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Qualitative vulnerability of the waters of a surface reservoir subjected to drought in a tropical semi-arid region[1]

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ABSTRACT - Irregular rainfall and the occurrence of droughts in tropical semi-arid regions have a negative impact on the quality and availability of water stored in reservoirs. The aim of this study was to evaluate the quality of water stored in an artificial reservoir in the tropical semi-arid region of Brazil during years of drought. The study area was the Pereira de Miranda reservoir, located in the district of Pentecoste, Ceará, Brazil. Seven water-sampling campaigns were carried out between April 2015 and September 2016. The variables to be analysed were chlorophyll-a (Cl-a), hydrogen potential (pH), electrical conductivity (EC), total nitrogen (N_{total}), total phosphorus (P_{total}), transparency (SD), fixed/volatile/total suspended solids (FSS/VSS/TSS), and temperature (T^0); the trophic state index (TSI) was then calculated. The variables which better explained the variance in water quality were identified by principal component analysis (PCA). The waters of the Pereira de Miranda reservoir were classified as hyper-eutrophic throughout the study period and at each of the collection points. The PCA identified that the variability in water quality was determined by suspended sediment and nutrients, showing that the reduction in variables made it possible to obtain high explainability of the conditions of the reservoir during monitoring, saving time and resources on the analyses. In addition, the occurrence of severe drought resulted in low accumulated volumes, which intensified and made vulnerable the quality of the waters. As such, the Pereira de Miranda reservoir proved to be in a process of degradation, mainly due to anthropogenic action, intensified by climate factors.

Key words: Monitoring. Eutrophication. Principal component analysis.

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INTRODUCTION

Water is essential for all forms of life. As the global demand for water resources grows, the probability of supplying fresh water is reduced. In this situation, aggravated by population growth together with high rates of water consumption, the adopted developmental model, climate conditions, and contamination of water resources by anthropogenic action, the tendency is for water resources to become scarcer, both qualitatively and quantitatively, if there is no energetic action aimed at improving the supply and demand of water for different uses (LOPES *et al*., 2014b).

In the semi-arid region of Brazil, climate variability (ANDRADE *et al*., 2016), the long residence time of the water (WIEGAND; PIEDRA; ARAÚJO, 2016), and the high rates of evapotranspiration, added to anthropogenic action upstream of the watershed (LOPES *et al*., 2014b), contribute to an increase in nutrient concentration in the water column, and accelerates the degradation of aquatic ecosystems (CHAVES *et al*., 2013; DUARTE *et al*., 2021; LOPES *et al*., 2021; ROCHA; ANDRADE; LOPES, 2015; SANTOS *et al*., 2014).

Reservoirs located in the semi-arid region of Brazil are subject to significant periods of water scarcity, this is mainly due to spatial and temporal variations in the rainfall and to the high rates of evaporation in the region. The region is characterised by short periods of rainfall followed by long periods of drought (ANDRADE *et al*., 2016), resulting in constant changes in the volume and quality, and the chemical, physical and biological characteristics of the water stored in the reservoirs (CUNHA; CALIJURI; LAMPARELLI, 2013; FRANÇA *et al*., 2013).

The degradation process in semi-arid reservoirs, in addition to being associated with hydroclimatic variation, is associated with improper management of the use and occupation of the land and reservoirs, further accelerating the eutrophication process. It is known that this is closely related to the entry of nutrients (especially phosphorus and nitrogen compounds) from sources of localised and diffuse pollution (VON SPERLING; FERREIRA; GOMES, 2008).

In this respect, there is a need to monitor the quantity and quality of the water available in the reservoirs. Such monitoring is carried out by verifying the volume of stored water and its quality, collecting water samples and analysing limnological variables in the laboratory.

It is therefore necessary to use tools that allow a reduction in the large amount of information generated as a result of monitoring water resources, including a multivariate function with several arguments, in such a way that would facilitate the interpretation and recognition of spatial and temporal trends. (ANDRADE *et al*., 2010; LI; LI; ZHANG, 2011).

Multivariate statistics, such as principal component analysis (PCA), have been widely used with data from monitoring water quality (ANDRADE *et al*., 2010; FERREIRA *et al*., 2015; LI; LI; ZHANG, 2011; LOPES *et al*., 2014a; ROCHA *et al*., 2016). This type of analysis reduces observational data, showing associations between variables, and making it possible to identify the possible factors/sources that affect the aquatic system (DUARTE *et al*., 2021; LOPES *et al*., 2014a; ROCHA; ANDRADE; LOPES, 2015).

The aim of this study, therefore, was to evaluate the dynamics of the limnological variables that cause pollution of the Pereira de Miranda reservoir, and to apply principal component analysis (PCA) to evaluate the factors that determine water quality.

