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Study of Water Quality of the Ebrié Lagoon and Proposal of Toxin Structures in Relation to Algal Efflorescences

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this work is to know the interrelationships of the physicochemical parameters likely to explain algal blooms and to identify the potential structures of molecules that can be secreted in an Ivorian lagoon environment: the Ebrié lagoon.
Methodology: Nine stations, selected according to natural influences and anthropogenic pressure, were subject to physicochemical monitoring. It consisted of in *situ* measurements (temperature, salinity, dissolved oxygen, electrical conductivity) and chemical analyses in the laboratory (pH, nitrates, nitrites). In addition to these measurements, observations were noted in the field, namely the climatology of the day, the colour and smell of the water, the presence of algae (micro and / or macroalgae).

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Results: Our results showed that the waters of the Ebrié lagoon are warm (T > 25 °C), with a pH between 6 and 9 and variable salinity. Salinity would be a discriminating factor for the presence of macroalgae. The nutrients levels (nitrates and nitrites) remain within the limits of acceptability.
Conclusion: The waters in our study area are favorable for algal blooms. Given the nuisances associated with algal blooms, the study proposes some structures of toxins which can be secreted on the basis of a literature review.

Keywords: Algal bloom; physicochemical characteristics; phycotoxins; cyanotoxins; water pollution.

1. INTRODUCTION

The marine and lagoon environments of the Atlantic coast of the Gulf of Guinea are under the yoke of anthropogenic pressures (urbanization, industry, agriculture, aquaculture, tourism, etc.). These uncontrolled anthropogenic inputs cause chemical, biological and hydrological imbalances in these ecosystems. Indeed, because of domestic, urban, industrial discharges and infiltrations from intense agricultural activities that use phytosanitary and fertilizers, the future of these environments is compromised [1]. This state leads to harmful natural phenomena such as algae blooms.

Naturally present in the aquatic environment without any problems being associated with it, algae (halogen and /or exogenous species) are very sensitive to their environment. Thus, under the appropriate environmental conditions (pH, luminosity, salinity, temperature, etc.), they will grow rapidly and form efflorescences, mostly of a harmful nature [2,3].

Depending on the species in question, a distinction is made between nuisances caused by non-toxic species and those caused by toxic species [4]. The species in this second group are the most dangerous and contribute to 48% of nuisances [5,6]. Indeed, these species have the capacity to produce toxins that can lead to mass mortalities of aquatic animals and present health risks for the consumer, because they can be bioaccumulated by living aquatic organisms.

Among the algal flora of the lagoon waters of the Gulf of Guinea, particularly that of Côte d'Ivoire, we find cyanobacteria (genera *Microsystis, Anabaena, Planktothrix),* diatoms (genus *Nitzschia)* and dinoflagellates (genera *Dinophysis* and *Gymnodinium)* which are listed as pests [7-9]. Harmful algal blooms (HABs) are known to produce a variety of toxins of varying effect on aquatic biota and human health, including fish kills, respiratory distress and neurological disorders [10]. Although toxin production is linked to blooms, many toxins are known to persist in the water column, sediments, or associated biota after the generative bloom has passed.

Their presence in Ivorian lagoon environments constitutes a real risk to human and environmental health. The recurrence of algae blooms being proven in coastal countries and in the face of climate change, it is important to know the environmental factors likely to explain these phenomena and the associated toxins that can generate nuisances for fauna, flora and man.

In this work, we have been interested in some standard and limiting physicochemical parameters that could allow us to explain the development of algae and to identify the probable molecular structures that could be secreted on the basis of a literature review, in a coastal lagoon environment of the Gulf of Guinea, the Ebrié lagoon.

2. MATERIALS AND METHODS

2.1 Study Area

The Ebrie Lagoon is a semi-enclosed paralic ecosystem, located on the Atlantic coast of Côte d'Ivoire. The area of its water body is estimated at 566 km² and its average depth is about 4-8 m [11]. Our study area can be divided into two sectors depending on the location of the sampling points and the cities crossed (Fig. 1 and Table 1). Sector 1 is located between the town of Grand - Bassam and the village of Azuretti. Sector 2 are located on the estuarian bays of the city of Abidjan. The city of Grand-Bassam is in extension and the city of Abidjan is an area of economic interest because of the industrial, tourist and port activities that take place there.

2.2 Sample Collection

The samples were collected from various stations covering the study area from July of the year 2019 to September of the year 2020. Sample were collected into a precleaned polyethylene bottles of one liter capacity with utmost care to avoid any kind of contamination and were brought to laboratory for the estimation of various physicochemical parameters. In each campaign, we noted the climatology of the day, the smell and color of the water, the presence of macroalgae.

2.3 Physicochemical Measurements

In situ measurements of electrical conductivity, salinity, temperature, etc. were carried out using the WTW 3430 multiparameter equipped with an electrochemical probe. In the laboratory, the nitrates and nitrites were determined respectively according to the cadmium reduction and diazotization method, using the HACH DR 6000 spectrophotometer. Specific reagents were used and the instruments were calibrated by known standards before the measurements and analysis.

3. RESULTS AND DISCUSSION

The results of the physicochemical parameters obtained are presented in Tables 2 and 3. It was established from the mean values of the various parameters studied. Observations at the different stations are presented in Tables 4 and 5. Macroalgae were noted at a few stations, with blackish colored waters and a strong odor. We also observed strongly colored waters (khaki, greenish), a sign of algal proliferation.

3.1 Temperature

Water temperatures range from a minimum of 26.57°C to a maximum of 29.80°C. Temperature varies little from one station to another, resulting a relative thermal homogeneity (Table 2, Fig. 2). The coefficient of variation was of the order of 3.36% in 2019 and 1.20% in 2020. Almost all the water samples are warm with temperatures above 25 °C. High temperature stimulates the metabolic activities of phytoplankton such as: enzyme activity, photosynthesis, respiration, nutrient adsorption and consequently growth [12]. The presence of algae on some stations confirms the work of Reynolds, 2006; which shows that the maximum growth rate of algae is reached at temperatures between 25°C and 35°C. These high temperatures could stimulate the proliferation of harmful microorganisms (bacteria and microalgae) that cause unpleasant odors [13].

