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(RESEARCH ARTICLE)

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Identification and analysis of the spatial distribution of Cyanobacteria in the Aghien lagoon

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Abstract

Introduction: Cyanobacteria are aquatic microorganisms that colonize a wide variety of ecosystems. Some produce secondary metabolites with pharmacological activities while some produce toxins harmful to human and animal health. Because of this dual interest, the issue of Cyanobacteria is the subject of much work worldwide. In this context, this study is carried out on the Aghien Lagoon (Cote d'Ivoire) in order to evaluate the photosynthetic activity and analyze the spatial distribution of Cyanobacteria.

Material and Methods: Samples were taken from June 2016 to March 2018 at six stations located on the Aghien Lagoon. Chlorophyll (a) present in the water was measured by monochromatic spectrophotometry. The identification of Cyanobacteria was carried out according to the technique of morphological keys of Cyanobacteria.

Results: The results of this study revealed that the Aghien lagoon is the site of strong photosynthetic activity measurable by variable levels of Chlorophyll a. Also, the results showed that 12 genera of Cyanobacteria are present in the lagoon with producers of secondary metabolites. Stations 2 and 3 near the village of Akandjé were the stations that contained the greatest number of genera of Cyanobacteria.

Conclusion: It emerges from this study that the Aghien lagoon contains several genera of Cyanobacteria with a spatio-dependent distribution. In addition, the genus Microcystis, potentially producing secondary metabolites, is the most widespread genus in this Lagoon.

Keywords: Cyanobacteria; Aghien lagoon; Chlorophylla; *Microcystis*; Secondary metabolites

1. Introduction

Cyanobacteria are aquatic microorganisms of the prokaryotic type with oxygenic photosynthesis that constitute the dominant phytoplankton group in fresh waters worldwide. They appeared on Earth approximately 3 billion years ago (Paerl and Paul, 2012), which allowed them to colonize a very wide variety of ecosystems. They are naturally present in the aquatic environment without any associated problems (less than 20,000 cells/mL). However, under certain conditions, species of Cyanobacteria can grow rapidly and form blooms (Marmen et al., 2016). These Cyanobacteria blooms disrupt and unbalance the functioning of aquatic ecosystems through the biomass they generate [3]. Furthermore, this imbalance has a negative impact on water quality, particularly when the species responsible are toxin

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producers [4]. These toxins contaminate fresh water resources, requiring distributors to resort to restrictive and costly treatments [5].

Conversely, some species of Cyanobacteria produce a vast repertoire of secondary metabolites with diverse biological activities [6]. The discovery of these properties has motivated a growing interest in the research of cyanobacteria in fresh waters.

Because of this dual interest, in recent decades, the problem of Cyanobacteria has been the subject of numerous studies worldwide, prompted by their pharmacological applications or their adverse effects on human and animal health.

To this end, on the African continent, several studies have been carried out in different watercourses on the research of cyanobacteria and their toxins [7, 8, 9]. In Cote d'Ivoire, the Aghien lagoon, identified as the largest freshwater reserve near Abidjan by the Ivorian authorities, is a probable alternative source for drinking water supply [10, 11] to meet the pressing needs of the population for drinking water.

In this context, the present study is conducted on the Aghien lagoon in order to evaluate the photosynthetic activity on the one hand and to analyze the spatial distribution of the Cyanobacteria present on the other hand.

2. Material and methods

2.1. Framework and period of the study

This study was carried out from June 2016 to March 2018 on six (6) stations located in the Aghien lagoon. The six stations surveyed have different characteristics, four of them being along a transect located on the largest diagonal of the lagoon, and the other two near two villages **(Figure 1).**