MATERIAL AND METHODS

Characterisation of the area

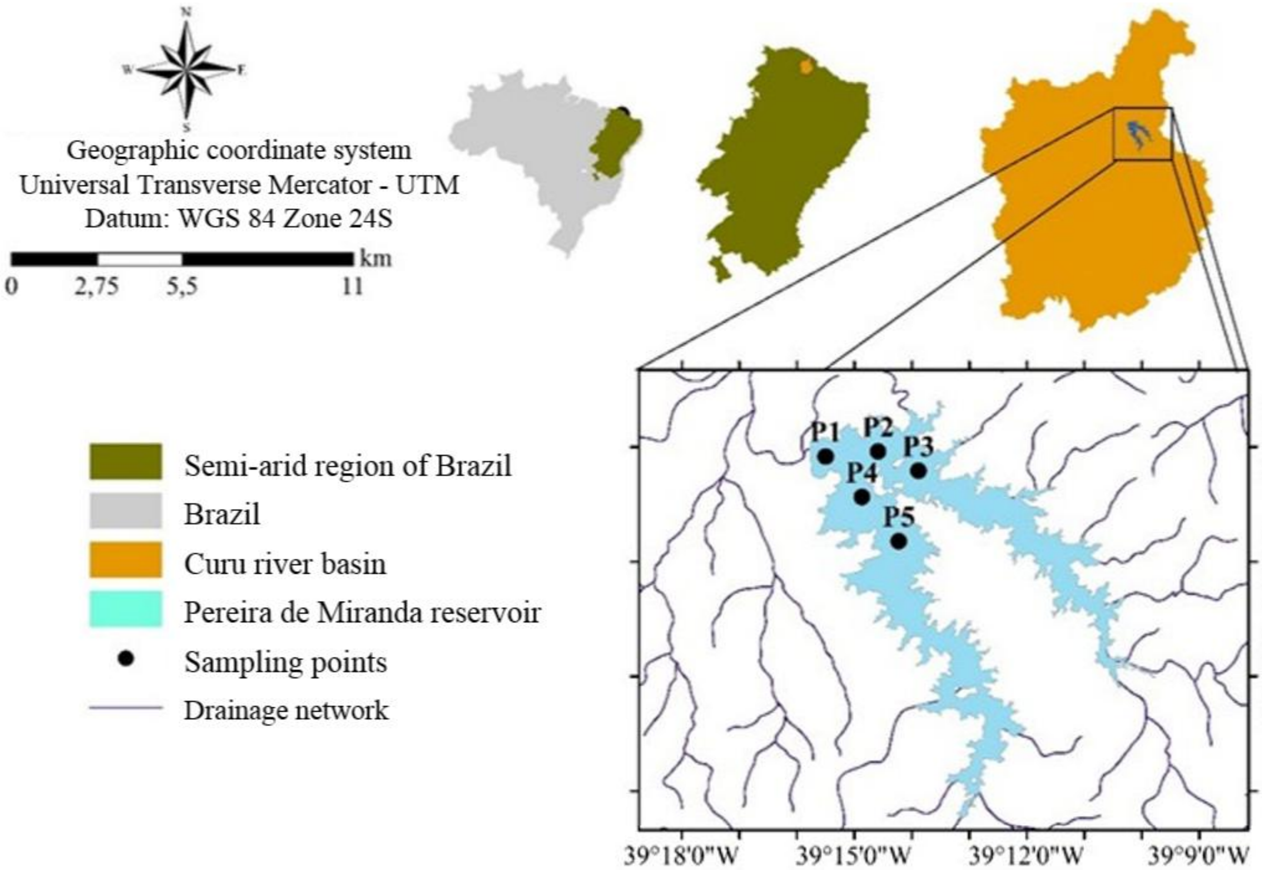
The study area corresponds to the Pereira de Miranda reservoir, located in the district of Pentecoste, in the semi-arid region of the state of Ceará (Figure 1).

The collection points are close, due to the low level of water in the reservoir during the study period, when the volume was less than 5%.

The reservoir dams the waters of the Canindé River, part of the drainage network of the Curu River. The climate in the region is BSw’h’ (hot semi-arid, with rainfall during the autumn and mean monthly temperatures always greater than 18 °C), with an annual rainfall of 763.24 mm (based on the 1974 to 2016 series from the rainfall station located in the city of Pentecoste), annual potential evaporation around 1,899 mm, and aridity index around 0.4 (CEARÁ FOUNDATION FOR METEOROLOGY AND WATER RESOURCES - FUNCEME, 2019).

Land use in the district of Pentecoste (Ceará) is predominantly agricultural (annual, temporary and permanent crops) and natural vegetation (woods and secondary vegetation), in addition to areas of human activity. The multiple uses served by the Pereira de Miranda reservoir, both nearby and downstream, include watering animals, local domestic use, primary contact recreation, public use, irrigation, artisanal fishing, intensive fish farming, industry, a resort, and tidal agriculture. (WATER RESOURCES MANAGEMENT COMPANY - COGERH, 2019).

Figure 1 - Geographical location of the study area showing the collection points in the reservoir



Limnological and climate data

The data under analysis were collected at five points distributed along the drainage basin of the Pereira de Miranda reservoir (Figure 1). The limnological variables analysed were chlorophyll-a (Cl-a), hydrogen potential (pH), electrical conductivity (EC), total nitrogen (N_{total}), total phosphorus (P_{total}), transparency (SD), fixed suspended solids (FSS), volatile suspended solids (VSS), total suspended solids (TSS) and temperature (T). The campaigns were carried out during April, July, September and December 2015, and March, June and September 2016.

T, EC, pH and transparency using a Secchi disc (SD) were measured in the field. The other limnological variables were analysed at the laboratories of the Department of Organic and Inorganic Chemistry and at the Department of Soil Sciences of the Federal University of Ceará (UFC). The analyses were carried out as per the methodology of the American Public Health Association (2005).

Rainfall data, such as daily precipitation (mm day^{-1}), accumulated annual precipitation (mm year^{-1}) and the volume of water stored in the reservoir (%) from 2015 to 2016 were also used. The volume data were obtained online from the Ceará Hydrological site (WATER RESOURCES MANAGEMENT COMPANY - COGERH, 2019).