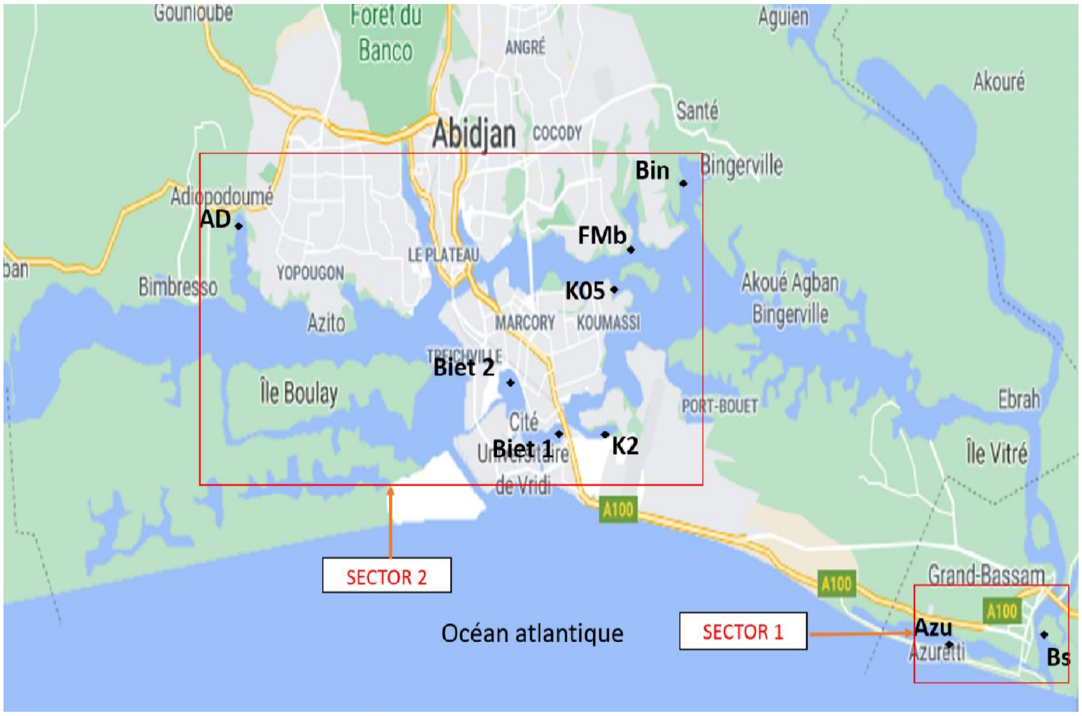


Fig. 1. Location of sampling points
(Source: Google Maps)

Table 1. Sampling stations and corresponding geographic coordinates

Sector	Station	Longitude	Latitude
Sector 1	Bs	5.197041	- 3.732280
	Azu	5.204771	- 3.777905
Sector 2	AD	5.334260	- 4.127184
	Biet 1	5.269287	- 3.963281
	K05	5.314723	- 3.940397
	FMb	5.331377	- 3.929883
	Bin	5.332161	- 3.804018
	K2	5.271352	- 3.960395
	Biet 2	5.288197	- 3.991899

**Bs= Bassam *Azu= Azuretti *AD= Adiapodoumé *Biet= Bietry *K= Koumassi *FMb= Front M'badon *Bin= Bingerville*

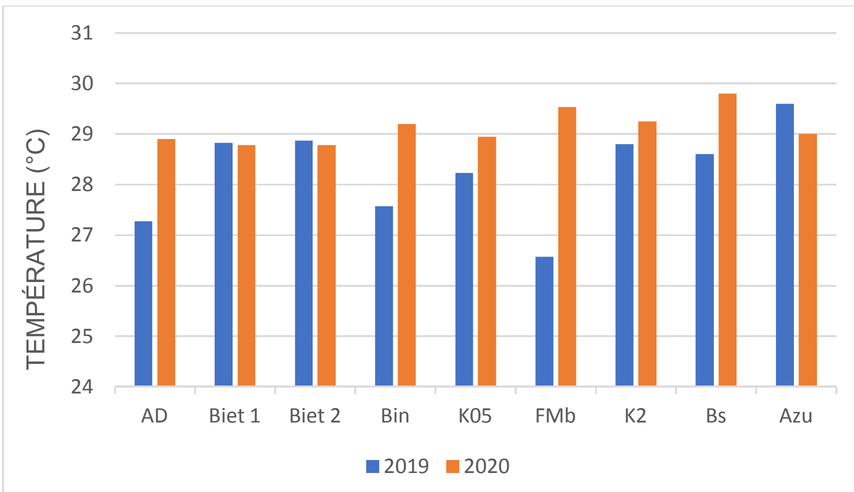


Fig. 2. Average water temperature of the Ebrié lagoon at each station

3.2 Salinity

A significant difference is observed for the stations AD, Biet 1, Biet 2, K05 and K2 for the average values of the two years of study. The coefficient of variation was 67.48% for the year 2019 and 72.93% for the year 2020. The spatial variation of salinity is heterogeneous, as evidenced by the coefficients of variation (Fig. 3, Table 2). The presence of macroalgae varies in intensity and frequency according to physicochemical conditions, mainly salinity values. This could explain the observations recorded in the field with the Bin, FMb stations, far from the communication with the ocean and the Bs station under the influence of the freshwaters. Indeed, the low salinities seem to be conducive to the development of macroalgae. This parameter appears to be a discriminating factor in our study.

3.3 Dissolved Oxygen

The AD station was well oxygenated, with the absence of macroalgae. There is oversaturation at Bin, FMb and K2 stations, with a peak of 8.55 mg / l in 2019 (Fig. 4). The main source of dissolved oxygen is photosynthesis. The allochthonous contributions of these regions with high demography, the strong sunshine during the sampling period and the high temperature of the water are factors that contribute to a strong photosynthetic activity, and therefore to the development of algae. Dissolved oxygen can be an indicator of algae growth. The low oxygen consumption by microorganisms and zooplankton may also explain our results [14]. The deoxygenation observed at Biet 1 and Biet 2 stations in 2020 is the result of intense bacterial activity, certainly favored by industrial and domestic water discharges during the study period [15].

