Abiotic factors and the growth of cyanobacteria in surface water reservoirs in the state of Pernambuco

https://doi.org/10.56238/sevened2024.026-040

Andreia Souza Regis[1], Ronaldo Faustino da Silva[2], Fabio Henrique Portella Corrêa de Oliveira[3] and Eduardo José Alécio de Oliveira[4]

ABSTRACT

Objective: Analyze the relationship between physical-chemical and climatic abiotic factors in relation to the occurrence of cyanobacteria genera in surface water reservoirs used for public supply in the state of Pernambuco.

Literature Review: Information is presented on cyanobacteria and the consequences of the release of untreated effluents on the eutrophication of surface waters with effects on the growih of cyanobacteria and consequences for aquatic organisms and humans and the climate in regions of Pernambuco where water reservoirs are located,

Method: Quali-quantitative descriptive and exploratory approach to the analysis of abiotic variables (pH, CE., Turbidity, Color, Calcium, Magnesium, Chlorides, Sulfate, Nitrogen, Phosphate, Alkalinity, Hardness, Iron, Manganese, Aluminum and rainfall) and biotic (Cyanobacteria density), collected from the Pernambuco Sanitation Company — COMPESA. The samples were from eutrophic freshwater reservoirs in Pernambuco collected between 2010 and 2020.

Results and Discussion: The most frequent genus of cyanobacteria was Raphidiopsis/Cylindrospermopsis, found abundantly in all reservoirs, where the increase in color, turbidity and pH were positively correlated with the presence of Microcystis and Raphidiopsis/Cylindrospermopsis, and negatively with the increase in toughness. A positive correlation was also observed between hardness and the increase in Planktorhrix density.

Research Implications: Generate guidelines for drinking water supply presenting tools for understanding abiotic conditions that influence the growth of cyanobacteria, in order to outline control or services, ‘mitigation strategies in ETAs.

Originality/Value: Generate useful information in the evaluation of abiotic parameters and cyanobacteria density, observed over a long period (10 years), showing positive/negative correlations in surface waters used for human consumption.

Keywords: Phytoplankton, Limnology, Water quality, Dam.

[1] Companhia Pernambucana de Sancamento (COMPESA), Recife, Pernambuco, Brazil.
E-mail: andrearegis@com.br
ORCID: https://orcid.org/0000-0001-8473-4666
[2] Federal Institute of Education, Science and Technology of Pernambuco (IFPE), Recife, Pernambuco, Brazil.E-mail: ronaldofaustino@recife.ifpe.edu.br
ORCID: https://orcid.org/0000-0001-8097-9420
[3] Companhia Pernambucana de Sancamento (COMPESA), Recife, Pernambuco, Brazil.
E-mail: fabiohenrique(Qcompesa.com.br
ORCID: https://orcid.org/0000-0002-2337-3489
[4] Federal Institute of Education, Science and Technology of Pernambuco (IFPE), Recife, Pernambuco, Brazil.
E-mail: eduardoalecio@recife.ifpe.edu.br
ORCID: https://orcid.org/0000-0003-3081-3865

INTRODUCTION

Water, a finite and increasingly limited resource, has suffered increasing stress due to high demand, climate change and pollution (Li & Wu, 2024). Anthropogenic activities that play an role in the exaggerated proliferation of toxic cyanobacteria include the construction of dams, river diversions and deforestation (Igwaran et. al., 2024) and those caused by the discharge of domestic and industrial effluents (Memamalini er a/ ., 2017). High biomass of cyanobacteria in fresh waters occurs due to abiotic factors such as excessive amounts of nutrients, including phosphorus and nitrogen, high temperatures, light intensity, and low depth of water beds, associated with biotic factors (Vanderley er al ., 2021).

Effluents released without treatment or with deficient treatment have a high content of organic compounds and combined with the high temperatures in Brazilian territory. they encourage the proliferation of cyanobacteria in water reservoirs used for public supply. In high concentrations, cyanobacteria impart flavor and odor to water, and their presence in treatment systems leads to lower decantation efficiency and increased filter overload (Bittencourt- Oliveira & Molica , 2003). The situation is made worse by the potential of cyanobacteria to produce metabolites that are toxic to aquatic beings and humans, called cyanotoxins (Carmichael ez al ., 2001, Yuan & Yoon , 2021)

Reservoirs located close to large urban centers are generally more prone to eutrophication, constituting favorable ecosystems for the expansion of algal and cyanobacterial blooms. According to Paerl & Paul (2012), these environments are the most appropriate for the growth of cyanobacteria, which are normally found in neutral alkaline waters (pH of 6.0 to 9.0), at temperatures between 15°C and 30°C and with high concentrations of nutrients, particularly nitrogen and phosphorus. However, other factors, such as the volume of water in reservoirs and the availability of light (transparency and turbidity) in the water column, significantly influence the structure and dynamics of the cyanobacteria community and its toxins in an aquatic ecosystem (Santos Silva et. al. , 2020).

Thus, the present work focused on the frequent episodes of blooms that occurred in four surface water reservoirs used for public supply in the State of Pernambuco, using historical monitoring data from the Quality Control of the Companhia Pernambucana de Saneamento (COMPESA), and rainfall. from the Pernambuco Agronomic Institute (IPA, 2024), in order to enable a better understanding of the interactions between the cyanobacteria community and abiotic physical, chemical/physical-chemical water and rainfall climatic variables, enabling a better understanding of the precursor factors of blooms that can serve as a basis for preventive actions.