Trophic State Index - TSI

The trophic state of the waters of the Pereira de Miranda reservoir was calculated using Carlson's Trophic State Index (TSI) (1977), modified by Lamparelli (2004) for lentic bodies of water: Equations 1, 2 and 3.

$$IET(SD) = 10 * \left(6 - \frac{\ln SD}{\ln 2}\right) \tag{1}$$

$$IET(Cl-a) = 10 * \left(6 - \frac{0.92 - 0.34 * (\ln Cl - a)}{\ln 2}\right) \tag{2}$$

$$IET(P_{total}) = 10 * \left(6 - \frac{1.77 - 0.42 * (\ln P_{total})}{\ln 2}\right) \tag{3}$$

where: SD - depth of the Secchi disc in m; Cl-a - chlorophyll-a concentration in μg.L^{-1}; P_{total} - Total phosphorus concentration in μg.L^{-1}; ln - natural logarithm.

The TSI was determined for each variable. The arithmetic mean of the three indices was then calculated, and the mean TSI was classified based on the limits established by Lamparelli (2004), Table 1.

Table 1 - Limits for different trophic-state levels according to the classification system proposed by Lamparelli (2004)

Trophic Level	Mean TSI
Ultraoligotrophic	TSI ≤ 47
Oligotrophic	47 < TSI ≤ 52
Mesotrophic	52 < TSI ≤ 59
Eutrophic	59 < TSI ≤ 63
Super-eutrophic	63 < TSI ≤ 67
Hyper-eutrophic	TSI > 67

Principal Component Analysis (PCA)

Identifying the variables that determine the variability of the water quality in the Pereira de Miranda reservoir was based on application of the multivariate statistical model of principal component analysis (PCA). To this end, the data were analysed using the Statistical Package for the Social Sciences 16.0 software (SPSS). Data consistency was checked using the Kayser-Mayer-Olkim (KMO) method. The PCA model applies to data where the KMO >0.50; for values between 0.50 and 0.70 the model is admissible, from 0.70 to 0.90, the model is considered adequate, and for values greater than 0.90, the model is considered excellent (SILVEIRA; ANDRADE, 2002).

Factor extraction was defined by the variance in the linear combination of the observed variables that explains the maximum variance existing in the sample; the linear combination offering the maximum explanation of the remaining variance; and so on (HONGYU; SANDANIELO; OLIVEIRA JUNIOR, 2016). The correlation of each variable with the factors is shown in Equation 4.

$$X_i = A_{il} \cdot f_1 + A_{i2} \cdot f_2 + \cdots + A_{il} \cdot f_1 + \xi \quad (4)$$

where: (X1, X2 ,..., Xi) - express the linear combination of factors (f); A - represents the factor loadings; ξ – the residual term of the variance not explained by the factors.

The number of extracted factors was defined using the criterion of eigen roots, in which only components with eigenvalues greater than one are considered (ANDRADE *et al*., 2010; FERREIRA *et al*., 2015; LOPES *et al*., 2014a).

RESULTS AND DISCUSSION

Rainfall

The effect of rainfall variability on the volume stored in the reservoir can be seen when it is noted that the same rainfall depth (Figure 2) results in different stored volumes.

On 1 January 2015, when the accumulated precipitation was 450 mm due to a sequence of rainfall events concentrated over a short period, the rainfall depth generated an accumulated volume of 2.9% (Figure 2), whereas for the following year (2016), the same rainfall depth generated a volume of only 1.2% of the storage potential. Such results show that the stored volume does not depend only on the total rainfall, but on the temporal and spatial distribution of the each event.

During the two dry years, the maximum accumulated volume of water was 4% of the capacity of the reservoir, which was responsible for increasing the concentration of pollutants, given that the water in the reservoir was not renewed. According to Rocha, Andrade and Lopes (2015), the low volumes of stored water contribute to the eutrophication process, the process being even more aggravated during the dry season.

Limnological variables

Electrical conductivity is an attribute commonly used to assess the salinity of water, and defines the ease with which a material is able to conduct an electric current due to the presence of ions. Electrical conductivity increases with increases in the salt concentration, these salts originating in the soil, and from the release of effluents.

During the study period, the EC was within the limits considered acceptable, albeit with some restrictions on using the water for irrigation, except at points P4 and P5 in the collection of April 2015, where the EC was less than 0.7 dS m^{-1}; as such there were no limitations for irrigation (Figure 3A).

As the volume of water stored in the reservoir went down, the EC increased; this is associated with an increase in the salt concentration due to the smaller volume of water available for dissolving the salts. The EC showed a small reduction by the end of the study period, which was due to a slight recharging of the water in the reservoir compared to the following months.

Figure 2 - Rainfall measured at the Pentecoste weather station and volume of water stored in the Pereira de Miranda reservoir, Ceará