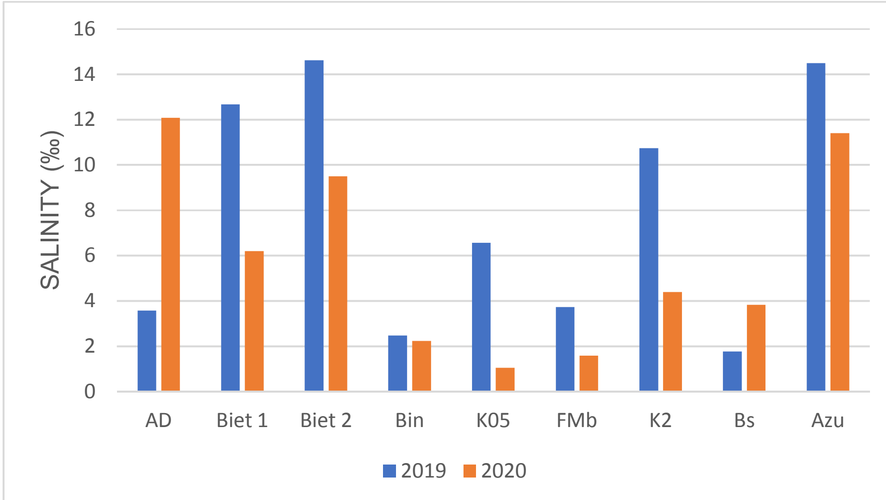


Fig. 3. Average salinity of the waters of the Ebrié lagoon at each station

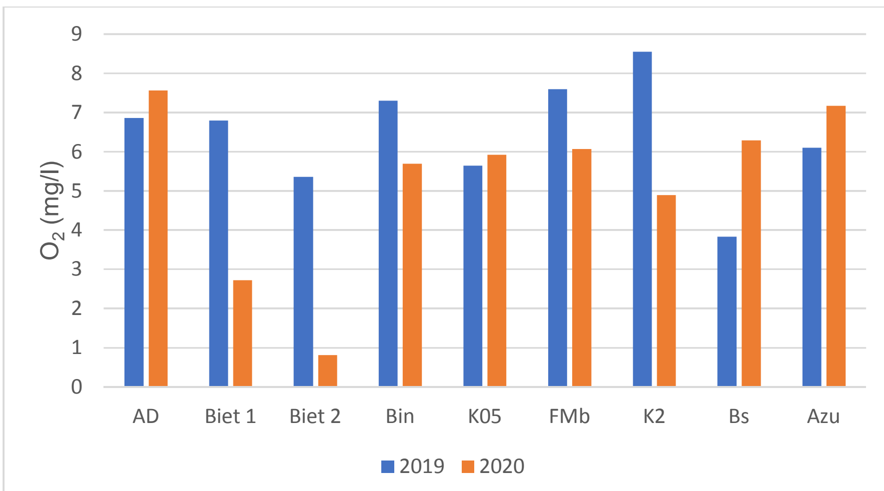


Fig. 4. Oxygen content of the waters of the Ebrié lagoon at each station

3.4 Electrical Conductivity

The average values of conductivity are high for all waters during the study period. It can demonstrate the influence of human activities via the intake of salts [16]. The enrichment of water bodies, by certain mineral salts, promotes the growth of certain groups of microalgae (identification not carried out) such as cyanobacteria, dinoflagellates, diatoms, Chlorophytes, and small autotrophic flagellates [17-19].

3.5 Hydrogen Potential pH

According to Fig. 6 and table 3, the pH values of all water samples were within the permissible limits prescribed by the WHO (6.5 - 8.5). It is a good indicator of the phases of biological activity and the intensity of photosynthetic activity. Surface waters (rivers, oceans, lagoons) absorb and store carbon dioxide released into the atmosphere by human activities. Following a biological process, part of the stored carbon is consumed by the plankton. A high pH is not always the cause of an intense primary activity, but rather of their persistence since the blooms would first deplete the dissolved inorganic carbon which in turn would generate the conditions where the proliferating species have an advantage [20,21].

3.6 Nitrogenous Nutrients

The nitrate concentration varies between 1.01 mg/l and 12 mg/l (Fig. 7A). The nitrite concentration fluctuates between 0.01 mg/l and 0.70 mg/l for the study period (Fig. 7B). Nitrogen is an essential nutrient for the life of plants and animals. In the aquatic environment, nitrates and nitrites are assimilated by algae and aquatic plants [22]. Algal blooms in our study would be favoured by inorganic nitrogen in the form of nitrates [23].

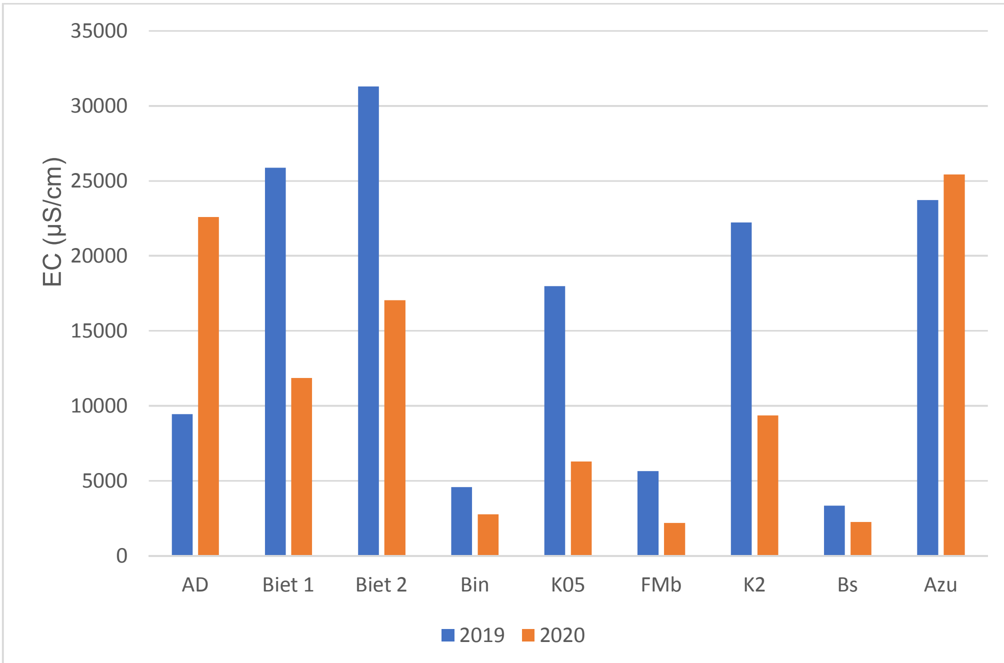


Fig. 5. Average electrical conductivity of the waters of the Ebrié lagoon at each station

