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Water quality and cyanobacterial blooms in the Piancó-Piranhas-Açu Watershed, Semi-arid Region of Northeastern Brazil: relationships with education toward sustainability

Greater emphasis has been attached to aquatic ecosystems in recent decades, as these are associated with indicators determinant of sustainability indices. The environmental impacts of these ecosystems with potential risk to human health in the semi-arid region of the state of Rio Grande do Norte have been frequently observed. This study aimed at evaluating the cyanobacteria density, and the indices that indicate the Piancó-Piranhas-Açu Watershed quality. It also targeted to identify the factors that impact most the blooming of these aquatic organisms. The sampling design consisted of 12 collections in different seasonal periods from 2009 to 2016, carried out by the Água Azul Program on 6 points along the basin. Environmental variables were used to analyze the Water Quality Index (WQI), Trophic State Index (TSI), and Cyanobacteria Density (CD). The mean WQI indicated 'Regular' water status for points PPA3 and PPA4, while PPA1, PPA2, PPA5 and PPA6 resulted in 'Good'. As for the TSI, the levels indicate average degree of eutrophication (mesotrophy) on three sampling points, high degree of eutrophication (eutrophy) on two points, and low degree of eutrophication (oligotrophy) on one point. In this sense, human activities - especially diffuse polluting sources - around the spring seemed to worsen these scenarios. The density of potentially toxic cyanobacteria was high, exceeding CONAMA Resolution 357/2005 that recommends a maximum value of 50,000 cells/mL, and the Ministry of Health Ordinance 2914/2011 that recommends a threshold of 20,000 cells/mL. Regarding the general correlation between CD and seasonality we found significant influence ($p < 0.05$), with greater proliferation of these organisms directly related to periods of drought. We concluded that although the WQI indicated that dams' waters are suitable for multiple uses, the TSI had limitations, considering the excessive primary productions associated with the presence of cyanobacteria and, thus, the potential occurrence of cyanotoxins ensuing from pollutant loads. The study led us to conclude that the adoption of education practices toward sustainability would help environmental preservation and local social development. It would also enable the establishment of effective priority public policies on mitigation of water pollution.

Palavras-chave: Eutrophication; Water quality index; Spot pollution; Rainfall; Semi-arid reservoirs.

Qualidade da água e florações de cianobactérias na Bacia Hidrográfica dos Rios Piancó-Piranhas-Açu, Região semiárida do Nordeste brasileiro: relações com a educação para a sustentabilidade

Nas últimas décadas tem-se dado maior destaque aos ambientes aquáticos, em função desses ecossistemas estarem associados aos indicadores que determinam os índices de sustentabilidade, cujos impactos ambientais com potencial risco à saúde humana da região semiárida do RN tem sido frequentemente observados. Este estudo objetivou avaliar a densidade de cianobactérias e os índices que inferem qualidade à água na Bacia Hidrográfica Piancó-Piranhas-Açu, assim como identificar os fatores de maior influência sobre a ocorrência da floração desses organismos aquáticos. O delineamento amostral se constituiu de 12 coletas em diferentes períodos sazonais de 2009 até 2016, realizadas pelo Programa Água Azul em 6 pontos ao longo da bacia. Foram utilizadas variáveis ambientais para analisar o Índice de Qualidade de Água (IQA), Índice de Estado Trófico (IET) e Densidade de Cianobactérias (DC). No IQA a média encontrada indicou um estado de água 'Média' para os pontos PPA3 e PPA4, enquanto PPA1, PPA2, PPA5 e PPA6 resultou em 'Bom'. Quanto ao IET, os níveis indicaram médio grau de eutrofização (mesotrofia) em três pontos amostrais, alto grau de eutrofização (eutrofia) em dois pontos e baixo grau de eutrofização (oligotrofia) em um ponto. Nesse sentido, atividades antrópicas no entorno do manancial, em especial as fontes poluidoras difusas, pareceram contribuir para o agravamento desses cenários. A densidade de cianobactérias potencialmente tóxicas se apresentou elevada, ultrapassando a Resolução CONAMA 357/2005 que preconiza um valor máximo de 50.000 cél/mL, bem como a Portaria do Ministério da Saúde 2914/2011 que sinaliza 20.000 cél./mL como valor limite. No tocante à correlação entre a DC e a sazonalidade, em termos gerais, obtivemos influência significativa ($p < 0,05$), com a maior proliferação desses organismos estando diretamente relacionada aos períodos de estiagem. Concluímos que apesar do IQA indicar que as águas dos açudes são próprias aos usos múltiplos, o IET apresentou limitações, considerando as excessivas produtividades primárias associadas à presença de cianobactérias e, portanto, potencialmente à ocorrência de cianotoxinas, oriundas de cargas poluidoras. Por meio do estudo apresentado, entende-se que a adoção de práticas de educação para a sustentabilidade auxiliaria no tocante a preservação do meio e desenvolvimento social local, bem como políticas públicas prioritárias eficazes na mitigação da poluição hídrica.

Keywords: Eutrofização; Índice de qualidade de água; Poluição pontual; Precipitação; Reservatórios do semiárido.