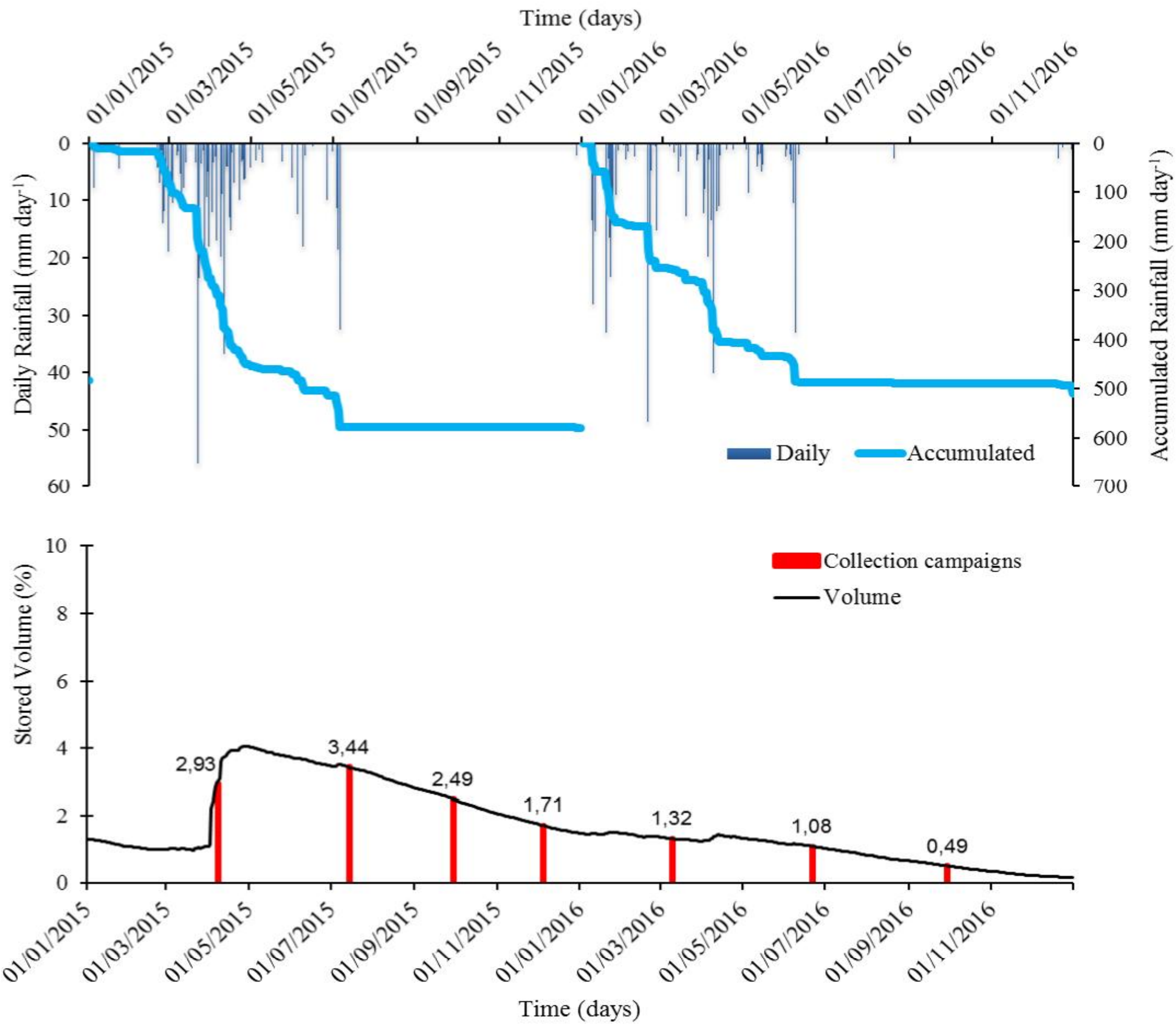
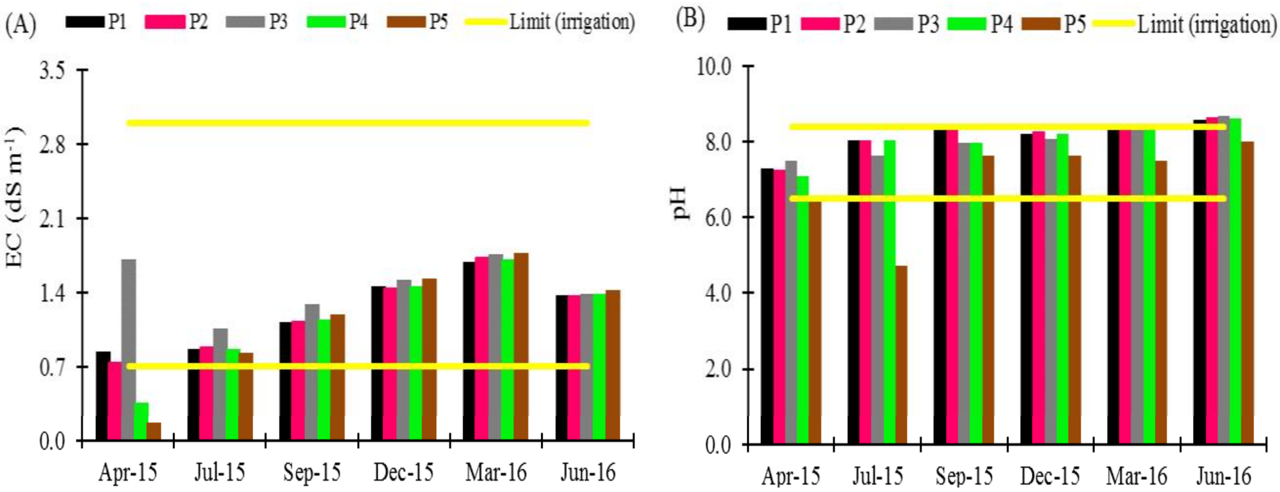


Figure 3 - EC (A) and pH (B) of water from the Pereira de Miranda reservoir showing the limits for irrigation



pH is the variable used to indicate the degree of acidity, neutrality or alkalinity of a body of water. The pH of the water depends on its origin and natural characteristics, but can be altered by the introduction of residue. The pH of the waters of the Pereira de Miranda reservoir mostly varied between 6 and 8 (Figure 3B). The first two collections had the lowest values for pH, a period which recorded the largest volumes of stored water.