LITERATURE REVIEW

Cyanobacteria are oxygen-producing photosynthetic bacteria that account for much of aquatic productivity. However, some freshwater cyanobacteria can produce various toxins, potentially toxic to humans and other animals (Yuan & Yonn , 2021). The poisoning of wild animals, domestic animals and fish by cyanotoxins is a corcern during blooms, and the toxins may be neurotoxic , hepatotoxic or paralyzing shellfish. The most emblematic human case occurred in Brazil, in the city of Caruaru-PE in 1996, when an outbreak of acute liver failure in a to hemodialysis center was reported in 116 patients, of whom 76 died, with 52 deaths attributed a syndrome known worldwide as "Caruaru Syndrome". Subsequent phytoplankton samples from the city's water supply reservoir demonstrated that toxigenic cyanobacteria were the main phytoplankton group , representing 99% of the total phytoplankton density (Carmichael er al ., 2001; Azevedo et al , 2002).

The production of cyanotoxins by cyanobacteria is affected by changes in abiotic factors, such as nutrients, light and water temperature (Ferrandes ef al. , 2009; Vanderley er al .. 2021). Although in some conditions the number of cyanobacteria is considered safe, there may be potentially toxic blooms, whose scientific gap needs to be filled, with the understanding of what are the "triggers" that can lead to the producticn of cyanotoxins , as well as the indication of which conditions environmental conditions are the most conducive to blooms in reservoirs. According to Glibert & Burkholder (2011), many potentially toxic blooms are associated with increased eutrophication. However, not all species respond equally to changes in to the environment. This is the great challenge to actually determine which blooms are related eutrophication, and to try to understand why some species proliferate under specific nutrient conditions and abiotic variables.

According to Vanderley er al . (2021) the drivers of persistent blooms are less understood when conditions such as light, temperature and nutrients favor year-round cyanobacteria growth, especially in regions with recurring periods of drought. Reports from the Minas Gerais Sanitation Company (COPASA) showed toxic and non-toxic blooms between 2005 and 2012, with a predominance of toxic strains fron: October 2005 onwards (Jardim ez al, 2014).

Regarding climatic conditions, the state of Pernambuco is located in the Intertropical Zone, with a predominance of high temperatures whose climate varies due to the interference of the relief and air masses. Three major rainfall regimes are observed depending on the region. In Zona da Mata and the Metropolitan Region of Recife, where the cities of Lagoa do Carro and São Lourengo da Mata are located, respectively, the autumn-winter rainy season (February to July) is predominant, with periods of drought and marked maritime influence. ; In the Agreste region, where the cities of Belo Jardim and Garanhuns are located, climates and precipitation can be seen that vary depending on the relief; and, in the Sertao, there is a shortage of rainfall, which is concentrated in a short period of three months, from January to March (Lucena, 2023).

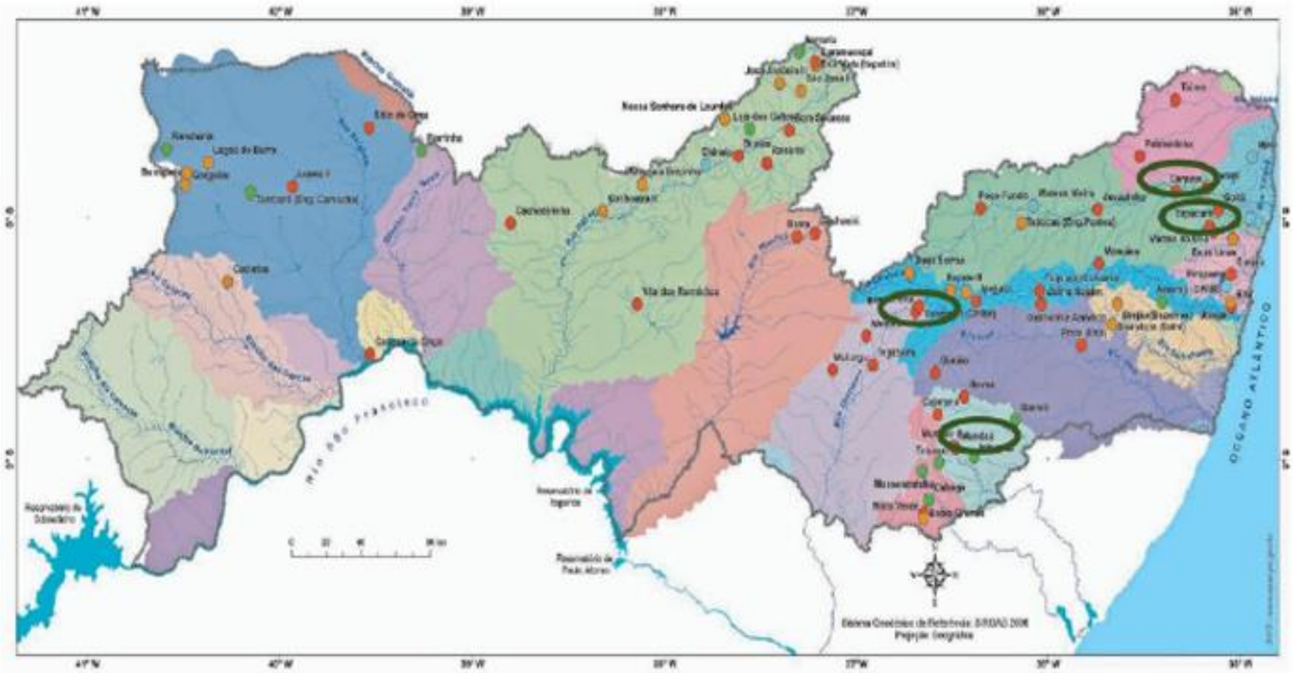
METHODOLOGY

This is a quali -quantitative, descriptive and exploratory approach with the analysis of data on abiotic variables (pH, Electrical conductivity, Turbidity, Color, Calcium, Magnesium, Chlorides, Sulfate, Nitrogen, Phosphate, Alkalinity, Hardness, Iron, Manganese , Aluminum and rainfall indices) and biotics (Cyanobacteria density). The physical-chemical parameters were collected from the Treatment and Laboratories Coordination of the Sanitation Company of the State of Pernambuco — COMPESA and the rainfall indices from the Pernambuco Agronomic Institute - IPA (2024).