Topic: **Desenvolvimento, Sustentabilidade e Meio Ambiente**

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INTRODUCTION

Water is a multiple-use asset and, as such, has several purposes such as public supply, power generation, transportation, dilution of domestic and industrial water, animals thirst-quenching, leisure, and residues of rural and urban activities. Because of its vital importance, greater emphasis has been attached to aquatic ecosystems in recent decades, considering their environmental impacts on human health, and the indicators determinant of sustainability indices.

Impacts become even more harmful when surrounding communities make direct use of these resources, mainly for human supply. This places environmental monitoring as an important tool for water resources management, capable of assisting the maintenance of the environment natural state (ZALEWSKA et al., 2017). This scenario, notably regarding aquatic ecosystems, demands performing tests with measurable parameters, whether physical, chemical or biological ones, as predictive indicators of the state of limnetic quality of surface springs (KOTT et al., 2018).

In order to meet this demand, some experts have developed indices applying statistical methodologies with variable weights according to the weighting of their importance, since evaluating different parameters is vital to understand the water quality. These analysis tools are efficient qualitative assessment techniques (ANDRIETTI et al., 2016). In Brazil, however, to have good quality for human consumption it still needs to be compliant with the CONAMA Resolution (2005), and meet the standards of the MoH Ordinance 2914 (2011).

The Water Quality Index developed by CETESB (2007) uses 9 parameters, which reflect the contamination of water bodies, especially by the discharge of domestic sewage. The Trophic State Index developed by Carlson (1977) is another largely used index. It uses two variables (phosphorus and chlorophyll *a*) to establish the degree of trophy (eutrophication) of water bodies, thus evaluating the effects related to the excessive accumulation of cyanobacteria biomass.

Cyanobacteria are known as blue algae, Cyanophyceae or Cyanophytes, and are one of the oldest groups of living beings inhabiting the Earth. This group is very diverse in terms of the environment they live in, is highly tolerant, and has adaptive capacity to survive in the most diverse situations. Under favorable conditions they may reach high biomass, forming blooms. One of the major problems of this blooming is that some organisms produce toxins, i.e., substances that are poisonous for most other living beings (CARMICHAEL, 1994). According to Falconer (1996), these toxins may present sets of different effects in the pharmacological light, due to their great variation of organic molecules.

In water, these toxins usually remain within the cells of cyanobacteria, and are only released after cell lysis that may occur due to senescence, use of algicide, chlorination, or cell stress. Still according to Carmichael (1994), a significant accumulation of these toxins on the banks of water springs, depending on concentration, may lead consumers to death.

This fact was also reported by Duy et al. (2000). The authors state that recreational and drinking water (animal or human), when exceeding the threshold values, affect children more because they are more susceptible to cyanotoxins. Therefore, the presence of cyanotoxins in the aquatic environment would directly affect the health of terrestrial animals, aquatic animals, and humans, making this an important indicator for monitoring.

Characterized as a natural process, the bloom of blue algae, mainly in reservoir waters, may be worsened by anthropogenic influence (HITZFELD et al., 2000), through activities such as sewage disposal, riparian forests deforestation, industrial contaminants, among others (NABOUT et al., 2013). These blooms are potentially harmful, given that their high cell density can promote high rates of toxic contaminants, damaging the many uses of the aquatic environment.

According to Haider et al. (2003), 40 genera have been reported in the literature as having toxic properties, and five of them were found in this study: *Raphidiopsis raciborskii*, *Planktolyngbya minor*, *Microcystis aeruginosa, Planktothrix agardhii* and *Aphanocapsa parasítica*. All over the world, cyanotoxins are most commonly associated with blooms that cause hepatotoxic and neurotoxic conditions.

To produce their toxic effects, the hepatotoxins actively move through the bile acid transportation mechanism, ending by reaching the liver cells and the intestine epithelium (FALCONER, 1996). The neurotoxins, although less frequent than hepatotoxins, interrupt the communication between neurons and muscle cells (CARMICHAEL, 1994).

Potentially toxic species have been widely studied in public supply reservoirs, and are pointed out as important bioindicators of water quality (COSTA et al., 2006; ARAGÃO et al., 2007; CHELLAPPA et al., 2009). Knowing their composition, abundance, distribution, and levels is an important tool to assist in the management and maintenance of these waters.

Located in the semi-arid region of Northeastern Brazil, the Piancó-Piranhas-Açu Watershed is located in the states of Rio Grande do Norte and Paraíba. The basin is of paramount importance for the region, and is the largest unit of the Eastern Northeast Atlantic (BRASIL, 2018). As this region is characterized by long periods of droughts and severe droughts, the basin plays an important role of water accumulation, serving several communities, rural properties, and urban centers.

The scarcity of water in recent times is often a reflection of consumption with no social responsibility, inefficient planning in the qualitative-quantitative light, and growing pollution from several anthropogenic sources. In many cases, the discharge of domestic sewage *in natura* or with insufficient treatment leads to increased concentration of nutrients, thus favoring shaper eutrophication of the aquatic system. The discharge is facilitated by modifications to aquatic environments aimed at meeting the needs of more urban areas (TUNDISI et al., 2007).