P5 had the lowest values for Ph in each collection, which is due to this point being at the principal water inlet of the Pereira de Miranda reservoir, the Canindé river. Although there was no significant rainfall, the entry of water via the river caused a reduction in ions, with a consequent reduction in pH.

The pH was within the range of 6.0 and 8.4, which is acceptable for irrigation and human consumption, albeit with some restrictions. According to Fernandes *et al*. (2009), with a low pH the water becomes acidic and corrosive, values greater than 7 indicate a basic pH with a tendency to form incrustations in the piping, pH values from 7.5 onwards intensify the eutrophication process.

Suspended solids are small particles that are suspended in the water due to 1) the density of the particle being less than or equal to that of the water, 2) to the resuspension of sediment at the bottom of springs, caused mainly by the action of the wind when the volume of water is low, and 3) due to the entrainment of soil sediment through erosion.

It can be seen that the concentration of fixed suspended solids was high in the collection of April 2015 (Figure 4). For the same period, the greatest input of water to the Pereira de Miranda reservoir was from rainfall (Figure 2). The impact of rainfall on the soil triggers the erosion process, and increases the concentration of solids (especially minerals) carried into the reservoirs (FRAGA *et al*., 2012). As such, the results were therefore associated with the rainfall that occurred during this period.

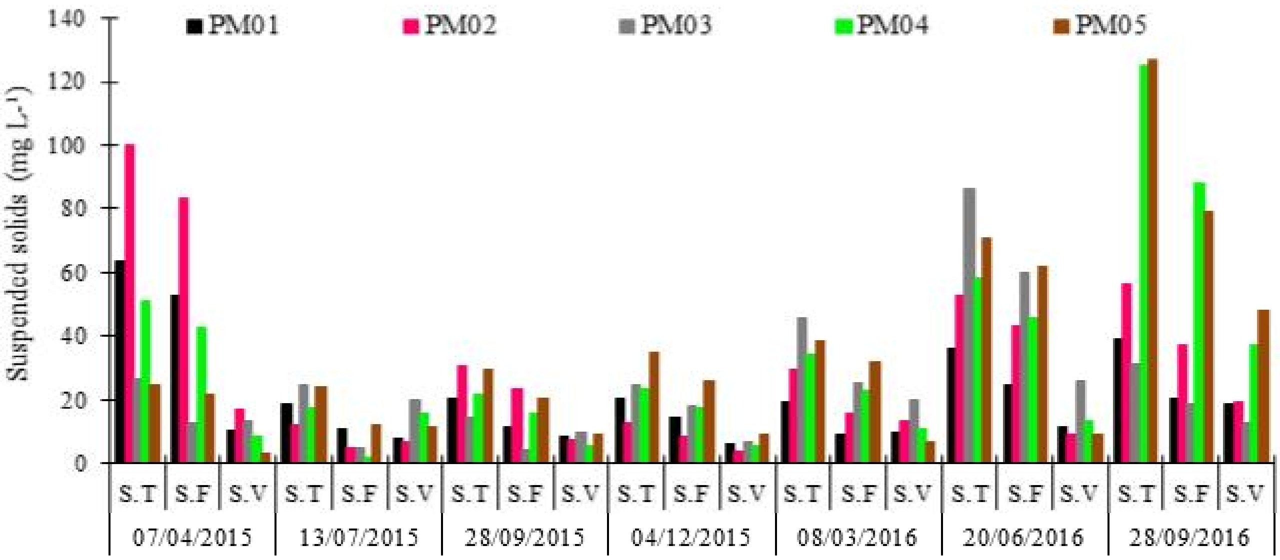
The suspended-solid concentrations were high in the collections of June and September 2016. As there was zero rainfall (Figure 2) during this period, the high concentrations of suspended solids were associated with resuspension of the bed sediment, mainly caused by the action of the wind and by human intervention.

In the September 2016 campaign, unlike the others, the fraction that most contributed to points P4 and P5 was the FSS, i.e. the inorganic sedimentary fraction. According to Von Sperling, Ferreira and Gomes (2008), such fractions are also known as non-algal particles, composed of silt, sand, clay, soil minerals, and particles of anthropogenic chemical origin.

N_{total} is considered an important indicator of the quality and eutrophication of natural water, and may enter the body of water from natural and anthropogenic sources, where natural includes the cellular composition of microorganisms, and anthropogenic includes domestic and industrial waste, animal excrement and fertilisers (VON SPERLING, 2014).

In the Pereira de Miranda reservoir, the values for N_{total} ranged up to around 7.0 mg L^{-1} (Figure 5A), showing the highest concentrations in the collections of 2016, especially March, when little water was input to the

Figure 4 - Concentration of suspended solids in the Pereira de Miranda reservoir



reservoir. Despite the small contribution to the volume of water in the reservoir, the rainfall for March 2016 was able to promote total entrainment of the nitrogen by washing the soils in the drainage basin. In a study by Chaves *et al.* (2013), it was found that drainage of the Curu basin contributed organic matter, the principal source of nitrogen.

The high concentrations of N_{total} during the dry period are strongly associated with the low volume of water in the reservoir, which ranged from 3.44% to 0.49%. According to Von Sperling (2014), the continuous input of nitrogen into surface waters occurs due to the release of animal faeces and domestic effluent, both of which are extremely rich in this nutrient.