STUDY AREA

Eutrophic freshwater reservoirs in the state of Pernambuco (Northeastern Brazil). The reservoirs have a history of cyanobacteria above 10,000 cells / mL , with genera potentially producing eyanotoxins . The reservoirs studied were: Tapacurá Dam , São Lourenço da Mata (8°3121"S 35°11'14"W, Capibaribe River basin, volume of 104,871 10 *m*) , Carpina Dam, Lagoa do Carro (7 °53'28"S 35°21'45"W, Capibaribe River basin, volume 270,000 10 * m *), Mundaú Dam, Garanhuns (8°58'59"S 36°28'27"W, Rio basin Mundaú, volume 19.283 10 *m *) and Pedro Moura Júnior Dam, Belo Jardim (8º20'43.6"S 36º22'29.2"W, Ipojuca River basin , volume 29.336 10 m?) (APAC. 2020).

Figure 1 Map of the state of Pernambuco with the area of the Tapacurá , Carpina, Pedro Moura Júnior and Mundaú reservoirs circled in green.



PHYSICAL. CHEMICAL AND BIOLOGICAL VARIABLES EVALUATED

Monitoring was carried out by COMPESA followiag the Sampling Plan based on the legislation then in force, Consolidation Ordinance n. 05, Annex XX, of the Ministry of Health

(BRASIL, 2017), updated by Ordinance No. 888/2021 (BRASIL, 2021). The historical period defined was 10 years, being correlated with periods of scasonality, as well as the identification of the main genera of cyanobacteria potentially producing cyanotoxins . The parameters analyzed in this study are listed in Table 1.

Physicochemical analyzes as well as the identification of the main genera of cyanobacteria potentially producing cyanotoxins were cerried out at COMPESA's Central Laboratory. The parameters analyzed were alkalinity. aluminum, calcium, chlorides, electrical conductivity, color, hardness. iron, total phosphorus, magaesium, manganese. total nitrogen. PH, sulfate, turbidity, identification and cyanobacteria count. All parameters were analyzed according to the APHA normative reference.

STATISTICAL TREATMENT OF RESULTS

The data were checked for ourliers and each situation was analyzed individually, as they could reflect measurement errors, as well as being incicative of a characteristic of the population analyzed. The caleulation of the Relative Abundance of cyanobacteria was adapted from Lobo & Leighton (1986), and the genera of cyanobacteria fell into the following categories: dominant (density of cyanobacteria >50% of the total density of the samples) and abundant (density greater than the average density, depending on the total number of cyanobacteria present in the sample). The normality of the variables was checked using the Shapiro Wilk test performed in R software (version 4.0.2). Generalized Linear Model (GLM) analysis, a non-parametric test of Multiple Linear Regression, was used to point out the joint correlation between abiotic variables in relation to cyanobacteria density. The correlation is established based on the coefficients generated for each variable. The correlation is significant when $P < 0.05$. Multivariate analyzes were performed to verify the influence of abiotic variables on cyanobacterial genera. For this, matrices of biotic and abiotic variables were constructed. A biotic matrix was constructed with cyanobacteria density data. Only genera that represented at least 5% of the total density in relation to the total density of cyanobacteria in each reservoir were considered. Biotic variables were log (x+1) transformed and all abiotic data were standardized using the range funcrion of the R software (version 4.0.2). The influence of abiotic variables on cyanobacteria densities was determined using redundancy analysis (RDA). This assay was chosen due to the smaller distribution of these data, calculated from the axis length provided by detrended correspondence analysis (DCA). In DCA, the various data from multiple variables are ordered, aiming to reduce the dimensionality of the data and analyze which are the main genera involved with the abiotic variables. Redundancy analysis (RDA) is the canonical form of principal component analysis (PCA), which selects the linear combination of environmental variables that gives the smallest sum of the total residuals from fitting table data to cyanobacterial genera. The ordistep function was used to select the variables, except those that presented inflation values greater than 20%, to avoid collinearity between the variables. All statistical analyzes were performed using R software (version 4.0.2, vegan package).

RESULTS AND DISCUSSIONS

The reservoirs have a history of potentially toxic with concentrations higher than the "trigger" (20,000 cells/ mL) determined for weekly monitoring of cyanobacteria counts and cyanotoxin analysis , as established in Ordinance No. 888/2021 (Brasil, 2021). Table 1 presents the average results and standard deviations for each parameter analyzed from 2010 to 2020. The results in Figures 2 a, b , c and c relate the period in which the samples were collected, with the rainfall index and cyanobacteria density.