In his speech, Leff (2010) highlights that one of the reasons that converses water abundance into scarcity is the worldwide spread of super-economization. The scarcity of a product raises its market value, and this economic logic is also applied to natural resources. The many uses, often based on waste and irrationality, end up generating conflicts that directly imply the loss of biodiversity and desertification, putting Earth's sustainability at risk. It is worthy of notice that such water management crisis boosts the process of commodification of nature, although this is an important universal resource and a right of all. Ecological awareness based on the balance between economic organization and the environment thus plays a core role in sustaining social development.

In this context, Education toward Sustainability (ES) becomes one of the main cornerstones to tackle the challenges faced by contemporary society, considering its potential of changing habits, in addition to teaching and raising awareness of subjects, enabling long-term water sustainability. The emerging practices that permeate the ES assist the development and implementation of strategies that ensure balance between environment and humans, through conscious consumption and reduction of water waste, promoting water resources preservation. Understanding the role played by ES is thus a transformative learning process in which individuals become capable of adopting more responsible behavior, imprinting new ways of thinking and acting before the society (DUBEY et al., 2017).

The huge ecological, social, and health relevance of aquatic ecosystems, environmental makes quality studies crucial for the water resources management. This study thus aimed at evaluating the cyanobacteria density, and the indices that indicate the Piancó-Piranhas-Açu Watershed quality. It also targeted to identify the factors that impact most the blooming of these aquatic organisms.

MATERIAL AND METHODS

Study area

The Piancó-Piranhas-Açu Watershed occupies a drainage area of approximately 43,638 km², partially inserted in the states of Rio Grande do Norte (40.6%) and Paraíba (59.4%), as shown in Figure 1. Its population is of about 1,406,808 inhabitants, distributed in urban (69%) and rural (31%) areas, according to the demographic census data[1]. Altogether, 147 municipalities are part of the watershed, with 47 belonging to Rio Grande do Norte and 100 to Paraíba.

Figure 1: Location of the Piancó-Piranhas-Açu Watershed. **Source:** ANA (2016).

[1] http://www.censo2010.ibge.gov.br

The selected area is characterized by high temperatures, with annual averages of 24.2 to 28.2°C. Lowest temperatures usually occur from June to August, while the highest ones occur from December to February[2]. The highest rainfall rates are concentrated in the period of February to May, with high variability. The highest mean values are around 1,050 mm/year, while the lowest ones are around 440 mm/year. The climate type of the region is A (tropical climate) and B (arid climate), according to Köeppen (1948) climate classification.

Sampling Points

Six sampling points were selected (Table 1) spread over the watershed, all of them belonging to the State of Rio Grande do Norte. The points were selected considering their storage capacity and, therefore, greater capacity to serve the population's multiple demands.

Table 1: Location of the points used for monitoring.

Code	Reservoir	Municipality	Maximum capacity (hm³)	Coordinates Lat./Long.
PAA1	Boqueirão de Parelhas Dam	Parelhas	84.8	-6º69'00"/-36º63'00.0"
PAA2	Itans Dam	Caicó	81.8	-6º49'00"/-37º07'00.0"
PAA3	Passagem das Traíras Dam	Jardim do Seridó	49.7	-6º50'82"/-36º92'85.4"
PAA4	Gargalheiras Dam	Acari	44.4	-6º41'67"/-36º60'00.0"
PAA5	Cruzeta Dam	Cruzeta	23.6	-6º41'05"/-36º79'29.4"
PAA6	Pataxós Dam	Ipanguaçu	15.0	-5º61'67"/-36º83'33.0"

The data used here are from the program *Programa Água Azul.* The program was made possible through a partnership between the government of the State of Rio Grande do Norte and other public agencies, such as the Secretary of Environment and Water Resources of Rio Grande do Norte (SEMARH), Institute of Sustainable Development and Environment of Rio Grande do Norte (IDEMA), Rio Grande do Norte State Water Management Institute (IGARN), Agricultural Research Company of the State of Rio Grande do Norte (EMPARN), Federal University of Rio Grande do Norte (UFRN), State University of Rio Grande do Norte (UERN), and Federal Institute of Education, Science and Technology of Rio Grande do Norte (IFRN). The regular monitoring of several points along Rio Grande do Norte was through analyses developed at the EMPARN, UFRN, UERN, IFRN and IGARN, the latter agency also being responsible for sample collections.

Sampling procedure

Twelve sampling campaigns were developed through qualitative-quantitative monitoring throughout the years 2009 to 2016. Water sampling was biannual, except for the years 2010 and 2014, when collections were annual. Sampling followed a seasonal schedule, comprising two hydrological cycles (rainy and dry periods). The Standard Methods for the Examination of Water and Wastewater (APHA, 2005; 2012) was used for water sample analysis and collection.

[2] http://www.inmet.gov.br

Water quality analyses

The following environmental indicators were analyzed in the study: cyanobacterial density (CD), thermotolerant coliform bacteria (TC), hydrogen potential (pH), biochemical oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP), temperature (T), turbidity (TU), total solids (TS), dissolved oxygen (DO), and chlorophyll *a* (CL). The Water Quality Index (WQI) was applied water quality, using 9 parameters arranged in different weights (Table 2). These weights suggest the relative importance of each parameter to assess the WQI.

