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EVALUATION OF THE WATER QUALITY OF THE MACEIÓ STREAM ESTUARY

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ABSTRACT

Water quality monitoring is an important tool to recognize the potential and deficiencies of the aquatic environments supporting capacity. The objective of this study was to monitor the water quality of the Maceió Stream estuary, located on the coast of Fortaleza-CE. Were evaluated the following parameters: Temperature, pH, Dissolved Oxygen, Biochemical Oxygen Demand, Nitrate, Total Phosphorus, Total Solids and Turbidity. The laboratory analyzes were followed as proposed in Standard Methods (APHA, 2001), with the exception of nitrate parameter, evaluated by the UV Method. Friedman's non-parametric statistical analyzes and the Spearman Correlation Matrix were also applied. The parameters that presented the worst scenarios were: DO, BOD and TP. Seasonality has shown important influence under the dynamics of monitored quality indicators. Statistical correlations allowed the recognition of influence factors on water quality and enhanced the dynamics of lotic environments. There was no significant variation between the concentration values of the parameters, according to Friedman's test. The Maceió Stream estuary presents a visible environment of water quality degradation, such as: proliferation of macrophytic algae in the water mirror, silting, deposition of solid waste, fish mortality, among other factors, which require effective mitigation actions.

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INTRODUCTION

Water resources have undergone an increasing process of degradation of quality and availability, mainly due to the anthropic impacts generated by the disorderly urban growth. The irregular launch of industrial and domestic effluents, deforestation, occupation of the banks, plumbing, among other degrading factors, have led to the loss of water and ecosystems quality. The watersheds are subject to a large number of diverse environmental impacts, such as the incidence of erosive processes (furrows, ravines and gullies), silting of drainage channels, inadequate disposal of diversified solid wastes, pollution and contamination of continental water resources (rivers, lakes, dams and reservoirs), soil exposure and remobilization of sediments, removal of riparian forests and lowland areas, which are often due to the disorderly growth of cities (CONTRI CAMPANELLI e LORANDI, 2012). Monitoring of water quality in a watershed is an important tool of data production and recognition of water resources deficiencies and potentials (MAIA, CARVALHO I e CARVALHO II, 2015). The monitoring of physical and chemical variables has some advantages in the evaluation of environmental impacts in aquatic ecosystems, such as: immediate identification of changes in the physical and chemical properties of water; precise detection of the modified variable and determination of these altered concentrations (CHAPMAN, 2016).

Ogata et al. (2016) emphasize that in order to carry out water quality control and monitoring, it is important to select indicators that express the water situation in an agile, cheap and representative manner. These indicators can be considered as sentinels and auxiliaries. Water availability has been threatened in quantity and quality by anthropogenic interference. Tucci (2004) stated that the population increase have an directly influence to the large amount of pollutants from domestic sewage, creating an inappropriate aquatic environment not only for consumption but also for the existence of the local biota. Maceió Stream estuary receives a high anthropic pressure, due to the diversity of socioeconomic activities developed in its surroundings, which, associated to the disordered urban growth, generate negative impacts on the water quality, affecting the supporting capacity of this environment. Given this scenario, monitoring is a necessary tool for recognizing the potentialities and deficiencies of water quality in this site, that constitutes an area of intense visitation, as well as for the diversity of water resources uses.

METHODOLOGY

Study Area: The research was carried out in the estuary of the water system called the "Papicu/Maceió Water Complex" (Figure 01), which is delimited by the UTM coordinates of 9,586,000 m South and 556,417 m East at 556,420 m West and North with the Atlantic

Ocean. The water complex, an integral part of the “Vertente Marítima” Watershed, is formed by the Papicu Lagoon, Papicu and Maceió streams and its estuaryis located inMucuripe Beach, occupying an area of 6 km^2, draining the districts of Papicu, Varjota, Mucuripe and Vicente Pinzon (SILVA, 2003).