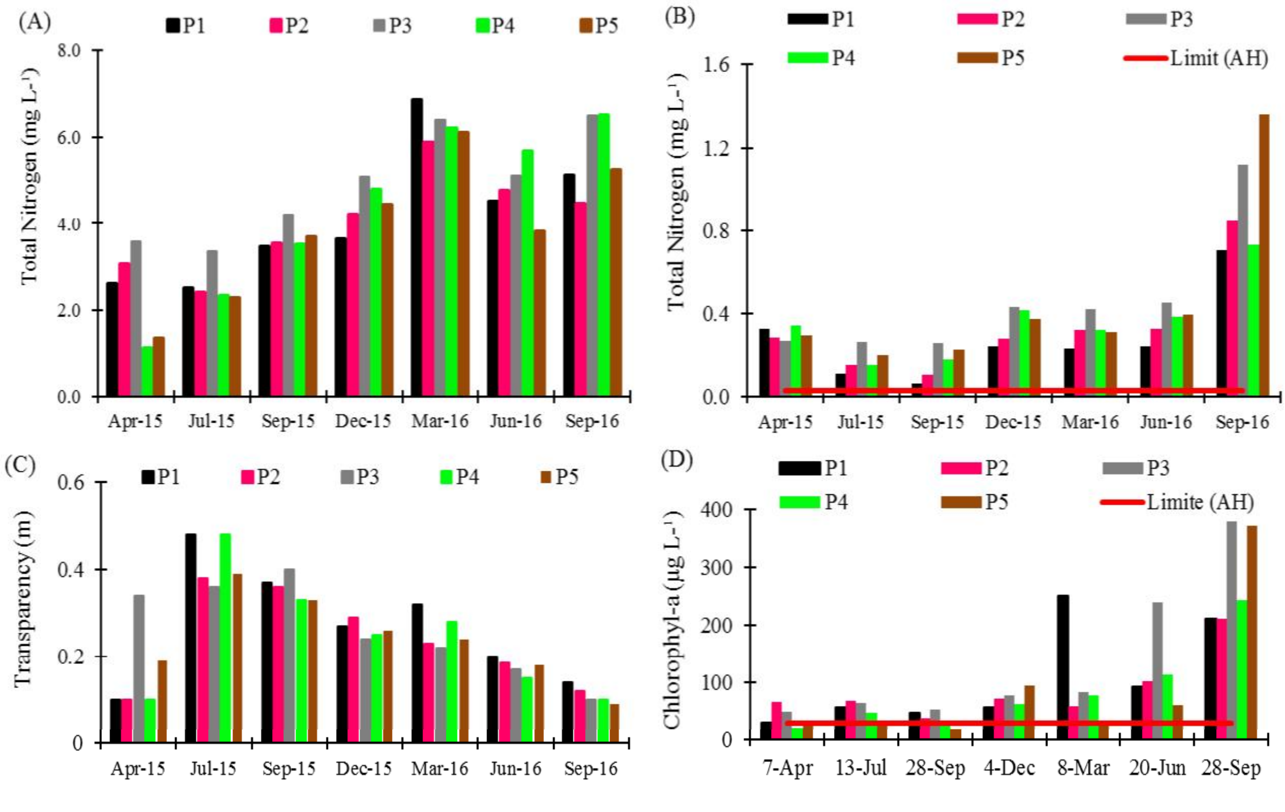
Similar to N_{total}, P_{total} can be found in the water body naturally and anthropogenically, the anthropogenic nutrient coming from domestic and industrial waste, animal excrement, and fertilisers, in addition to detergents (VON SPERLING, 2014). Its presence in the reservoir should be understood as a measure of the eutrophication potential, acting as the main causative agent of the process (LOPES *et al*., 2014a).

The campaign of September 2016 had the highest values for P_{total}, especially at collection point P5, which exceeded 1.2 mg L^{-1}. The remaining points in the other campaigns had lower concentrations, albeit higher than the limit established in Resolution No. 357/2005 of the National Council for the Environment (CONAMA) (BRASIL, 2005), which is 0.030 mg L^{-1} for lentic reservoirs of Class 2 fresh water.

It should be noted that the highest levels of P_{total} occurred during the dry periods in the region. The most acceptable explanation is related to reductions in the volume of water in the reservoir and to the resuspension of bed sediment due to mechanical processes caused by the wind. For Wiegand, Piedra and Araújo (2016), the phenomenon that best explains the high retention of phosphorus in reservoirs of the semi-arid region is the residence time of the water, since, as the water is not renewed, this directly affects the residence time of the phosphorus.

Analysing the transparency of the water, a variation of between 0.09 m and 0.50 m can be seen (Figure 5C), with the maximum values for the collections of July and September 2015, a period during which the reservoir had the highest stored volumes. The lowest values for transparency were seen in the collections of April 2015, when a water recharge occurred (Figure 2), and September 2016, the period with the lowest volume of stored water (Figure 2).

Figure 5 - Concentrations of N_{total} (A) and P_{total}, with the limit for human consumption (B); SD (C); Cl-a and the acceptable limit for human use (D)



The Cl-a concentration (Figure 5D) is one of the most important attributes for assessing the productivity of water environments, and often varies greatly in time and space (MATSUSHITA *et al*., 2015). The concentration must meet a quality standard for Class 2 waters, for which, according to CONAMA Resolution No. 357/2005, the established limiting value is up to 30 µg L^{-1} (BRASIL, 2005). The measured value is taken as a response of the body of water to the agent causing the pollution, thereby indicating the level of algal growth in the water.

The result exceeds the limit for quality in each of the collections, particularly in September 2016, reaching maximum values of approximately 400 µg L^{-1} at points P3 and P5. During 2015, a period with the lowest concentrations of Cl-a, the values at point P5 ranged from 20.29 µg L^{-1} (September) to 95.19 µg L^{-1} (December).