Table 2: Values of W_i weights of parameters used to assess the WQI.

Parameter	W_i
Thermotolerant Coliform Bacteria	0.15
pH	0.12
Biochemical Demand for Oxygen	0.10
Total Nitrogen	0.10
Total Phosphorus	0.10
Temperature	0.10
Turbidity	0.08
Total Solids	0.08
Dissolved Oxygen	0.17

The WQI is calculated through the weighted product of the nine parameters, according to the formula, where: WQI = Water Quality Index. A number ranging from 0 to 100; qi = quality of the ith parameter. A number ranging from 0 to 100 extracted from the respective quality graph, as a function of concentration or measurement; wi = weight corresponding to the ith parameter established as a function of its relevance to global quality conformation, i.e., a number between 0 and 1.

$$WQI = \prod_{i=1}^{n} q_i^{Wi} \qquad (1)$$

Where, in which: n ins the number of parameters included in the WQI calculation.

$$\sum_{i=1}^{n} w_i = 1 \qquad (1)$$

Having calculated index, water quality at every point of the watershed was measured, according to the WQI ranges (Table 3). The closer the index is to zero, the worse the state of the water, and the closer to 100, the better it is.

Table 3: Water quality classification.

WQI ranges	Classification
90 < WQI ≤ 100	Excellent
70 < WQI ≤ 90	Good
50 < WQI ≤ 70	Regular
25 < WQI ≤ 50	Poor
0≤ WQI ≤ 25	Very Bad

Source: Adapted from CETESB (2007).

The Trophic State Index (TSI) proposed by Carlson (1977) and modified by Lamparelli (2004) was used to assess eutrophication of the reservoirs under study. The results of Total Phosphorus and Chlorophyll a were used, through the equations, where: PT: total phosphorus concentration; CL: chlorophyll a concentration; ln: natural logarithm.

$$IETCL = 10 * 6 - 0,92 - 0,34 * \ln CL \ln 2 \quad (1)$$

$$IETPT = 10 * 6 - 1,77 - 0,42 * \ln PT \ln 2 \quad (2)$$

$$IET = IETPT + IETCL2 \quad (3)$$

After performing all the calculations shown in Table 4, the water trophic state classification was inferred.

Table 4: Classification of the water trophic state.

TSI categories	Weighting
Ultraoligotrophic	TSI ≤ 47
Oligotrophic	47 < TSI ≤ 52
Mesotrophic	52 < TSI ≤ 59
Eutrophic	59 < TSI ≤ 63
Supereutrophic	63 < TSI ≤ 67
Hypereutrophic	TSI> 67

Source: Adapted from CETESB (2007).

Classification as Ultraoligotrophic or Oligotrophic is an indication of clean water body with low nutrient production, and no impairment to the many uses of the water. Mesotrophic indicates intermediate production, with potential undesirable, yet still acceptable, implications in most cases. The Eutrophic and Supereutrophic levels present high productivity, suggesting negative interference on the many uses of water. The Hypereutrophic level evidences high concentrations of organic matter, and accumulation of nutrients.

Statistical Analysis

Data were first analyzed on an individual basis, by means of the aforementioned WQI and TSI calculations. Next, in order to verify seasonal differences, the non-parametric ANOVA test was used with a significance level of 5%. In order to evaluate the correlation between rainfall and physical, chemical, and microbiological parameters, Pearson's non-parametric test was performed (range -1 to 1). The analyses used the *Statistica 10* software, and the *Microsoft Excel*.

RESULTS AND DISCUSSION

Water Quality Index

Historically, based on data collected by the *Programa Água Azul*[3], the WQI oscillated between bad, medium, and good, and good quality prevailed. The quality index indicated 'Regular' water status for points PPA3 and PPA4, while PPA1, PPA2, PPA5 and PPA6 resulted in 'Good' (Figure 2).

The reduced quality of the Passagem das Traíras Dam is attributable to the higher concentrations of TS, BOD and TC, indicating pollutant discharges in the cities of São José do Seridó and Jardim do Seridó. In their study, Souza et al. (2014) also note that the rise in TS many times result from the increase in pollutant point sources.

The WQI in Gargalheiras Dam was usually reduced by the high values of TU, TP, TS, BOD and TC, with

[3] http://programaaguaazul.ct.ufrn.br/relatorios/aguas_superficiais/

phosphorus occasionally exceeding the maximum allowable values (VMPs) established by CONAMA 357/2005. It is worth mentioning that this dam receives sewage *in natura* or with precarious treatment from the city of Currais Novos, damaging the water resources. These pollutant sources full of organic debris (bacteria and algae) and inorganic particles (suspended solids) may change the spring turbidity, preventing the light beams from overcoming the water column (CETESB, 2016). This fact favors the aquatic ecosystem unbalance, since decreased light directly implies photosynthesis and, consequently, availability of oxygen.