Tapacurá , Pedro Moura Jinior and Mundaú reservoirs showed peaks in cyanobacteria density (cel / mL) during periods of low rainfall for most of the monitored period. According to Chaves eral. (2013) and Brasil et. al. (2016), tropical ecosystems can be eutrophicated during the dry period, due to the concentration of organic matter, favoring the bloom of cyanobacteria. There are still studies that state that periods of greater rainfall have increased the bloom of results cyanobacteria and the concentration of nutrients due to the mixing process, causing the re- suspension of these nutrients (Meng et al. , 2016; Zhou et a!. , 2016). These studies corroborate the found in the Carpina reservoir, whose results fluctuated, presenting peaks of cyanobacteria in some periods of greater rainfall.

Other studies carried out in this same reservoir also confirmed the increase in counts associated with high rainfall (Oliveira ez al. , 2015; eral.,2012). Teixeirade Oliveira et. al. , 2011 and Dantas et al., 2012).

Figure 3 shows the classification according to the calculation of the Relative Abundance of cyanobacteria, according to the classification proposed by Lobo & Leighton (1986). It was observed that no genus was dominant, while the genera Raphidiopsis / Cylindrospermopsis . Planktothrix and Microcystis were abundant in at least one of the reservoirs analyzed. Raphidiopsis / Cylindrospermopsis was abundant in all ecosystems, while Planktothrix was abundant in the Pedro Moura Júnior and Carpina reservoirs, and the genus Microcystis abundant in Tapacura and Munda,

According to Vieira et al. (2020) the presence of :he genus Cylindrospermopsis in a reservoir in the semiarid region of Ceará was abundant during the monitoring period, occurring throughout the sampled period and present at all study points. Cyiindrospermopsis and Planktothrix were also reported in a reservoir in Rio Grande do Norte (Oliveira et. al. , 2019). Tn the state of Paraiba Vasconcelos et. al. (2011) observed the frequency of the genera Cylindrospermopsis , Planktothrix and Microcystis in reservoirs, while Vanderley eral . (2021), evaluating abiotic factors in reservoirs in the semi-arid region of northeastern Brazil, also found Microcystis as abundant and dominant genera and Raphidiopsis.

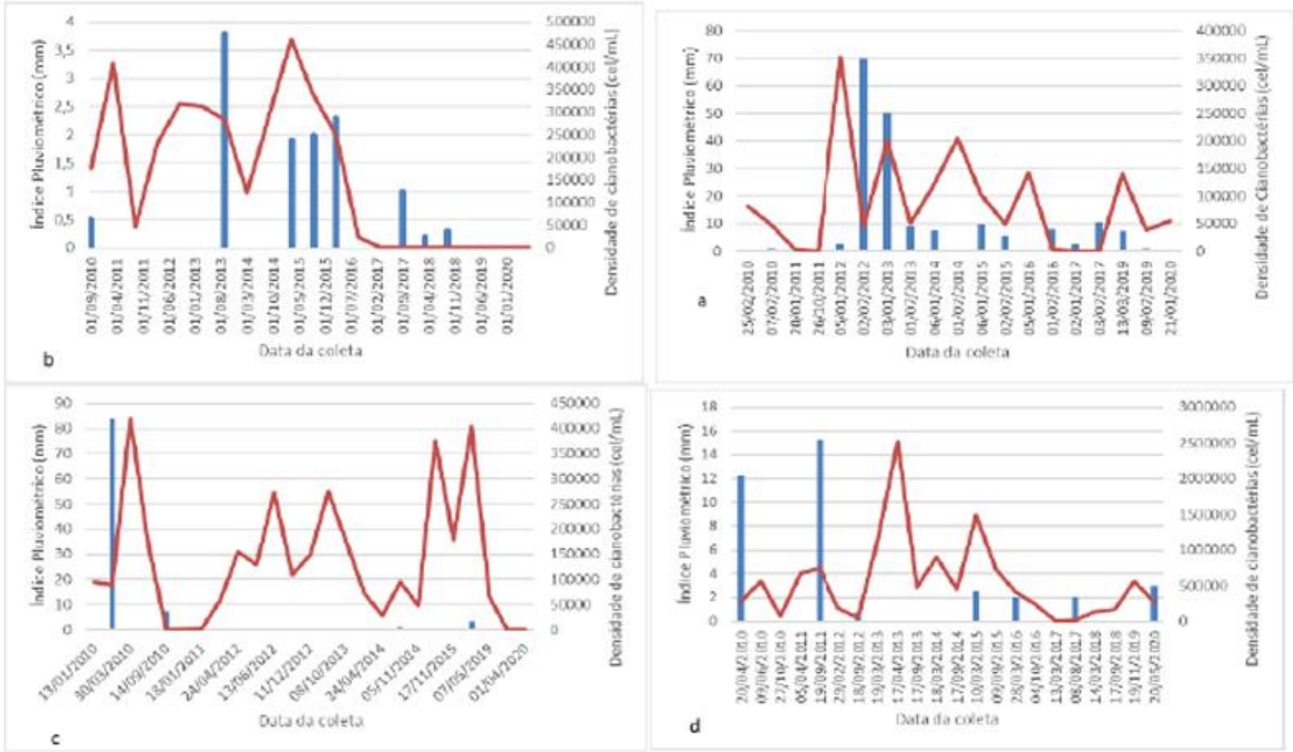
Table 1 biotic and biotic parameters of the Tapacurá , Pedro Moura Jinior, Carpina and Mundai reservoirs, in Pernambuco monitored from 2010 to 2020.