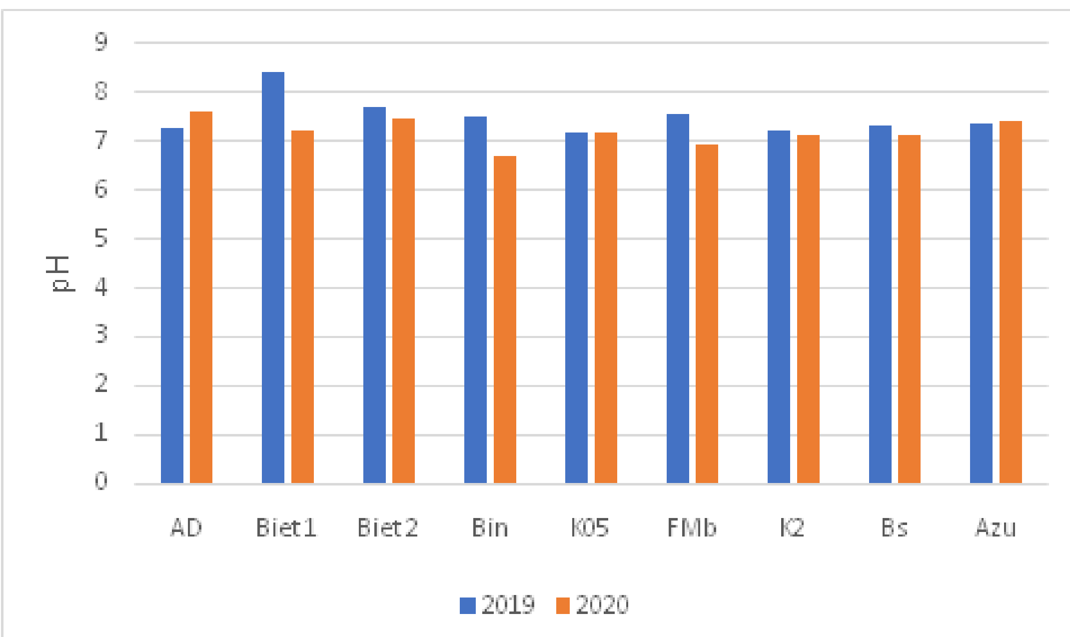


Fig. 6. Average pH of the water of the Ebrié lagoon at each station

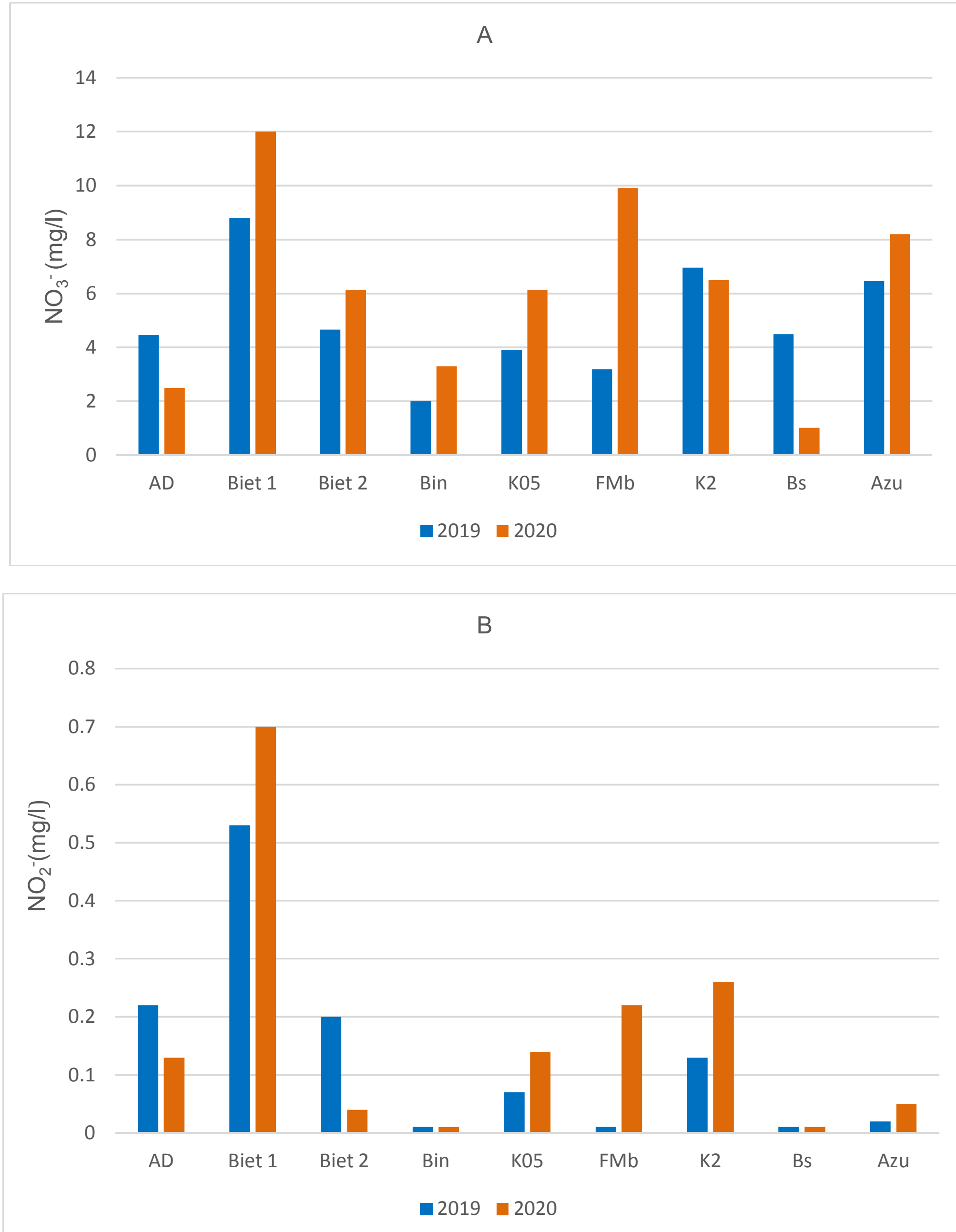
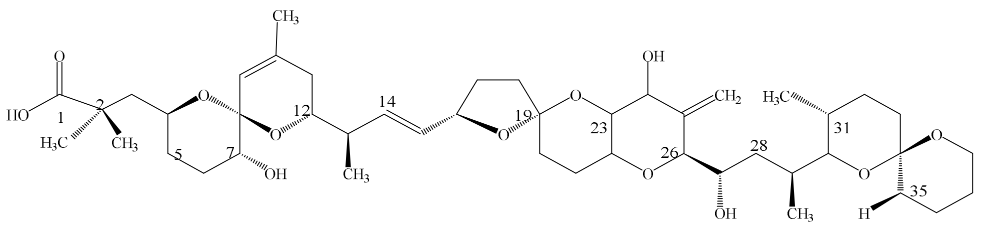
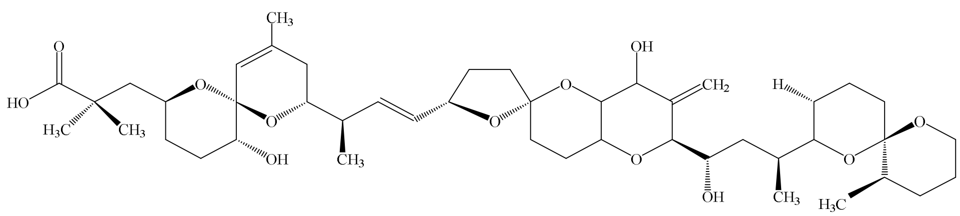


Fig. 7. Nitrate (A) and nitrite (B) concentrations in the waters of the Ebrié lagoon at each station

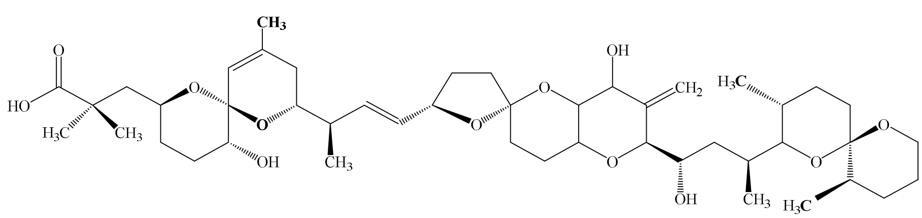
No hypothesis is able to individually explain the appearance of blooms and these hypotheses are not exclusive. The environmental conditions (physico-chemical and biochemical) certainly influenced our results. In addition, no parameter taken individually is capable of predicting the predominance of macroalgae and / or microalgae (identification of the genus and species not made) on certain sampling stations. In addition, no parameter, taken individually, is capable of predicting the dominance of macroalgae or microalgae (identification not made) on certain sampling stations. According to Kouassi and co-workers, Skullberg and co-workers, [24,25]. water rich in nutrients (NO_2^- = 0.052 mg/l and NO_3^- = 0.099 mg/l), a temperature between 15 °C and 30 °C, with a pH varying between 6 and 9 reflect a eutrophic environment. such a medium is favorable to a proliferation of microalgae, in particular cyanobacteria. Phytoplankton studies carried out on the lagoons of Côte d'Ivoire have identified the presence of harmful microalgae, in particular cyanobacteria, diatoms and dinoflagellates [7,26,27]. Particularly in the Ebrié lagoon, the work of Seu-Anoi identified some harmful microalgae. Mention may be made of the genera *Anabaena*, *Dinophysis*, *Gymnodinium*, *Nitzschia* and *Oscillatoria*. These genera can produce secondary metabolites such as phycotoxins and cyanotoxins. The structures of some phycotoxins and their analogues are shown in Figs. 8, 9, 10 and 11. They are all nitrogen molecules and polyethers [28-30]. They can cause massive mortalities of fish that have bioaccumulated them (case of fish dead from the red tide along the coasts of Florida, United States [31]. This toxic effect can even represent a threat to humans either indirectly in consuming the seafood caught, either directly by drinking contaminated water. For humans, the severity of the effects depends on the types of toxins, the amounts ingested and individual sensitivity. The characteristic symptoms are gastrointestinal. intestinal (nausea, abdominal pain, vomiting), neurological (muscular and respiratory paralysis), amnesic (reversal of hot/ cold thermal sensitivity) [30].