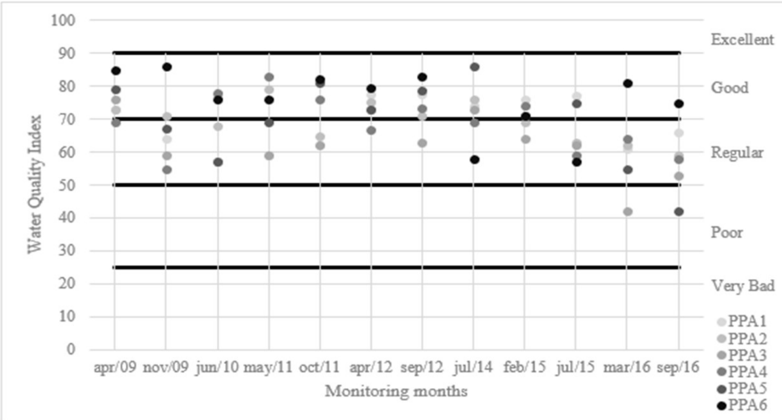

Figure 2: Water Quality Index History.

The Boqueirão de Parelhas Dam experienced quality loss that may have been caused by the relative increase in the concentrations of TC, BOD and TS, due to the agricultural uses on the dam and its surroundings. According to Huang et al. (2010), this type of activity is a potential contaminant of water bodies, since land use is many times improper, and natural resources are exploited in an uncontrolled way. The levels of these contaminants, strong indicators of pollution, deserve attention, especially the thermotolerant coliform, that are bacteria naturally found in the intestines of animals and humans (SILVA et al., 2017), easily carried over to water bodies.

Itans Dam showed high indices of the following parameters: TN, TP, TC, TS, BOD and TU, what may have caused a loss of water quality. This dam is located in the Caicó city hinterland, and is the spillway of several sources of pollution such as waste disposal, animals thirst-quenching, among others. As Valadão et al. (2018) point out, a high anthropic pressure around the basin tends to increase the spring contamination from domestic waste, seriously damaging the environment.

The qualitative decrease of Cruzeta Dam ensured from high levels above the VMPs for the parameters TN, TP, BOD, TU and TS. The increased levels of phosphorus and nitrogen contribute significantly to nourish the biological processes, hastening the development of eutrophication (LIMA et al., 2016). These elements are constituted by decomposed organic matter, accumulation of domestic sewage or industrial effluents (SPERLING, 2007).

In general, the Pataxós Dam showed high concentrations of BOD and TS, partially limiting its quality. It is worth noting that the biochemical demand for oxygen is expressed by the amount of oxygen needed to stabilize the oxidizable organic matter (ALBERTO et al., 2012), that is, it represents the required consumption by the existing microorganisms to perform aerobic respiration in the aquatic ecosystem (SPERLING, 2014). The uncontrolled expansion of this parameter indicates the high input of these materials, implying the decay of oxygen available in the water, directly affecting aerobic aquatic animals, and potentially causing mortality.

Trophic State Index

As for the Trophic State Index, there was oscillation between the 'Ultraoligotrophic' and 'Hypereutrophic' ranges, with most of the samplings being characterized as Mesotrophic (Figure 3).

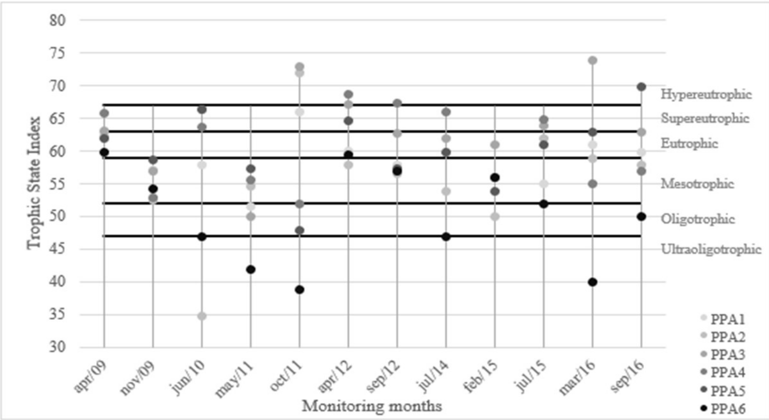

Figure 3: Trophic State Index History.

After evaluating the TSI history, we found the following mean trophy of these ecosystems: PPA1, PPA2 and PPA5 mesotrophic, indicating medium level of eutrophication in these dams; PPA3 and PPA4 eutrophic, indicating high eutrophication on springs; PPA6 oligotrophic, pointing out to low level of eutrophication in water resources.

Eutrophication, as an impact of decreased water quality, is strongly characterized by the accumulation of nutrients in the aquatic ecosystem, especially TP. Phosphorus is an important component for the biological systems; according to Leme (1990) it plays a vital role in the metabolism of living beings, storing energy, and structuring the cell membrane. The over-release of this macronutrient into water, however, may lead to uncontrolled growth of the aquatic organisms (algae) population, directly implying in eutrophication.