Reservoir	pH	CE	UT	Color (Hz)	Here (mg/L)	mg (mg/L)	CL (mg/L)	OS_4 (mg/L)	N Total (mg/L)	OP_4 (mg/L)	Alkaline . (mg/L)	Toughness (mg/L)	Faith (mg/L)	Mn (mg/L)	Al (mg/L)	IP	Cyanobacteria Density (cel / mL)
Tapacurá	**7.52**	**448**	**15**	**123**	**12**	**8**	**83**	**12**	**1.14**	**0.47**	**82**	**61**	**0.3**	**0.1**	**0.4**	**10**	**86188**
DP	0.35	65	11	69	3	two	15	10	1.12	0.25	13	12	0.3	0.0	0.3	18	88739
Pedro Moura Junior	**7.40**	**2086**	**9**	**112**	**62**	**93**	**714**	**42**	**1.75**	**0.13**	**114**	**536**	**0.6**	**0.6**	**0.4**	**4**	**134733**
DP	0.72	1637	8	68	44	81	639	51	2.23	0.10	105	430	0.6	1.2	0.6	16	123994
Carpina	**8.12**	**2124**	**9**	**116**	**29**	**83**	**715**	**47**	**1.61**	**0.24**	**204**	**415**	**0.2**	**0.2**	**0.4**	**1**	**114577**
DP	0.32	492	5	63	10	18	149	13	0.99	0.10	55	60	0.1	0.1	0.2	1	156690
Mundaú	**8.38**	**681**	**30**	**260**	**21**	**12**	**134**	**3**	**1.80**	**0.19**	**137**	**100**	**0.4**	**0.1**	**0.4**	**two**	**546233**
DP	0.71	96	15	119	5	3	45	6	1.42	0.10	34	23	0.6	0.0	0.7	4	567709

Source: The authors. EC= Electrical conducivity (uS/Cm at 20ºC); UT= Turbidity unit; Alkaline. =Alkalinity; IP= Average monthly rainfall (mm).

Cyanobacteria are potentially toxin producers, with some genera producing more than one type of toxin in a single bloom (EPA, 2024). The dominant genera identified, Raphidiopsis / Cylindrospermopsis . Planktothrix and Microcystis , are among the taxa producing diverse toxins. Rhaphidiopsis usually produces cylindrospermopsin whose primary toxic action oceurs in the liver and kidneys. It can also cause damage to DNA and bioaccumulate in invertebrate and vertebrate aquatic beings (EPA, 2024). The Microcysris genera and Planktothrix are associated with the production of neurotoxins such as anatoxin-a , capable of affecting the central nervous system by binding to neuronal receptors.

Figure 2 Cyanobacteria Density x Rainfall Index in reservoirs — a) Tapacurá ; b) Carpina; c) Pedro Moura Júnior and d) Mundaí. The red line indicates the rainfall index (mm) on the collection date and the blue column indicates the temporal variation m cyanobacteria density.



The genus Microcystis it is also potentially a producer of microcystins , the most common toxins, with microcystin -LR being hepatotoxic and the most studied form. Microcystins can be found intracellularly or dissolved in water and can bioaccumulate in invertebrates and vertebrates (EPA, 2024). It is worth mentioning that the most serious case of human poisoning with cyanotoxins occurred in the city of Caruaru-PE, where microcystins and eylindrospermopsin were found in the materials used to treat water used in hemodialysis (Azevedo et. al. , 2002).

The cyanobacteria cell count is a clear example of values that present a gap, that is, high standard deviation values (Table 1). However, they should not be excluded, as, taking into account the large possible variation in environmental analyses, it was decided to keep all data, since the outlier values found may be a reflection of the real situation of the environment. As expected, as these were environmental data, the distribution of some variables did not follow a normal distribution, therefore non-parametric tests of the variables were used.

After Generalized Linear Models (GLM) analysis, all abiotic variables showed a significant correlation with cyanobacteria density ($p < 0.05$) in all reservoirs studied. The abiotic variable Total Nitrogen showed an indirect correlation in all reservoirs. The influence of abiotic variables on the density of cyanobacterial genera is shown in the RDA present in Figure 4. The model generated explained 24.52% of the variation in the density of cyanobacterial genera involved in blooms in the studied reservoirs. Both axes were significant ($p < 0.05$) and explained 56.24% (axis 1) and 33.75% (axis 2) of the total percentage of the model.

Figure 3 Classification of the Relative Abundance of cyanobacteria in the Tapacurá , Pedro Moura Júnior, Carpina and Mundaú reservoirs in Pernambuco from 2010 to 2020.

Genres/Reservoirs	Tapacurá	Pedro Moura Junior	Carpina	Mundaú
Raphidiopsis / Cylindrospermopsis sp.	Abundant	Abundant	Abundant	Abundant
Planktothrix sp.	Rare	Abundant	Abundant	Rare
Geitlerinema sp.	Rara	Rara	Rara	Rara
Merismopedia sp.	Rara	Rara	Rara	Rara
Planktolyngbya sp.	Rara	Rara	Rara	Rara
Anabaenopsis sp.	Rara	Rara	Rara	Rara
Coelomoron sp.	Rara	Rara	Rara	Rara
Dolichospermum sp.	Rare	Rare	Rare	Rare
Microcystis sp.	Abundant	Rare	Rare	Abundant
Romeria sp.	Rare	Rare	Rare	Rare
Oscillatoria sp.	Rare	Rare	Rare	Rare
Radiocystis sp.	Rare	Rare	Rare	Rare
Aphanocapsa sp.	Rare	Rare	Rare	Rare
Pseudanabaena sp.	Rare	Rare	Rare	Rare
Cuspidothrix sp.	Rare	Rare	Rare	Rare
Chroococcus sp.	Rare	Rare	Rare	Rare
Sphaerospermopsis sp.	Rare	Rare	Rare	Rare

Source: The authors.