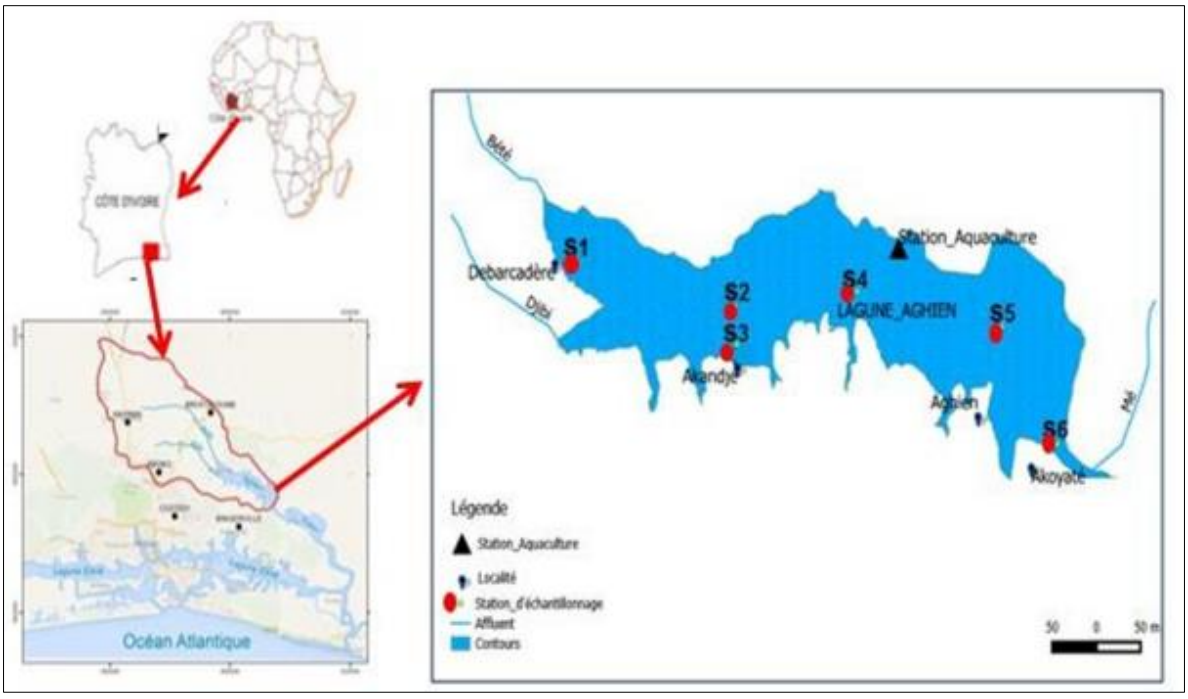


Figure 1 Study area [12]

2.2. Water sampling techniques

Water samples for microscopic observation were collected using a 20 µm porosity plankton net. The subsample was fixed with 5% formalin (V/V).

For the determination of chlorophyll (a), the water samples used were collected according to the technique described by Laplace-Treyture *et al.* [13].

2.3. Identification of Cyanobacteria

In this study, the identification of Cyanobacteria was carried out according to the morphological keys of Cyanobacteria described by John *et al.* [14] and Komárek and Anagnostidis [15].

2.4. Chlorophyll (a) assay

Chlorophyll (a) present in the Aghien lagoon was assayed by monochromatic spectrophotometry as described by Lorenzen [16].

2.5. Statistical analyses

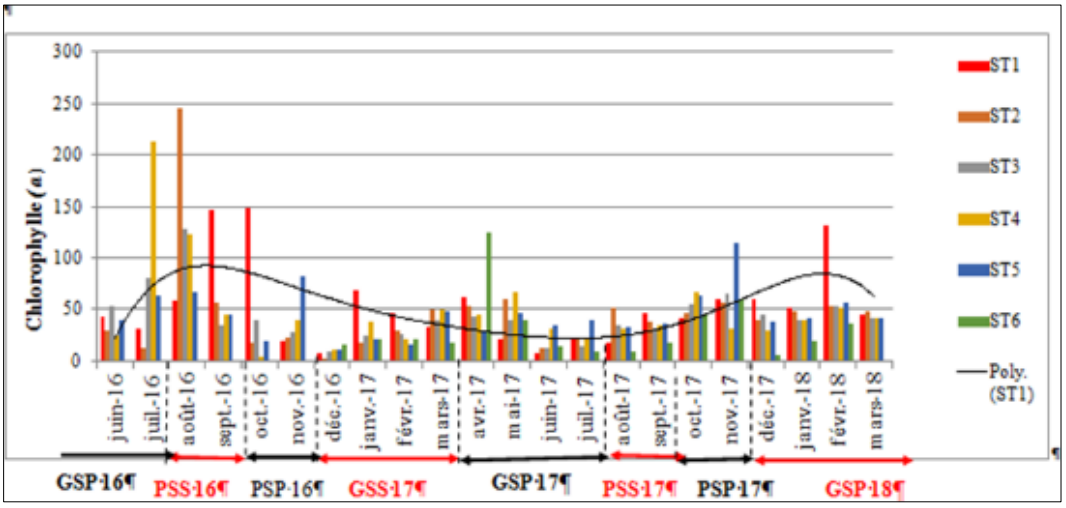
The results obtained by station during the different sampling months were entered into Excel 2016 software. The averages of the different results obtained were calculated according to the different stations. The Kruskall-Wallis non-parametric test was used to test the variance of the chlorophyll biomass between the different sampling stations. These tests are significant for a probability value lower than 0.05 ($p < 0.05$).

The frequency of Cyanobacteria or occurrence index, which is the ratio of the number of samples in which a species is recorded at a given station and the total number of samples taken at the same station (was calculated as described by Dajoz [17].

3. Results

3.1. Chlorophyll biomass

The results of this study revealed chlorophyll (a) values that ranged from 1.45 µg/L recorded in December 2016 at station 2 to 245.64 µg/L measured at station 2 in August 2016. The average value was 44.57 ± 11.54 µg/L (**Figure 2**). Statistical analyses revealed a significant difference ($p < 0.05$) between months.