In order to understand the trophic level of a water body, one should also evaluate the Chlorophyll *a*, considering its important role in indicating the effect of nutrient enrichment, and the availability of phytoplankton biomass (ZHANG, 2014). This parameter allowed inferring a high algal production at two points of the study (PPA3 and PPA4).

Anthropic activities, agriculture, and sewage discharge are factors that further promote the eutrophic process, in addition to sediment deposition along the water body in a given time space (ALEMAYEHU et al., 2016; SILVINO et al., 2015), becoming a facilitating agent for algal growth. The process of overgrowth of these organisms, as observed at some points in this study, ends up becoming a serious problem.

Cyanobacterial Density

The density of cyanobacteria was high at most points analyzed in each annual period (Figure), according to the CONAMA Resolution 357/2005 that recommends a maximum value of 50,000 cells/mL, and the Ministry of Health Ordinance 2914/2011 that recommends a threshold of 20,000 cells/mL. This, however, could have been observed due to the prolonged dry season that caused sharp water deficit in the semi-arid region of Rio Grande do Norte, intensifying the previously observed eutrophication process, and promoting the cyanobacteria persistence.

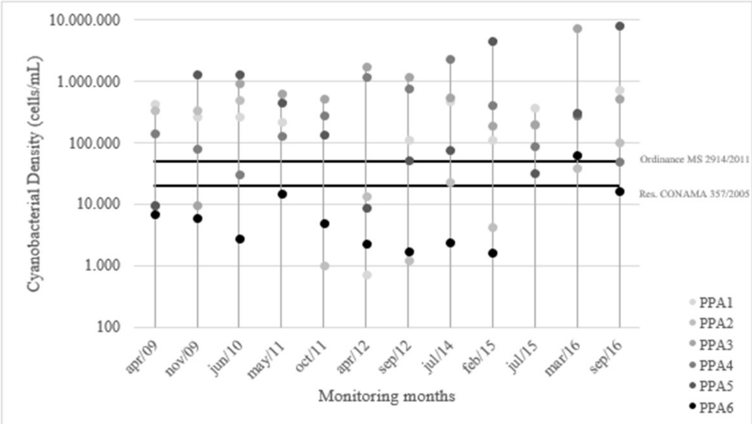

Figure 4: Cyanobacteria Density History.

With very high concentrations, PPPA1 presented non-compliance in virtually all samples, being compliant with the standards only in April/2012. In this spring, most cyanobacteria genera were: *Raphidiopsis raciborskii, Planktolyngbya minor* and *Microcystis aeruginosa*. PPA2 was in compliance in four campaigns according to CONAMA (2005), and 6 according to the MoH (2011); however, data show high rates for the reservoir. The main genera are *P. minor* and *R. raciborskii*. At the collection point PPA3, the same pattern as PPA1 was observed; however, the compliant collection was November/2009. *Planktothrix agardhii, R. raciborskii* and *P. minor* were the most relevant genera found.

The point PPA4, also reported very high values of CD, with almost all the analyses above the VMPs, except for June/2010, when it was in compliance with the Ordinance 2914/2011. The concentration of these organisms was also high in PPA5, being not in compliance with the MoH (except April/2009, April/2012, and July/2015) and CONAMA (except April/2009 and April/2012). In the last two points, the predominance was of the genera *R. raciborskii* e *P. minor*. Additionally, in PPA6, the presence of *Aphanocapsa parasitica* was identified. Except for the collection performed in March 2016, the PPA6 dam was the one that presented the best quality, being within the values allowed.

The exacerbated accumulation of cyanobacteria causes not only environmental, but also social and economic damage, given their ability to produce toxins that may give rise to significant and irreparable health losses, due to their toxigenic potential. As example worth of notice we have the genus *R. raciborskii* that has been widely studied over the years (BRANCO et al., 1991; SOUZA et al., 1998; ISVÁNOVICS et al., 2000; BOUVY et al., 2000; PADISÁK et al., 2003; SANTANNA et al, 2006; PANOSSO et al., 2007) especially because they produce algal blooms containing toxins that inhibit protein synthesis in the liver, thus damaging organs such as kidneys, lungs, gastric mucosa, and the liver.

Table 5 shows the linear correlation data between water quality parameters and cyanobacterial density. It shows a positive correlation between the CD and many parameters, except for the TC that showed a slight but not significant negative correlation. Among the parameters noted with moderate positive correlation, we have: TP, TU, TS, and CL.

Table 5: Linear correlation matrix between water quality parameters and cyanobacteria density.

	CD	*TC*	*pH*	*BOD*	*TN*	*TP*	*T*	*TU*	*TS*	*DO*	*CL*
CD											
TC											
pH	-0.007										
BOD	0.130*	-0.058									
TN	0.331*	0.012	-0.132								
TP	0.020	-0.096	0.195	0.012							
T	0.640**	-0.013	0.168	0.304	0.115						
TU	0.075	-0.077	0.090	0.015	-0.017	0.129					
TS	0.669**	0.042	-0.034	0.223	0.088	0.538	0.046				
DO	0.406**	-0.059	0.401	-0.014	0.417	0.434	-0.038	0.078			
CL	0.181*	0.106	0.157	0.314	-0.096	0.185	-0.047	0.102	0.137		
	0.455**	-0.070	0.336	0.224	0.141	0.230	-0.041	0.085	0.465	0.139	

*Weak positive correlation (from 0.1 to 0.3); **Moderate positive correlation (from 0.4 to 0.6).