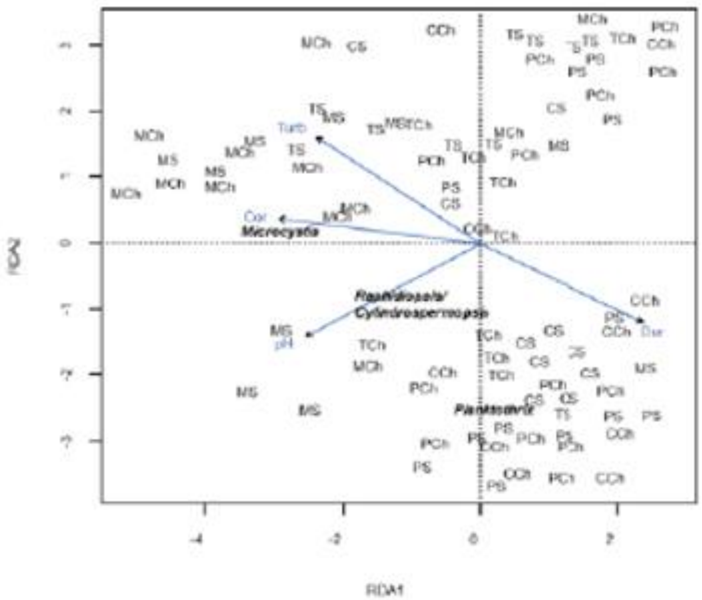
Axis 1 of the RDA separated the samples from the Mundaú reservoir, which were negatively correlated with the axis, while the other samples had a positive relationship. Although present on the positive side of axis 1, the samples from the Carpina reservoir were predominantly distributed on the negative side of axis 2, while the samples from Tapacurá and Pedro Moura Júnior were mostly plotted on the positive side of this. As for abiotic variables, 7). turbidity (-0.61) and PH (-0.65) were negatively associated with this axis. Analyzing the biotic variables, the density hardness (0.61) was positively associated with axis 1, while color (- of Microcystis (-2.61) and Raphidiopsis / Cylindrospermopsis (-1.18) are negativeiy related to axis 1, while Planktothrix densities (-2.41) were negatively related to axis 2.

Although no climate variable alone showed a significant correlation with the samples, it was possible to observe that sets were formed depending on seasonality. In this way, it was observed that higher values of color, turbidity and pH. and lower concentrations of hardness favored the growth of Microcystis and Raphidiopsis / Cylindrospermopsis . Laboratory studies (Patifio et. al. , 2023) showed that low concentrations of calcium stimulate the single-cell growth of Microcvstis aeruginosa , as well as the presence of magnesium, acting interactively. Growth Reducing Effects of Cylindrospermopsis raciborskii in high caleium concentration were reported by Carneiro et. al. (2011), which may partially corroborate the effect of hardness on metabolism. On the other hand, increasing hardness and pH favored the growth of Planktothrix.

It was observed that the Mundaú reservoir had flowerings characterized mainly by species of the genus Microcysris , while the Carpina reservoir had its flowerings characterized mainly by the genus Planktothrix . The Tapacurá and Pedro Moura Júnior reservoirs showed temporal alternation in the genera that make up the flowerings.

The pH in the reservoirs studied presented values ranging from neutral-alkaline to alkaline (Table 1), which is corroborated in several other studies (Moura et al ., 200 al,, 2014; Câmara ef al, 2015; Tardim ef al ., 2014), in studies of eutrophic reservoirs in the States of Pernambuco, Rio Grande do Norte and Minas Gerais. According to Esteves (2011), algae can interfere with the pH value through the assimilation of CO > because during the photosynthetic process they can raise the pH of the environment, especially where blooms oceur, which can justify pH values above neutrality.

Figure 4 Redundaney Analysis (RDA) diagram showing the variation in the density of cvanobacterial genera involved in blooms in relation to abiotic variables in the Carpina, Mundaú, Pedro Moura Júnior and Tapacurá reservoirs in the period from 2010 to 2020, in Pernambuco.



TS — Tapacurd Reservoir , dry period: TCh - Tapacurd Reservoir , ra.ny season ; MS - Mundaú Reservoir, dry period; MCh - Mundaú Reservoir, rainy season; PS - Pedro Moura Jinior Reservoir, dry period: PCh — Pedro Moura Túnior Reservoir, rainy season; CS - Carpina Reservoir, dry period: Dur = hardness: Turb = turbidity

Regarding turbidity, studies have shown a negative correlation of this variable with the density of cyanobacteria, possibly due to the interception of solar rays, compromising the photosynthetic process (Dantas et al ., 2012; Jardim er al ., 2014; Oliveira; Fonseca; Lopes, 2019; Santos Silva et. al. , 2020). However, the results of this work showed that the genus Microcvstis its growth was favored by murkier waters. Tkis behavior can be justified by the fact that representatives of this species have aerotopes in their cells, which allow them to move vertically in the water column. During periods of greater solar radiation, the species migrates the epilimnion of the reservoirs to carry out photosynthesis and this allows its growth. The excessive development of these organisms creates a shading effect in the reservoir, preventing solar rays from reaching the lower layers, where other genera of cyanobacteria are located. This competition did not show inhibition, however, of species of the genus Raphidiopsis / Cylindrospermopsis environments. In which, according to Reynolds er al (2002) tolerates low light this way, it could be inferred that the increase in turbidity does not directly favor the growth of Microcystis , but rather that the growth of these bacteria creates a condition that inhibits the growth of others (interspecific competition) and, as a result, their density increases. This same reasoning can be used to explain the effect of color on the growth of Microcysiis

The presence of divalent cations such as calcium and magnesium, measured by water The ‘hardness, participate in photosynthetic reactions and help in the aggregation of colony-forming species (CARNEIRO et. al., 2013). Calcium and magnesium also act on the balance between nitrogen and carbon in filamentous species. such as the genus Planktothrix (WALTER et al , 2016). results presented in the RDA (Figure 4) show a positive correlation between hardness and the increase in Planktothrix densitv , despite the vector showing greater representation on axis 1.