GSS: Long Dry Season; GSP: Long Rainy Season; PSS: Short Dry Season; PSP: Short Rainy Season ST1: Station 1; ST2: Station 2; ST3: Station 3; ST4: Station 4; ST5: Station 5; ST6: Station 6.

Figure 2 Spatio-temporal variation of chlorophyll biomass in water samples from the Aghien lagoon from June 2016 to March 2018

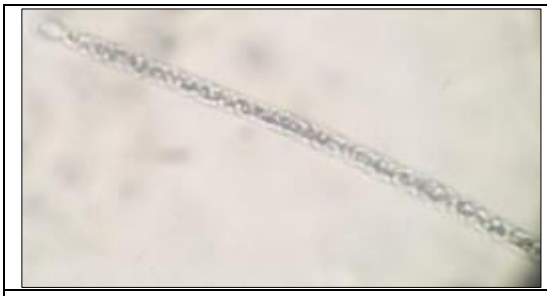
3.2. Qualitative study of Cyanobacteria

3.2.1. Composition of Cyanobacteria

The results of microscopic observations of the water samples collected revealed the presence of 12 genera of Cyanobacteria at the six stations of the Aghien lagoon.

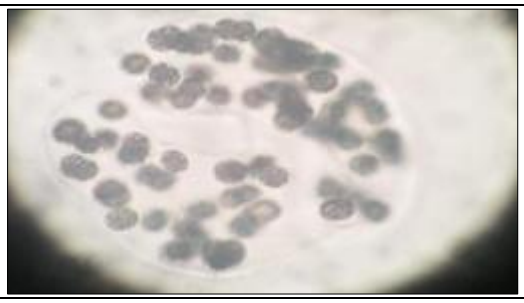
The identified Cyanobacteria were divided into 3 genera: Oscillatoriales, Chroococcales and Nostocales (**Figure 3**). Oscillatoriales were the most represented (5/12, or 41.66%) followed by Chroococcales (4/12 or 33.33%) and finally Nostocales (3/12 or 25%) were the least represented (**Table1**). The results of the study also showed that filamentous

Cyanobacteria were more diverse (8/12 or 66.66%) than unicellular Cyanobacteria (4/12 or 33.33%) (**Table 2**). From the point of view of the spatial distribution of cyanobacteria genera, stations 2 and 3 were the most diverse with 11 genera observed on each while station 6 located at the mouth only 4 genera were observed.



A : *Cylindrospermopsis* sp (X400)

B: Anabaena trichomes with differentiated heterocyst-like cells (X400)



C: *Microcystis* colonies de (X400)

D: *Pseudanabaena* sp (X400)

E: Filament of *Planktothrix* sp (X400)

Figure 3 Some genera of Cyanobacteria observed in the Aghien lagoon

Table 1 Order and genera of Cyanobacteria observed

Order of classification	**Cyanobacteria genera observed**
Oscillatoriales	*Oscillatoria, Planktothrix, Lyngbya, Pseudanabaena, Limnothrix*
Chroococcales	*Microcystis, Chrococcus, Aphanocapa, Aphanothece*
Nostocales	*Anabaena, Cylindrospermopsis, Aphanizomenon*

Table 2 Forms of the different Cyanobacteria observed

Form of the Cyanobacteria observed	Genera of Cyanobacteria observed
Filamentous	*Oscillatoria, Planktothrix, Lyngbya, Pseudanabaena, Limnothrix Anabaena, Cylindrospermopsis, Aphanizomenon*
Colonials	*Microcystis, Chrococcus, Aphanocapa, Aphanothece*

3.2.2. Frequency of Cyanobacteria

The analyses carried out on a total of 126 water samples made it possible to identify 12 genera of Cyanobacteria.

The genera *Microcystis* and *chroococcus* were the most represented with a frequency of 100%, followed by the genera Aphanocapsa (95.45%), *Planktothrix* (90.90%), Anabaena and *Limnotrix* (86.36%), *Cylindrospermopsis* (81.81%), *Oscillatoria* (77.27%) and *Aphanizomenon* (72.72%). As for the genera *Lyngbya* (68.18%), *Pseudanabaena* and *Aphanothece* (59.09%), they were identified with lower proportions (Figure 4).