Given the foregoing, it was observed that total phosphorus significantly contributes to the development of dense populations of cyanobacteria, since this compound serves as a nutrient for their growth. This statement is supported by Esteves (1998) in his study. Turbidity and total solids are also considered an important factor, since their increase enables favorable conditions for the fluorination of these organisms. These data were also considered in the studies by Costello et al. (2005) and Oliver et al. (2009). There is also the positive correlation with chlorophyll *a*, also recognized by Jardim et al. (2014), as it is a photosynthetic pigment of cyanobacteria.

Regarding the correlation between these indicators of water quality and rainfall (Table 6) in general, we found significant influence ($p < 0.05$) of CD and TS. This relevance may be explained by the intensified climate change, which lead to high dominance in the density of cyanobacteria, including over the other groups of algae, especially in warmer seasons (ELLIOTT, 2012).

Table 6: Pearson's correlation test (rainfall x water quality parameters).

Pair of Variables	Pearson's Correlation	
	P-value	***r Coefficient***
Rainfall x CD	0.025*	-0.120
Rainfall x TC	7.39	0.496
Rainfall x pH	3.89	-0.585
Rainfall x BOD	2.43	0.115
Rainfall x TN	1.23	-0.135
Rainfall x TP	9.91	-0.015
Rainfall x T	1.12	0.019
Rainfall x TU	3.36	-0.030
Rainfall x TS	0.001*	-0.205
Rainfall x DO	2.88	0.143
Rainfall x CL	9.51	-0.192

*Significance ($p < 0.05$).

As seen, the seasonality factor influences the proliferation of cyanobacteria ($p < 0.05$); however, other correlated factors directly interfere with this mechanism of action. Paerl et al. (2008) state that in addition to temperature variations, the high nutrient load, long residence time, and thermal stratification are associated elements that foster their dominance in aquatic ecosystems.

Regarding the average CD values throughout all sampling campaigns, shown in Figure 5, it could be inferred that there is considerable variation between the points, with PPA3 and PAA5 being more negatively impacted by the proliferation of these organisms. This can be explained considering the potential pollutants that pressure the dams.

Statistically, dry periods showed small increase in the cyanobacteria density, which is supported by Davis et al. (2009) who concluded in their study that the increase in temperature caused the growth of cyanobacteria that produce cyanotoxins. Points PPA3 and PPA6, however, increased in the rainy season. This fact was also identified by Souza et al. (2018) who, when analyzing a reservoir in the semi-arid region, despite the diluting factor of the rainy season, found an increase in the abundance of cyanobacteria in that same period. However, considering that it is a point with compromised quality (PPA3), the association of several parameters may have led to these results.

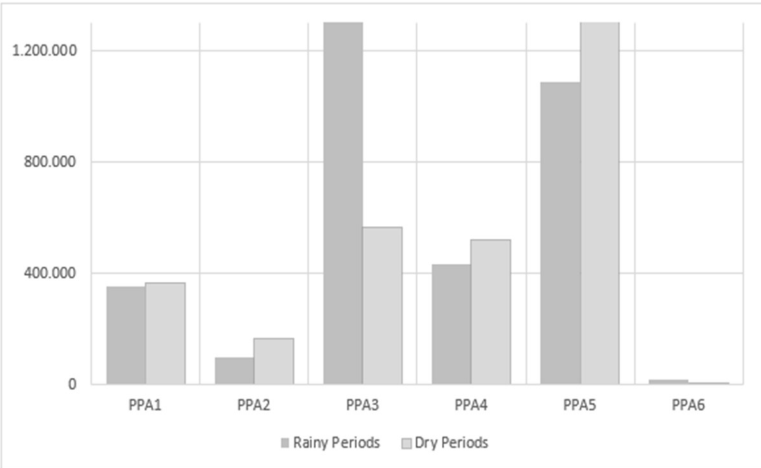

Figure 5: Mean values of Cyanobacteria Density at the six sampling points in the rainy and dry periods on the Piancó-Piranhas-Açu watershed.

It is worth noting that the years comprising collections were characterized by low rainfall rates in the Seridó region of Rio Grande do Norte, mediating the deterioration of several indices of water quality, as supported by Arenas et al. (2016).

Water quality and education toward sustainability: considerations for the semiarid region

Water issue is directly related to education toward sustainability, considering that the multiple environmental relations, including water resources degradation, are conversed into social commitments and concerns. The individuals' awareness and perception regarding the socio-environmental issues faced throughout time are an extremely relevant aspect that will impact the quality of life for several peoples to come. Therefore, education toward sustainability helps individuals to gain a new vision based on collaborative experiences and active practices, contributing to less exploitation and greater maintenance of the environment.

