station and the season.

The highest concentrations of phosphor and nitrogen compounds were recorded during the rainy season. This observation may be due to the fact that during this season, the Aghien lagoon receives run-off water loaded with leaching products from the catchment areas and water from continental sources rich in compounds. In fact, according to Konan et al.[25] the Aghien lagoon receives a large quantity of organic matter through wastewater. The highest phosphorus levels were measured at station 6, close to the mouth of the Mé. In addition, the highest nitrate values were recorded at station 3 near the village of Akandjé. These results could be explained, on the one hand, by the anthropic activities (washing up, laundry and bathing) of the riverside populations. All the products used for this purpose, particularly detergents, are rich in phosphorus and nitrogen compounds[25]. And secondly, that nitrate and orthophosphates come from fertilisers used in agriculture upstream and around the lagoon [27].

From a seasonal point of view, the analyses show significant variations in the parameters targeted in this study.

During the dry season, the results of the analyses showed low concentrations of nutrients, particularly nitrate and phosphorus. These low concentrations of these elements could be explained by the fact that during the dry season, there is little influence from the river. In addition, algal growth could lead to a depletion of reactive nitrate and phosphorus in the environment.

These results are in agreement with those reported by Seu–Anoi et al.[26] and Yéo et al.[28] in Grand-Lahou lagoon and Aghien lagoon respectively. This season is also characterised by high temperature and pH values. The high temperatures recorded during the dry period due to the high insolation could increase the rates of chemical and biochemical reactions [29].

The results of the analysis showed that the rainy period is characterised by the opposite phenomena in terms of variations in physico-chemical parameters. In fact, during rainy periods, the low pH values are due to the effect of dilutions linked to freshwater inputs from rivers and rainfall inputs. However, during this period, the water temperatures are relatively low. This observation would be due to the low insolation favoured by a generally overcast sky.

V. Conclusion

At the end of this work, it emerged that the physico-chemical parameters and nutrient levels favouring the proliferation of Cyanobacteria in the Aghien lagoon vary according to the seasons and sampling stations. It appears that the Aghien lagoon is subject to an input of nutrient salts of indigenous or exogenous origin linked to rainfall and leaching in the catchment area. The stations near the mouth and the village are the richest in nutrient salts. With regard to the influence of the seasons, temperature and pH were higher during the dry season, while conductivity, turbidity and nutrient concentrations were higher during the rainy season.

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