Among the 12 genera observed, 4 genera (33.33%) are considered as potential producers of secondary metabolites. The main potentially toxic Cyanobacteria described in the literature were observed: *Microcystis*, *Anabaena*, *Planktothrix* and *Oscillatoria.*

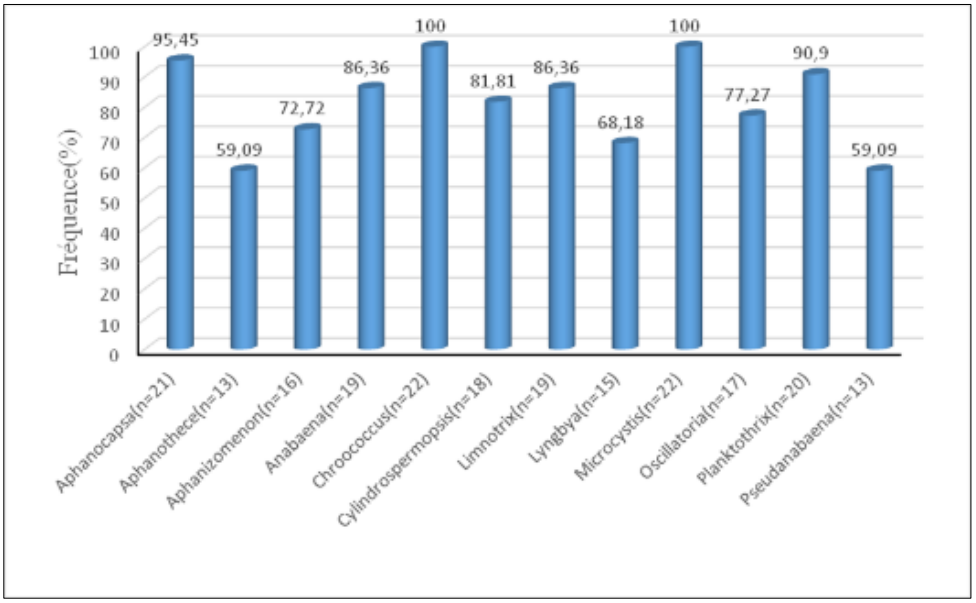


Figure 4 Frequency of Cyanobacteria observed in the water samples collected

4. Discussion

In this study, the aim was to assess the chlorophyll biomass and analyze the spatial distribution of cyanobacteria genera present in the Aghien lagoon.

The average values of chlorophyll (a) varied during this study and the maximum values were obtained during the dry seasons. These values reflect a richness in phytoplankton biomass through a relatively dense chlorophyll activity. According to Salla *et al*. **[**18] and Ouffoue *et al*. [19], high concentrations of chlorophyll a indicate biomass and specific richness. The high photosynthetic activity observed during the dry season is favored by the low turbidity that allows the sun's rays to penetrate the water column [20]. This photosynthetic activity would be due to the algal bloom that releases large quantities of oxygen.

Moreover, the inventory of Cyanobacteria carried out in this study in the Aghien lagoon revealed the presence of 12 genera. Similar proportions have already been reported in recent studies carried out on this lagoon [21, 22, 23].

The analysis of the population of cyanobacteria in the Aghien lagoon shows that it can be considered rich and diverse. This density of cyanobacteria in the Aghien lagoon would be linked to the strong disturbance of ecosystems due to the supply of nutrients on the one hand and to the stability of the lagoon waters on the other hand. The results of the present study confirm this postulate. Indeed, almost all of the genera of cyanobacteria identified in this study were observed in the waters taken at stations 2 and 3 near the village of Akandjé. For many scientists, the input of nutrients from anthropogenic activities (laundry, dishes, baths) of riverside populations would promote biological processes, in particular the complete cycles of reproduction and development of Cyanobacteria.

This abundance of Cyanobacteria is also related to the stability of the waters. These observations were also noted by Komoe *et al*. [20] and Seu-Anoï [24].

By analogy, the samples taken at station 6, located near the mouth of the Me River, are those that presented few genera of Cyanobacteria. In fact, station 6 near the mouth directly receives continental waters, disrupting the stability of the lagoon watershed necessary for the proliferation of cyanobacteria.

Regarding the frequency of genera producing secondary metabolites, the present study revealed that there is a strong presence of the genus *Microcystis*, *Planktothrix*, *Anabaena* and *Oscillatoria*, in the Aghien lagoon. These results corroborate those of Coulibaly *et al*. [21] and Niamien–Ebrottie *et al*. [22]. Also, it was noted that the genus Microcystis was the most widespread. According to El Ghazali *et al*. [8], this genus is the most widespread in the world especially during blooms. In addition, according to Meissner *et al*. [25], this genus would adapt to a multitude of environmental conditions and would be able to proliferate in extreme conditions. This predominance of the genus Microcystis could also be explained by the strategies it develops to avoid being targeted by grazers such as zooplankton and phytophagous fish and also by the release of toxins (microcystins) to defend itself against herbivores and parasites, competitors who compete for the same resources [26].

5. Conclusion

At the end of this work, it appears that the Aghien lagoon contains several genera of Cyanobacteria with a spatio-dependent distribution. In addition, the genus *Microcystis*, potentially producing secondary metabolites, is the most widespread genus in this Lagoon.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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