Use Name: Okadaïc acid
Synonym: 9,10-deepithio-9,10-didehydroacanthifolicin ; OA
IUPAC Name: (2R)-2-hydroxy-3-[(2R,6R,11R)-11-hydroxy-2-[(E,2R)-4-[(2'R,4R,6S)-4-hydroxy-2-[(1S,3S)-1-hydroxy-3-[(2S,3R,6S)-3-methyl-1,7-dioxaspiro[5.5]undecan-2-yl]butyl]-3-methylidenespiro[4a,7,8,8a-tetrahydro-4H-pyrano[3,2-b]pyran-6,5'-oxolane]-2'-yl]but-3-en-2-yl]-4-methyl-1,7-dioxaspiro[5.5]undec-4-en-8-yl]-2-methylpropanoic acid



Use Name: Dinophysistoxin-2
Synonym: 9,10-deepithio-9,10-didehydro-31-demethyl-35-methyl-acanthifolicin ; DTX-2
IUPAC Name: (2R)-3-[(2S,6R,8S,11R)-2-[(E,2R)-4-[(2S,2'R,4R,4aS,6R,8aR)-4-hydroxy-2-[(1S,3S)-1-hydroxy-3-[(2S,6R,11R)-11-methyl-1,7-dioxaspiro[5.5]undecan-2-yl]butyl]-3-methylidenespiro[4a,7,8,8a-tetrahydro-4H-pyrano[3,2-b]pyran-6,5'-oxolane]-2'-yl]but-3-en-2-yl]-11-hydroxy-4-methyl-1,7-dioxaspiro[5.5]undec-4-en-8-yl]-2-hydroxy-2-methylpropanoic acid



Use Name: Dinophysistoxin-1
Synonym: 35-methylokadaic acid ; DTX-1
IUPAC Name: 3-[2-[(E)-4-[2-[3-(3,11-dimethyl-1,7-dioxaspiro[5.5]undecan-2-yl)-1-hydroxybutyl]-4-hydroxy-3-methylidenespiro[4a,7,8,8a-tetrahydro-4H-pyrano[3,2-b]pyran-6,5'-oxolane]-2'-yl]but-3-en-2-yl]-11-hydroxy-4-methyl-1,7-dioxaspiro[5.5]undec-4-en-8-yl]-2-hydroxy-2-methylpropanoic acid

Fig. 8. Structures and names of phycotoxins belonging to group of Diarrhetic shellfish poisoning toxins

Table 2. Surface water temperature, salinity, dissolved oxygen, electrical conductivity at sampling stations in lagoon Ebrié 2019-2020 (in situ measurement)

Parameter	Year	AD	Biet 1	Biet 2	Bin	K05	FMb
T °C	2019	27.27±0.39	28.83±0.57	28.87±0.04	27.57±1.17	28.23±0.37	26.57±0.96
	2020	28.90±0.06	28.78±1.11	28.78±1.51	29.20±0.31	28.95±0.60	29.53±0.57
Salinity ‰	2019	3.57±2.88	12.67±3.22	14.63±2.08	**2.47±1.08**	6.57±0.31	3.74±0.58
	2020	12.07±1.18	6.20±0.82	9.50±1.42	**2.23±0.17**	**1.05±0.11**	**1.58±0.53**
O_2 mg/l	2019	**6.86±0.99**	**6.79±4.74**	**5.36±0.72**	**7.30±0.49**	**5.65±0.84**	**7.59±0.09**
	2020	**7.56±0.82**	2.72±0.49	0.81±0.06	**5.69±2.66**	**5.92±0.27**	**6.07±0.29**
EC µS/cm	2019	9 453.33±4502.22	25 866.67±6177.78	31 300.00±6666.67	4 580.00±1853.33	17 983.33±3988.99	5 653.33±571.11
	2020	22 590.67±1178.88	11 848.25±3392.44	17 030.75±1469.55	2 776.25±201.33	6 284.50±3910.88	2 193.00±150.00

Parameter	Year	K2	Bs	Azu	WHO
T °C	2019	28.80±0.46	28.60±0.53	29.60±1.2	
	2020	29.25±0.98	29.80±0.33	29.00±0.33	≤ 25
Salinity ‰	2019	10.73±2.51	**1.77±0.18**	14.5±0.10	
	2020	4.40±0.27	3.83±0.51	11.40±0.8	≤ 3.5
O_2 mg/l	2019	**8.55±3.35**	3.83±1.01	**6.10±0.23**	
	2020	4.89±0.27	**6.29±0.7**	**7.17±0.18**	≥ 5
EC µS/cm	2019	22 243.33±3604.44	3 363.33±288.89	23 733.33±577.77	
	2020	9 357.50±1075.55	2 265.33±302.88	25 426.33±1616.22	≤ 2000

Bolded values are those that are below the recommended limits by WHO (2004)

Table 3. Surface water pH and nutrient concentrations at sampling stations in lagoon Ebrié 2019-2020 (laboratory measurement)

Parameter	Year	AD	Biet 1	Biet 2	Bin	K05	FMb
pH	2019	**7.28±0.16**	**8.41±0.43**	**7.71±0.04**	**7.52±0.00**	**7.19±0.35**	**7.58±0.08**
	2020	**7.60±0.2**	**7.25±0.24**	**7.48±0.36**	**6.72±0.24**	**7.17±0.25**	**6.92±0.26**
NO_3^- mg/l	2019	**4.45±0.00**	**8.80±0.00**	**4.65±0.00**	**2.00±0.01**	**3.90±0.01**	**3.19±0.00**
	2020	**2.50±0.01**	**2.50±0.00**	**2.50±0.01**	**2.50±0.00**	**2.50±0.00**	**2.50±0.00**
NO_2^- mg/l	2019	0.22±0.00	0.53±0.00	0.20±0.00	**0.01±0.00**	**0.07±0.01**	**0.01±0.00**
	2020	**0.13±0.00**	0.70±0.00	**0.04±0.00**	**0.01±0.00**	**0.14±0.00**	0.22±0.00

Parameter	Year	K2	Bs	Azu	WHO
pH	2019	**7.21±0.38**	**7.31±0.02**	**7.37±0.47**	
	2020	**7.15±0.18**	**7.13±0.16**	**7.44±0.14**	**6.5 - 8.5**
NO_3^- mg/l	2019	**6.95±0.03**	**4.50±1.10**	**6.45±0.00**	
	2020	**2.50±0.00**	**2.50±0.00**	**2.50±0.00**	**≤ 50**
NO_2^- mg/l	2019	**0.13±0.00**	**0.01±0.00**	**0.02±0.00**	
	2020	0.26±0.00	**0.01±0.00**	**0.05±0.00**	**≤ 0.2**