The increase in Cl-a concentration during 2016 compared to 2015 may have been due to the reduction in the volume of stored water, since for the same amount of available nutrients, the volume of water decreased, thereby increasing the Cl-a concentration.

For the Óros reservoir, another highly important reservoir for the state of Ceará, Santos *et al*. (2014) acknowledge that the mean Cl-a concentrations also vary in time and space as a result of the effect of the seasonal climate and land use. As such, the effect of the rainfall and, consequently, the volume stored in the reservoir, should be considered for each collection, as well as land use and occupation in the watershed when planning, controlling and managing the water resources.

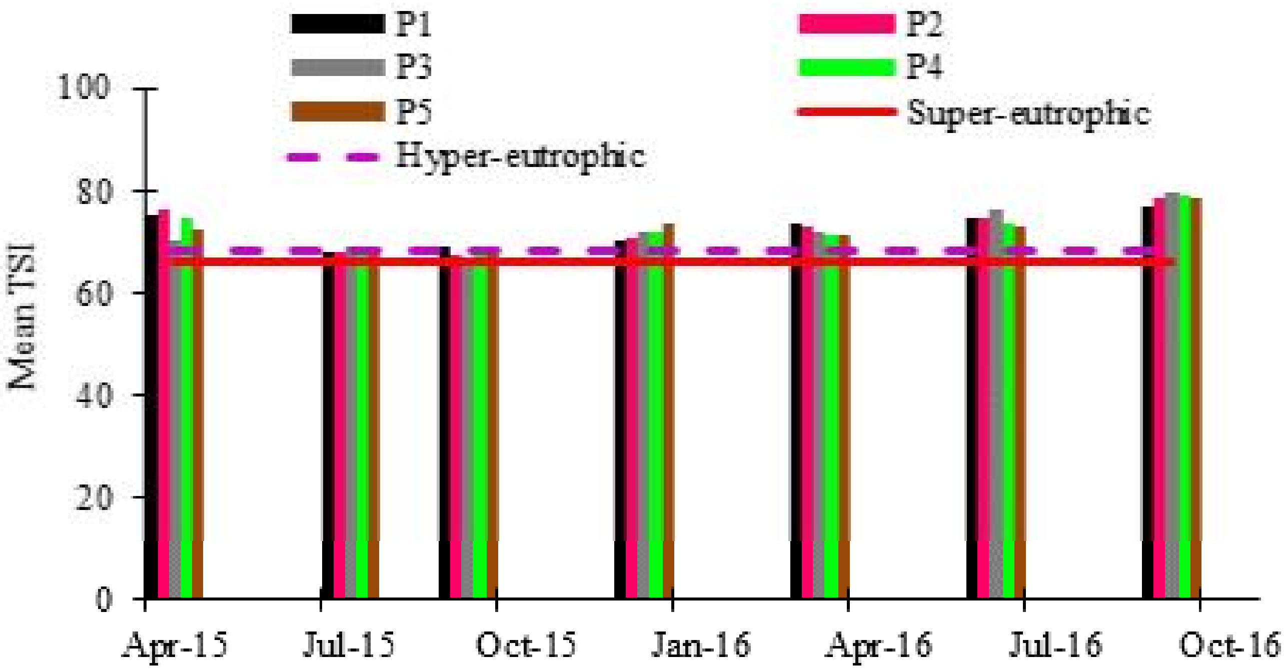
Trophic State Index - TSI

The water of the Pereira de Miranda reservoir was classified as super-eutrophic throughout the study period. According to Chaves *et al*. (2013), the high levels of eutrophication in reservoirs of the semi-arid region may be related to the inappropriate use and occupation of the watershed, which, together with the hydroclimatic characteristics of these regions, such as the high residence time, high rate of available solar energy, and high temperatures, among others, can result in episodes of cyanobacterial blooms that compromise the various uses of the water and may cause widespread fish mortality.

This result is due to the concentration of the limnological variables under analysis: Cl-a > 69.05 µg L^{-1}, SD < 0.6 metres, P_{total} > 0.233 mg L^{-1}, and ETI > 67 (Figure 6).

Among the collections, that of September 2016 had the highest TSI, reaching a value of 80 (Figure 6), this was due to the smallest volume of stored water during the study period being recorded on that date (Figure 2). The lowest calculated TSI was associated with the reservoir having one of the largest volumes during the study period; even so, the reservoir was classified as hyper-eutrophic. Chaves *et al*. (2013) observed similar behaviour in the General Sampaio reservoir in 2010, where TSI values gradually increased

Figure 6 - Trophic State Index and trophic classification of the Pereira de Miranda reservoir



as the reservoir lost volume. The authors attributed this to the rainfall that occurred during the previous period, which contributed with high concentrations of phosphorus, together with the input of organic matter from the watershed.

Principal component analysis - PCA

Although eleven variables were evaluated, the sensitivity test carried out by the principal component analysis model identified that only nine of them had any significance in explaining the total variance of the data (Table 2). The Kaiser-Meyer-Olkin (KMO) test for adequacy, presented an index equal to 0.65, considered acceptable according to Silveira and Andrade (2002), showing that the model can promote a significant reduction in the dimension of the original data (ANDRADE *et al*., 2010). Lopes *et al*. (2014a), studying the factors that determine surface-water quality in the Orós reservoir, which is located in the basin of the Alto Jaguaribe river in Ceará, found a lower value for KMO, of 0.60, albeit still classified as acceptable.