According to Leff (2010), it is essential to consider how the concepts of economic order influence human life and the ecosystem, being able to shape several societies, and the way they are managed. The hunt for economic development is strongly linked to environmental exploitation, typically in an unsustainable way. It implies market benefits to the detriment of the common good. In face of that, economic behaviors and, above all, people's individual and collective mindset should change if we are to evolve as a society. In this sense a feasible option is the investment in environmental awareness-raising, bound to education toward sustainability.

In this sense, it is necessary to envision a more democratic water management, capable of ensuring the restructuring of social processes linked to consumption and production, as well as practices of recycling and reuse since its 'endless' cycle needs time for renewal, time that the modern globalized world has not respected in recent decades.

As a possibility way to overcome this distorted vision in the humanity-environment relationship, especially in the context of water quality in the semi-arid region, it would be worth investing in public policies aimed at citizen nurturing, in order to prepare them for the challenges of contemporaneity through the implementation of programs on Sustainable Development (ARAÚJO et al., 2019).

These Sustainable Development programs may be in line with the Sustainable Development Goals (SDGs) and, despite several flaws in this agenda, correspond to political plans and strategies to achieve equitable development.

We highlight here the onset of a new field of knowledge, with transdisciplinary epistemic bias, named Sustainability Science. It has caused changes in education, especially in science teaching-based Education toward Sustainability (PEDROSA, 2018), where it may assist individuals in understanding the interactions between natural systems and human society, and foster the systematic approach of mutual problems that arise constantly (VILCHES et al., 2016).

Education toward Sustainability may be a way to subsidize actions aimed at the constitution of critical thinking on education and the environment, especially coordinated with local demands. This is the case for the semi-arid region of Rio Grande do Norte, where the population co-exists with the risks of eutrophication. Considering the foregoing, a set of instruments that could boost the dissemination of the social, economic and environmental implications of water quality issues in this region is needed. This is true mainly when one considers, among others, studies that show that students and teachers are unfamiliar with the interfaces between this environmental issue and the ecological dynamics (ARAÚJO et al., 2019).

It is thus observed that this issue of eutrophication and cyanobacterial blooms is also attributable to an educational issue of the population's conformism with the situation in which they are inserted. This may be a result of the difficulty in perceiving their own reality, i.e., living with the imminent risk of contamination by cyanotoxins, a potential risk to human and environmental health and, above all, the possibility of interruption of domestic water supply due to the action of toxic cyanobacterial blooms in the reservoirs of this watershed.

This is said based on the difficulty that teachers face in designing pedagogical actions coordinated with the trans- and interdisciplinary nature of sustainability. This, in turn, results in practices that are to some extent decontextualized or that neglect ethical and moral aspects involving the social, economic and environmental dimensions of sustainability (ARAÚJO et al., 2014).

Considering the aforementioned, a Sustainable Development program should ensure more comprehensive education-oriented public policies, in order to propose coordinated actions supportive to teachers, including the necessary training in this field (SANTOS et al., 2015). This could entail positive returns as an educational process, engendering social engagement and enabling actions aimed at the sustainable development, especially with regard to eutrophication, cyanobacterial blooms and water quality impairment. These could be integrative curriculum units for critical, reflective and emancipatory training, especially for schools in the semi-arid Northeast.

CONCLUSION

The parameters analyzed indicate that dams are in a state of high eutrophication, suggesting a potential environmental degradation, and a threat to the water quality of the Piancó-Piranhas-Açu watershed. This critical trophic state, perceived in almost all the studied springs, is associated with high concentrations of phosphorus, implying high density of cyanobacteria population. These biotic indicators evidence strong possibility of pollution in the regions of the dams, as well as of damage to human health and local biodiversity, due to the presence of genera capable of producing toxins with neurotoxic effects.

The WQI results indicated that that dams' waters are suitable for multiple uses; the TSI, however, had limitations, considering the excessive primary productions associated with the presence of cyanobacteria and, thus, the potential occurrence of cyanotoxins ensuing from pollutant loads.

The wide range of uses, typically based on waste and irrationality in the management of these water resources, eventually leads to conflicts directly involving loss of biodiversity. These conflicts bear the imminent potential for interruption of domestic supply in the semi-arid region of Rio Grande do Norte, because of the risk of water contamination from cyanotoxins through the action of toxic blooms, putting at risk the sustainability of this region. It is worthy of notice that such water management crisis boosts the process of commodification of nature, although this is an important universal resource and a right of all.

This study supports recommending the government to implement priority public policies aiming at the effectiveness in the fight against pollution and toward water safety, in order to ensure the reduction of the risk to society entailing from cyanobacterial blooms. Another important issue is to understand the vital role of Education toward Sustainability as a daily practice in all processes aimed at citizenship-building, also allow it to expand beyond the school walls.

When it comes to cyanobacterial blooms and loss of water quality due to diffuse pollution, what is under debate is, first of all, the crisis of reason due to low levels of citizens' education, as well as the lack of effective public policies, and the disregard for the environment and education. Thus, strategies should be devised to promote educational practices for communities, through the implementation of public policies aimed at Education toward Sustainability, as a means of developing individuals' skills and competencies to understand the situation in which they live, and seek alternatives to mitigate these issues involving the socio-environmental development of the semi-arid region of Rio Grande do Norte, in the light of sustainability.

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