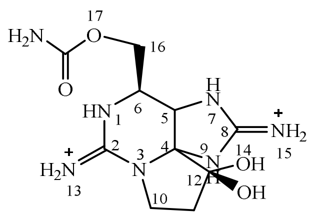
[*]Bolded values are those that are below the recommended limits by WHO (2004)

Table 4. Sampling conditions during the various campaigns carried out in 2019

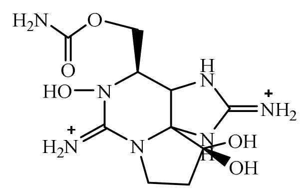
	July		August		September	
	Sector 1	**Sector 2**	**Sector 1**	**Sector 2**	**Sector 1**	**Sector 2**
Climatology of day	Sunny and dry	Sunny and dry	Overcast and rainy	Overcast and rainy	Overcast and rainy	Overcast and dry
Odour	Yes	Yes	Yes	Yes	Yes	Yes
Water color	Yes	Yes	Yes	Yes	Yes	Yes
Presence of macroalgae	Yes	-	Yes	-	Yes	-

Table 5. Sampling conditions during the various campaigns carried out in 2020

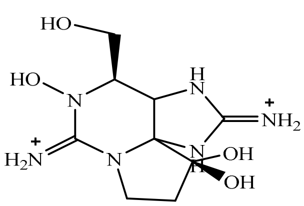
	June		July		August	
	Sector 1	**Sector 2**	**Sector 1**	**Sector 2**	**Sector 1**	**Sector 2**
Climatology of day	Sunny - Dry and rainy	Sunny - Dry and rainy	Sunny - Dry and rainy	Sunny - Dry and rainy	Rainy	Rainy
Odour	Yes	Yes	Yes	Yes	Yes	Yes
Water color	Yes	Yes	Yes	Yes	Yes	Yes
Presence of macroalgae	Yes	-	Yes	-	Yes	-



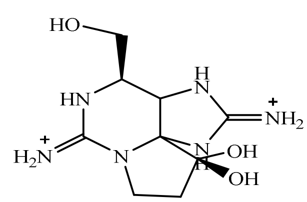
Use Name:Saxitoxin
Synonym: STX
IUPAC Name: [(3aS,4R,10aS)-2,6-diamino-10,10-dihydroxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methyl carbamate



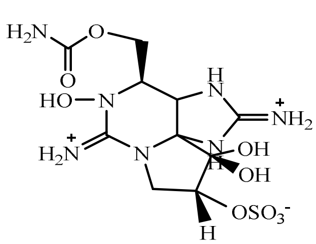
Use Name:Neosaxitoxin
Synonym: neoSTX
IUPAC Name: [(3aS,4R,10aS)-2,6-diamino-10,10-dihydroxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methyl carbamate



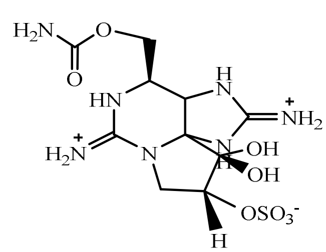
Use Name:Decarbamoylneosaxitoxin
Synonym: dcneoSTX
IUPAC Name: (3aS,4R,10aS)-2-amino-5-hydroxy-4-(hydroxymethyl)-6-imino-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purine-10,10-diol



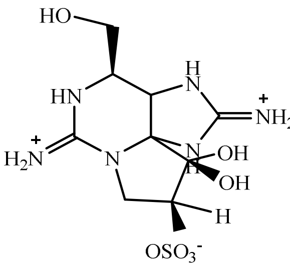
Use Name:Decarbamoylsaxitoxin
Synonym: dcSTX
IUPAC Name: (3aS,4R,10aS)-2,6-diamino-4-(hydroxymethyl)-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purine-10,10-diol



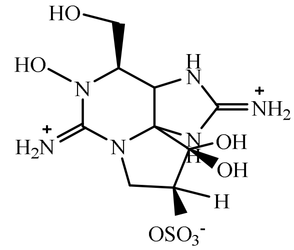
Use Name:Gonyautoxin-1
Synonym: GTX-1
IUPAC Name: [(3aS,4R,9R,10aS)-2,6-diamino-10,10-dihydroxy-5-oxido-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-5-ium-4-yl]methyl carbamate



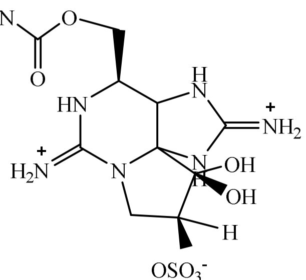
Use Name:Gonyautoxine-2
Synonym: GTX-2
IUPAC Name: [(10aS)-2,6-diamino-10,10-dihydroxy-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methyl carbamate



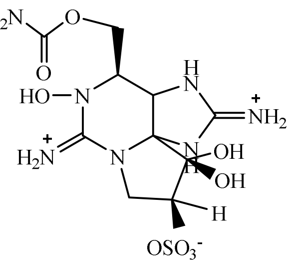
Use Name: decarbamoylgonyautoxin-3
Synonym: dcGTX-3
IUPAC Name:: [2,6-diamino-10,10-dihydroxy-4-(hydroxymethyl)-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-9-yl] hydrogen sulfate



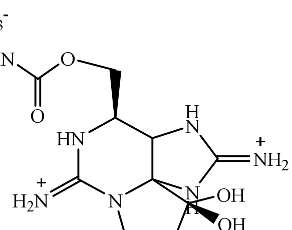
Use Name: decarbamoylgonyautoxin-4
Synonym: dcGTX-4
IUPAC Name:: [[(3aS,4R,9S,10aS)-2-amino-5,10,10-trihydroxy-4-(hydroxymethyl)-6-imino-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-9-yl] hydrogen sulfate



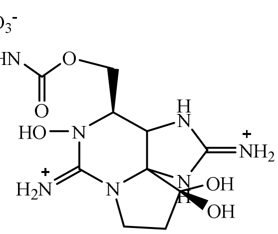
Use Name: gonyautoxin-3
Synonym: GTX-3
IUPAC Name:: [(3aS,4R,9S,10aS)-2,6-diamino-10,10-dihydroxy-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methyl carbamate



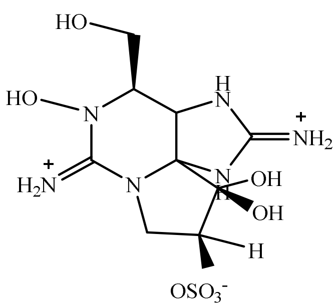
Use Name: gonyautoxin-4
Synonym: GTX-4
IUPAC Name:: [(3aS,4R,9S,10aS)-2,6-diamino-10,10-dihydroxy-5-oxido-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-5-ium-4-yl]methyl carbamate



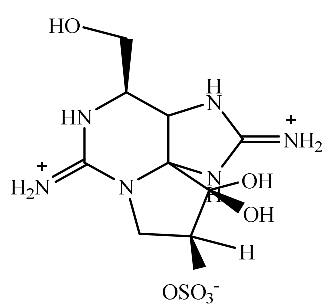
Use Name: gonyautoxin-5
Synonym: GTX-5
IUPAC Name:: [(3aS,4R,10aS)-2,6-diamino-10,10-dihydroxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methoxycarbonylsulfamic acid