To minimise the high degree of difficulty in identifying significant factors in the factor loading matrix, orthogonal transformation was used, employing the Varimax method, or a simple rotation of the factor loading matrix, thereby maximising the weighting of each principal component (ANDRADE *et al*., 2010; LOPES *et al*., 2014a). As a result, the components C1, C2 and C3, showed variance values of 31.75%, 29.43% and 21.15%, respectively, explaining 82.33% of the total variance (Table 2). Similar results were found by Li, Li and Zhang (2011), using multivariate analysis in identifying natural and anthropogenic sources of surface water pollution in the Changjiang and Huaihe basins of the Yellow and Haihe rivers in China, where they found a model comprising five components and explaining 83.35% of the total variance. Ferreira *et al*. (2015), studying water quality in the Orós reservoir, found a model for the surface waters formed by four components and explaining 66.04% of the total variance.

C1 presents high positive coefficients for FSS (0.926), TSS (0.904) and P_{total} (0.700), and a negative coefficient for transparency (-0.670). The variables grouped by component C1 mainly represent a physical, nutrient factor, expressing the influence of the surface runoff from agricultural areas, anthropogenic areas, and bare soil. In addition, 66.3% of the total area of the watershed of the Pereira de Miranda reservoir is dominated by a Luvissol, which, according to Lopes *et al*. (2011), is more susceptible to erosion.

The results showed that transparency is directly influenced by the concentrations of suspended solids, since low values for transparency are related to the resuspension of sediment caused by the wind when the volume of water in the reservoir is low.

Component 2 consisted of the variables Ntotal (0.915), temperature (0.824) and electrical conductivity (0.775), showing a greater association with the variable indicating enrichment by nutrient and soluble ions. Nutrients are mainly produced by natural sources, the release of domestic and industrial sewage, human activities, animal excretion, fertilisers for agriculture, and the use and occupation of the land.

Table 2 - Rotated factor loading matrix of the limnological variables transformed using the Varimax algorithm

Variable	Factor		
	C1	C2	C3
FSS (mg L^{-1})	0.926	-0.054	0.257
TSS (mg L^{-1})	0.904	0.034	0.325
Ptotal (mg L^{-1})	0.700	0.517	-0.048
Transparency (m)	-0.670	-0.121	-0.627
Ntotal	0.091	0.915	0.140
Temperature (ºC)	-0.151	0.824	0.183
EC (dS m^{-1})	0.282	0.775	-0.250
pH	0.339	-0.176	0.865
Cl-a (µg L^{-1})	0.137	0.464	0.688
Eigenvalue (Fi)	2.858	2.649	1.903
Variance (%)	31.753	29.435	21.150
Accumulated Variance (%)	31.753	61.188	82.338

Present in the C2 component, temperature is considered an important factor, which, according to Souza, Bertossi and Lasteria (2015), interferes with chemical and biochemical reactions, in addition to altering biological processes that take place in water. High values for temperature indicate the presence of nutrients that are in the reservoir for natural reasons or through anthropogenic action (FRANÇA *et al*., 2013). For EC, a high coefficient is characteristic of environments with increased concentrations of soluble ions due to low storage volumes, a result of the long period of drought and intense evaporation in the semi-arid region.

C3 received the greatest weight from pH and Chlorophyll-a, respectively (Table 2), being a component indicating organic pollution. Here, C3 appeared as a component indicating anthropogenic action on water quality. In studies carried out by Lopes *et al*. (2014a) in the Orós reservoir, the authors found that the main causes of the sources of diffuse pollution were the agricultural and pastoral activities in the region, and the low percentage of households connected to the domestic sewage network in the watershed of the Orós reservoir, which influenced nutrient concentrations in the surface waters.

There is a relationship between pH and Cl-a in C3, which represents the influence of various chemical and biological processes in bodies of water (SOUZA; BERTOSSI; LASTORIA, 2015). The pH can be directly influenced by the photosynthetic rates of the ecosystem, since when these increase, favoured by nitrogen and phosphorus enrichment of the water, the pH of the water tends to rise, becoming more alkaline due to a reduction in the concentrations of carbon dioxide in the water (BUZELLI; CUNHA-SANTINO, 2013).

The limnological variable, chlorophyll-a, is considered an indicator of the presence of nutrients, especially phosphorus and nitrogen, as seen in C1 and C2 (Table 2). The presence of chlorophyll-a in aquatic systems represents the effect of the eutrophication process, which is the phenomenon by which an ecosystem becomes increasingly productive through nutrient enrichment (CHAVES *et al*., 2019; LOPES *et al*., 2014a). The eutrophication process has a global impact on the environment, and is one of the most serious problems related to water conservation (SMITH; SCHINDLER, 2009). According to data from COGERH (2019), of the 140 artificial surface reservoirs monitored in the state of Ceará in August 2018, 75% had their waters classified as eutrophic.

CONCLUSIONS

1. The limnological variables of water quality under analysis proved to be greatly influenced by the volume of stored water and by the temporal variability of the rainfall in the region. The smaller the volumes of stored water, the worse the water quality of the Pereira de Miranda reservoir;
2. The Pereira de Miranda reservoir was classified as super-eutrophic throughout the study period; the results show that it suffers strong anthropogenic action, promoting nutrient enrichment and the consequent proliferation of potentially toxic organisms (cyanobacteria) that rules out its being used for many purposes;
3. Principal component analysis allowed the selection of three components that indicate the quality of surface water, explaining 82.34% of the total variance. The variations in water quality were defined by one group of suspended solids, one group of nutrients and soluble salts, and one group of organic material.

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