Although some studies indicate that phosphorus and nitrogen are the limiting nutrients for primary production, these were not significantly correlated with cyanobacteria density in this study, a similar result was also observed by Sonobe er al . (2019) when studying the growth of cyanobacteria in reservoirs in the state of São Paulo. It is known how important these elements are for the development and maintenance of cyanobacteria species in eutrophic environments , however, when the number of parameters is expanded, the weight of other variables is revealed, highlighting the importance of the synergistic action between the several biotic and abiotic variables for the ecology of cyanobacteria.

CONCLUSION

Data analysis allowed us to observe that the reservoirs studied presented, over a ten- year history, cyanobacteria density results above 20,000 cells / mL in the studied period from 2010 to 2020. The cyanobacteria most frequently identified in episodes with density above 20,000 cells , / mL belonged to the potentially foxigenic genus Raphidiopsis Cylindrospermopsis , which were found in all reservoirs in abundant condition. Abundance of Planktothrix and Microcystis , potentially toxigenic . were also observed in the Pedro Moura/Carpina and Tapacurá /Mundaú reservoirs , respectively, demonstrating the potential risk of abstracting water for treatment and human consumption. According to the Redundancy Analysis (RDA), itis possible to state that the increase in color, turbidity and pH were positively correlated with the presence of the genera Microcystis and Raphidiopsis / Cylindrospermopsis and negatively correlated with the increase in hardness; as well as a positive correlation was observed between hardness (caleium and magnesium) and the increase in density of the genus Planktothrix , even though the vector has a greater correlation with axis 1. The inhibition of growth (density) of many genera of cyanobacteria, observed by relative abundance, could not be attributed to the concentration of total phosphorus, even though it was present in high concentrations throughout the evaluated period, and was not even significantly correlated in the RDA analysis.

ACKNOWLEDEMENTS

To the Professional Master's program in Environmental Management at the Federal Institute of Education, Science and Technology of Pernambuco, Recife Campus and Companhia Pernambucana de Saneamento - COMPESA.

REFERENCES

1. Azevedo, M. F. O., Carmichael, W. W., Jochimsen, E. M., et al. (2002). Human intoxication by microcystins during renal dialysis treatment in Caruaru, Brazil. *Toxicology*, 181/182.

2. Bittencourt-Oliveira, M., & Molica, R. (2003). Cianobactéria invasora. *Revista Biotecnologia Ciência e Desenvolvimento*, (30).

3. Brasil, Ministério da Saúde. (2017). Anexo XX da Portaria de Consolidação GM/MS nº 5, de 28 de setembro de 2017.

4. Brasil, Ministério da Saúde, Gabinete do Ministro. (2021). Portaria nº 888, de 04 de maio de 2021.

5. Brasil, J., Attayde, J. L., Vasconcelos, F. R., et al. (2016). Drought-induced water-level reduction favors cyanobacteria blooms in tropical shallow lakes. *Hydrobiologia*, 770(1). https://doi.org/10.1007/s10750-015-2578-5

6. Câmara, F. R. A., Rocha, O., & Pessoa, E. K. R., et al. (2015). Alterações morfofuncionais da comunidade fitoplanctônica durante anomalia pluvial em um reservatório tropical. *Brazilian Journal of Biology*, 75(3). https://doi.org/10.1590/1519-6984.19513

7. Carmichael, W. W., Azevedo, S. M. F. O., An, J. S., Molica, R. J. R., et al. (2001). Human fatalities from cyanobacteria. *Chemical Perspectives*, 109(7).

8. Carneiro, R. L., Alípio, A. C. N., & Bisch, P. M. (2011). Evidence for cyanotoxins: The inhibitory effect of calcium on *Cylindrospermopsis raciborskii* (cyanobacteria) metabolism. *Brazilian Journal of Microbiology*, 42(4).

9. Chaves, F. L. B., Lima, P. F., Leitão, R. C., et al. (2013). Influence of rainfall on the trophic status of a Brazilian semiarid reservoir. *Acta Scientiarum - Biological Sciences*, 35(4). https://doi.org/10.4025/actascibiolsci.v35i4.18261

10. Dantas, E. W., Bittencourt-Oliveira, M. do C., & Moura, A. do N. (2012). Dynamics of phytoplankton associations in three reservoirs in northeastern Brazil assessed using Reynolds' theory. *Limnologica*, 42(1). https://doi.org/10.1016/j.limno.2011.09.002

11. EPA - United States Environmental Protection Agency. (2024). Species of cyanobacteria that produce. Retrieved from https://www.epa.gov/habs/learn-about-harmful-algae-cyanobacteria-and-cyanotoxins-overview

12. Esteves, F. A. (2011). *Fundamentos de limnologia* (3rd ed.). Interciência.

13. Fernandes, V. de O., Cavati, B., & de Oliveira, L. B., et al. (2009). Ecologia de cianobactérias: Fatores promotores e consequências das florações. *Oecologia Brasiliensis*, 13(2). https://doi.org/10.4257/0eco.2009.1302.03

14. Glibert, P. M., & Burkholder, J. A. M. (2011). Harmful algal blooms and eutrophication: Strategies for nutrient uptake and growth outside the Redfield comfort zone. *Chinese Journal of Oceanology and Limnology*, 29(4). https://doi.org/10.1007/s00343-011-0502-z

15. Hemamalini, J., Mudgal, B., & Sophia, I. D. (2017). Effects of domestic and industrial effluent discharges into the lake and their impact on the drinking water in Pandravedu village, Tamil Nadu, India. *Global NEST Journal*, 19(2).