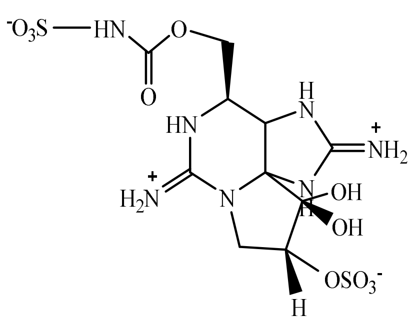
Use Name: gonyautoxin-6
Synonym: GTX-6
IUPAC Name:: [(3aS,4R,10aS)-2,6-diamino-10,10-dihydroxy-5-oxido-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-5-ium-4-yl] methoxycarbonylsulfamic acid



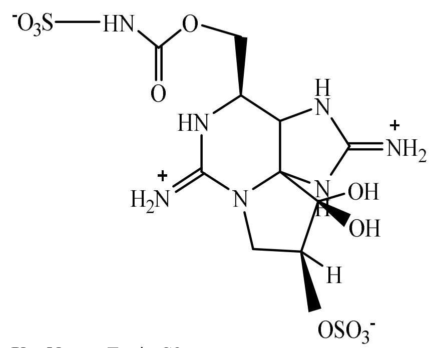
Use Name: Decarbamoylgonyautoxin-1
Synonym: dcGTX-1
IUPAC Name:: **[**(3aS,4R,10aS)-2-amino-5,10,10-trihydroxy-4-(hydroxymethyl)-6-imino-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-9-yl] hydrogen sulfate



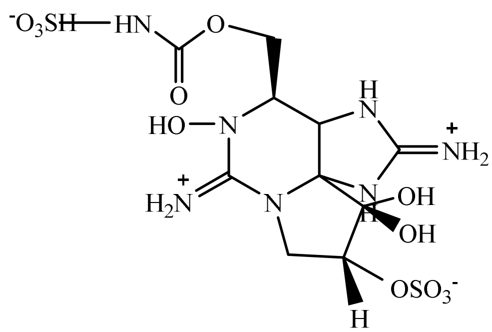
Use Name: Decarbamoylgonyautoxin-2
Synonym: dcGTX-é
IUPAC Name:: **:** [(3aS,4R,9R,10aS)-2,6-diamino-10,10-dihydroxy-4-(hydroxymethyl)-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-9-yl] hydrogen sulfate



Use Name: Toxin C1
Synonym: protogonyautoxin-1,
IUPAC Name:: (2,6-diamino-10,10-dihydroxy-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl) methoxycarbonylsulfamic acid

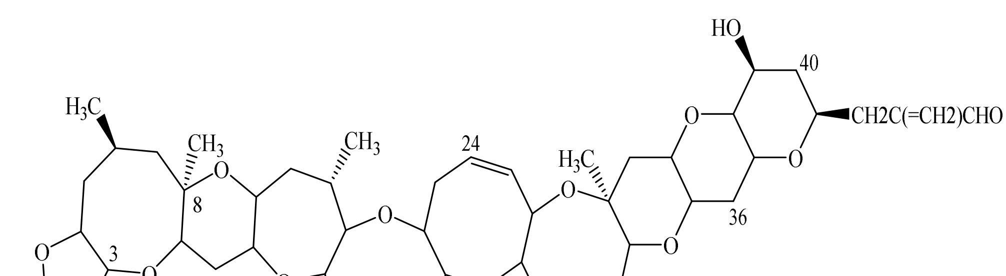


Use Name: Toxin C2
Synonym: protogonyautoxin-2
IUPAC Name:: [[(3aS,4R,9S,10aS)-2,6-diamino-10,10-dihydroxy-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-4-yl]methoxycarbonylsulfamic acid

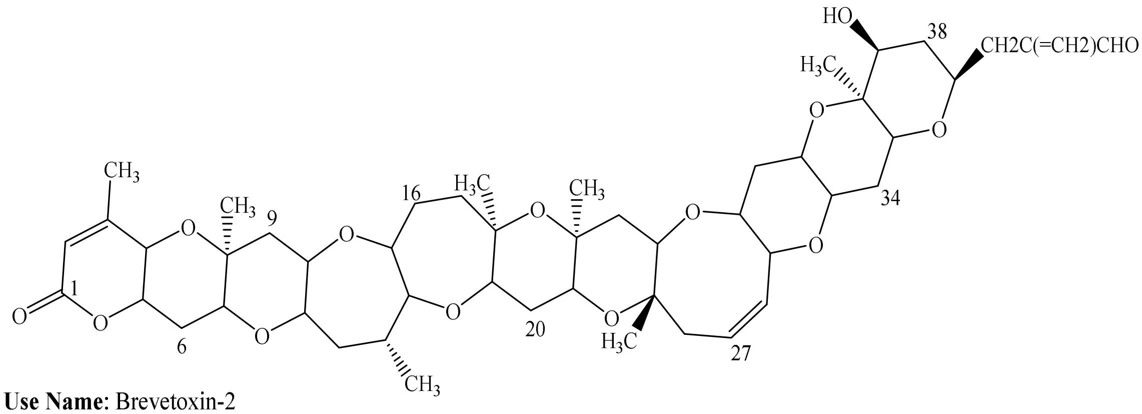


Use Name: Toxin C3
Synonym: protogonyautoxin-3; anaphylatoxin
IUPAC Name:: (2,6-diamino-10,10-dihydroxy-5-oxido-9-sulfooxy-3a,4,8,9-tetrahydro-1H-pyrrolo[1,2-c]purin-5-ium-4-yl) methoxycarbonylsulfamic acid

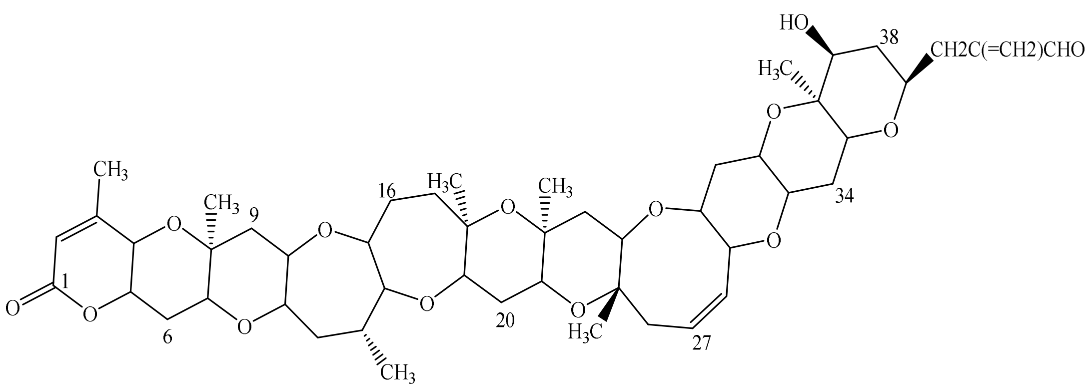
Fig. 9. Structures and names of phycotoxins belonging to group of Paralytic shellfish poisoning toxins



Use Name: Brevetoxin-1
Synonym: Brevetoxin A ; PbTX-1
IUPAC Name:: 2-[[(1S,3R,4S,6S,8R,10R,12S,16R,18S,20R,22S,24Z,27R,29S,33R,35S,37R,39R,41S,42S,44R,46S,48R,49Z)-41-hydroxy-4,8,10,46-tetramethyl-14-oxo-2,7,13,17,21,28,34,38,43,47 decaoxadecacyclo[25.24.0.03,22.06,20.08,18.012,16.029,48.033,46.035,44.037,42]henpentaconta-24,49-dien-39-yl]methyl]prop-2-enal

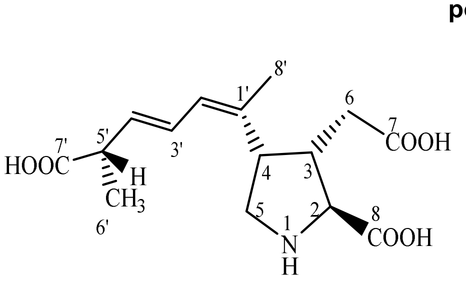


Use Name: Brevetoxin-2
Synonym: Brevetoxin B ; PbTX-2
IUPAC Name:: 2-[[(21Z)-12-hydroxy-1,3,11,24,31,41,44-heptamethyl-39-oxo-2,6,10,15,19,25,29,34,38,43,47-undecaoxaundecacyclo[26.22.0.03,26.05,24.07,20.09,18.011,16.030,48.033,46.035,44.037,42]pentaconta-21,40-dien-14-yl]methyl]prop-2-enal

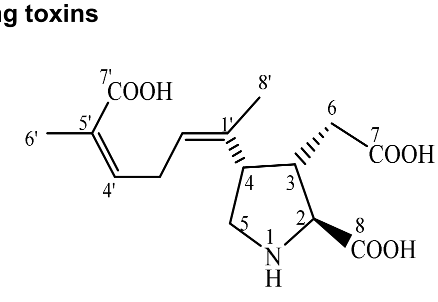


Use Name: Brevetoxin-3
Synonym: Dihydrobrevetoxin B ; PbTX-3
IUPAC Name:: (21Z)-12-hydroxy-14-[2-(hydroxymethyl)prop-2-enyl]-1,3,11,24,31,41,44-heptamethyl-2,6,10,15,19,25,29,34,38,43,47-undecaoxaundecacyclo[26.22.0.03,26.05,24.07,20.09,18.011,16.030,48.033,46.035,44.037,42]pentaconta-21,40-dien-39-one

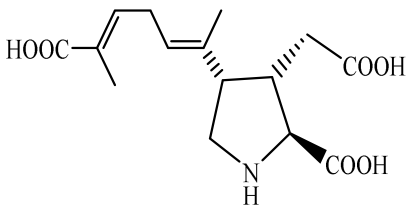
Fig. 10. Structures and names of phycotoxins belonging to group of Neurologic shellfish poisoning toxins



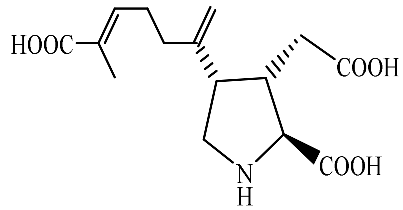
Use Name: Domoic acid
Synonym: 2-carboxy-4-((1Z,4E)5-carboxy-1-methyl-1,3-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2Z,4E,6R)-6-carboxyhepta-2,4-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



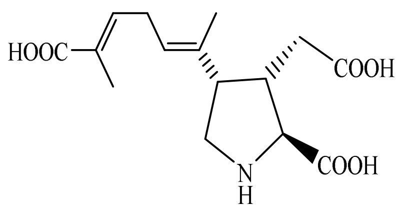
Use Name: Isodomoic acid A
Synonym: 2-carboxy-4-((1Z,4Z)-5-carboxy-1-methyl-1,4-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2Z,5E)-6-carboxyhepta-2,5-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



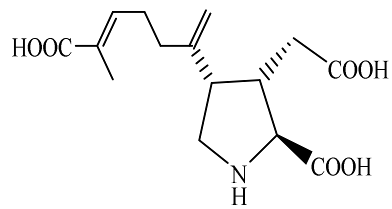
Use Name: Isodomoic acid B
Synonym: 2-carboxy-4-((1E,4E)-5-carboxy-1-methyl-1,4-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2E,5E)-6-carboxyhepta-2,5-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



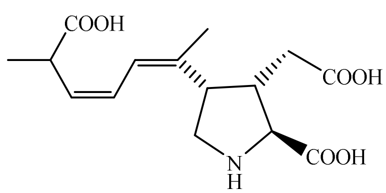
Use Name: Isodomoic acid C
Synonym: 2-carboxy-4-(5-carboxy-1-methylidene-4-hexenyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(5E)-6-carboxyhepta-1,5-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



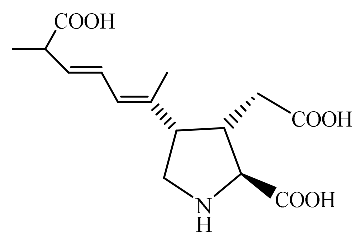
Use Name: Isodomoic acid B
Synonym: 2-carboxy-4-((1E,4E)-5-carboxy-1-methyl-1,4-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2E,5E)-6-carboxyhepta-2,5-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



Use Name: Isodomoic acid C
Synonym: 2-carboxy-4-(5-carboxy-1-methylidene-4-hexenyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(5E)-6-carboxyhepta-1,5-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



Use Name: Isodomoic acid D
Synonym: 2-carboxy-4-((1E,3E)-5-carboxy-1-methyl-1,3-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2Z,4Z,6R)-6-carboxyhepta-2,4-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid



Use Name: Isodomoic acid E
Synonym: 2-carboxy-4-((1E,4E)-5-carboxy-1-methyl-1,3-hexadienyl)-3-pyrrolidineacetic acid
IUPAC Name:: (2S,3S,4S)-4-[(2E,4E,6R)-6-carboxyhepta-2,4-dien-2-yl]-3-(carboxymethyl)pyrrolidine-2-carboxylic acid

Fig. 11. Structures and names of phycotoxins belonging to group of Amnesic shellfish poisoning toxins

4. CONCLUSION

The waters of the Ebrié lagoon are warm and alkaline. Some average values such as electrical conductivity and temperature exceed standards. Nitrogen nutrient concentrations are still within acceptability limits. In light of these results, we can suggest that our study area is conducive to the development of algae. The only parameter that could be discriminating is the salinity. For the other parameters retained in this study, they make it possible to explain the algal blooms (micro and / or macroalgae), although in the case of our study, no specific value can be set for the prediction of this phenomenon. The recurrence of algae blooms can present health risks to fauna, flora and humans. The review of the literature made it possible to identify some molecules associated with this phenomenon. These molecules are many and diverse. To better assess the health risks associated with algal blooms in Côte d'Ivoire, it would be interesting to identify and quantify phycotoxins in matrices such as aquatic organisms, marine and lagoon waters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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