16. Igwaran, A., Kayode, A. J., Moloantoa, K. M., et al. (2024). Cyanobacteria harmful algae blooms: Causes, impacts, and risk management. *Water, Air, Soil Pollution*, 235(71). https://doi.org/10.1007/s11270-023-06782-y

17. IPA. (2024). Sessão de índices pluviométricos. Recuperado de https://www.ipa.br/indice_pluv.php

18. Jardim, A., Sperling, E. V., & Jardim, B. F. M., et al. (2014). Fatores determinantes das florações. https://doi.org/10.1590/S1413-41522014019000001026

19. Lira, G., Moura, A., Vilar, M., et al. (2014). Vertical and temporal variation in phytoplankton assemblages correlated with environmental conditions in the Mundaú reservoir, semi-arid northeastern Brazil. *Brazilian Journal of Biology*, 74(3 Suppl 1). https://doi.org/10.1590/1519-6984.27612

20. Lobo, E., & Leighton, G. (1986). Estructuras comunitarias de la fitocenosis planctónicas de los sistemas de desembocaduras de ríos y esteros de la Zona Central de Chile. *Revista de Biología Marina*.

21. Lucena, R. T. L. (2023). Projeto de Lei do Plano Plurianual do Estado de Pernambuco - período 2024-2027. Recuperado de https://www.alepe.pe.gov.br/wp-content/uploads/2023/PL/PPA-2024-2027.pdf

22. Meng, P.-J., Tew, K. S., Hsieh, H.-L. Y., et al. (2017). Relationship between magnitude of phytoplankton blooms and rainfall in a hyper-eutrophic lagoon: A continuous monitoring approach. *Marine Pollution Bulletin*, 124(2). https://doi.org/10.1016/j.marpolbul.2016.12.040

23. Paerl, H. W., & Paul, V. J. (2012). Climate change: Links to global expansion of harmful cyanobacteria. *Water Research*, 46.

24. Patiño, R., Christensen, V. G., Graham, J. L., et al. (2023). Toxic algae in inland waters of conterminous United States. *Water*, 15(15). https://doi.org/10.3390/w15152808

25. Reynolds, C. S., Huszar, V., Kruk, C., et al. (2002). Towards a functional classification of the freshwater phytoplankton. *Journal of Plankton Research*, 24(5). https://doi.org/10.1093/plankt/24.5.417

26. Santos Silva, R. D., Severiano, I. S., Oliveira, D. A., et al. (2020). Spatio-temporal variation of cyanobacteria and cyanotoxins in public supply reservoirs of the semi-arid region of Brazil. *Journal of Limnology*, 79(1).

27. Sonobe, H. G., Lamparelli, M. C., Cunha, D. G. F. (2019). Spatial and temporal assessment of sanitary aspects of public water supply reservoirs in São Paulo, Brazil, with emphasis on cyanobacteria and cyanotoxins. *Engenharia Sanitária e Ambiental*, 24(5). https://doi.org/10.1590/S1413-41522019193351

28. Teixeira de Oliveira, M., Rocha, O., & Peret, A. (2011). Structure of the phytoplankton community in the Cachoeira Dourada reservoir (GO/MG), Brazil. *Brazilian Journal of Biology*, 71(3). https://doi.org/10.1590/1519-69842011000400003

29. Vanderley, R. F., Kemal, A. G., & Becker, V., et al. (2021). Abiotic factors driving cyanobacterial biomass and composition under perennial bloom conditions in tropical latitudes. *Hydrobiologia*, 848. https://doi.org/10.1007/s10750-020-04504-7

30. Vasconcelos, J. F., Barbosa, J. E. L., & Diniz, C. R., et al. (2011). Cianobactérias em reservatórios do Estado da Paraíba: Ocorrência, toxicidade e fatores reguladores. *Boletim da Sociedade Brasileira de Limnologia*, 39.

31. Vieira, R. de S., Oliveira, E. C. C., & Ricarte, E. M. F., et al. (2020). Dominância de cianobactérias na composição do fitoplâncton em reservatório de abastecimento no semiárido cearense. *Research, Society and Development*, 9(11). https://doi.org/10.33448/rsd-v9i11.9476

32. Walter, J., Lynch, F., & Battchikova, N., et al. (2016). Calcium impacts carbon and nitrogen balance in the filamentous cyanobacterium *Anabaena* sp. PCC 7120. *Journal of Experimental Botany*, 67(13). https://doi.org/10.1093/jxb/erw112

33. Yuan, Z., & Yoon, K. (2021). Overview of PCR methods applied for the identification of freshwater toxigenic cyanobacteria. In *Cyanobacteria: Advances in taxonomy and applications* (pp. 1–27). IntechOpen.

34. Zhou, J., Qin, B., & Casenave, C., et al. (2016). Effects of turbulence on alkaline phosphatase activity of phytoplankton and bacterioplankton in Lake Taihu. *Hydrobiologia*, 765(1). https://doi.org/10.1007/s10750-015-2413-2