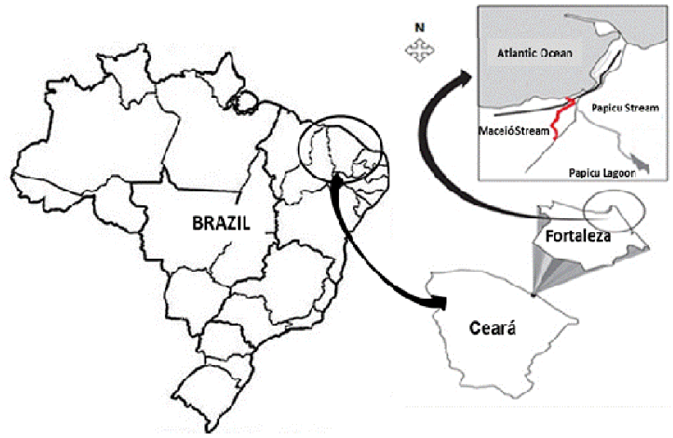

Figure 1. Papicu/Maceió Water Complex, Fortaleza-CE (modified from Silva *et al.*, 2011)

The estuary has the following peculiarities, according to a municipal report of the *Orla* Project (2006):

- Characteristics: Bowed edge (inlet) and exposed; incipient vegetative cover; direct access; consolidated urbanization with high density. Excerpt with verticalization (residential, commercial and hotel buildings). Beach line associated with coastal engineering works with the construction of protection spikes (Iracema beach embankment). Beach sector with urban drainage equipment (rain gutters) with clandestine sewage connections.

In 2013 was carried out the construction of the *Otacílio Teixeira Lima Neto*’s Park, where the stream section monitored in this study is located. There is no difficulty in accessing the water resourceat the park area, which favors the use of water for various activities, such as fishing, bathing, leisure, among others, already reported by local residents, street dwellers or even employees responsible for maintaining the park.

Sampling points and collection period: The point’s sampling occurred from September 2015 to July 2016, totaling six collections on a bimonthly basis. The monitoring covered two characteristic climatic periods of Fortaleza, dry and rainy climate. On, September 2015 was characterized as dry period, December 2015 and January to March of 2016, characterized the rainy season, after this rainy interval, the months of May and July of 2016 again characterized the dry period.

Point 01

- It has the geographic coordinates of 3°43'25.1"S and 38°28'57.9"W, located in the boundaries of *Bisão* Park, being the closest point of *Abolição* Avenue, a larger one at the park area, and also the first in the Maceió Stream estuary downstream sense.
- This point is close to buildings bordering the park, as well as, receives the first contributions of water from the rain gutters of the Papicu-Maceió water complex estuary.
- It also presents an excessive growth of plants that have adhered to the sediments accumulated on the sides of the stream channel, besides the deposition of solid residues.

Points 02 and 03: It has the following geographical coordinates: 3°43'25.1"S and 38°29'00.4"W and 3°43'24.8"S and 38°29'01.8"W, respectively. Both located in the middle of the park. It is noteworthy that in the vicinity of each collection points there is an exit from the culvert of the area's drainage system, which flows into the stream. The Figure 02 shows the three collection points.

Figure 2. Sampling Points (Google Earth, 2017)

Laboratory methods: The laboratory analyzes were followed according to the methodologies indicated in Standard Methods, as proposed by Silva (2001) in the Manual of physical-chemical analyzes of water supply and wastewater, except for the nitrate parameter, evaluated by UV Method (Table 01).

Table 1. Laboratory methods for analyzing water quality parameters (Author, 2017)

Parameter	Laboratory evaluation method
Temperature	Celsius graduated thermometer (measurement in loco)
pH	Electrometrically through potentiometers and electrodes
Dissolved Oxygen	Iodometric Method or Winkler Method
Total phosphorus	Ascorbic acid method after digestion with persulfate
Nitrate	UltravioletMethod
Total Solids	Gravimetric Method
Turbidity	NephelometricMethod
BOD	BOD at 20 ° C - for 5 days (BOD_5)

The laboratory results of the parameters were compared with Resolution no. 357/2005 of the National Environmental Council (CONAMA), according to the Maximum Permissible Values (MPA).

Statistical analyzes: Initially, was tabulated the data obtained in the field research with their due concentration values already calculated. Subsequently, was performed the descriptive statistical analysis of the data, addressing the following parameters: mean, median, quartiles, interquartile range test, standard deviation, number of data, maximum, minimum. The grouping of the statistical variables supported the construction of the "boxplot" graphs, which together with the descriptive statistics tables served as a representation of the results obtained for each parameter of water quality. The statistical method used was the non-parametric Friedman test, considering that the data did not present normal distribution, considering the small number of elements per series evaluated. In order to classify the significance between the variations of the parameters, a level of significance of 5% was used with tabulated probabilistic values, where: $p > 0.05$ (non significant); $0.01 < p \leq 0.05$ (significant); $0.001 < p \leq 0.01$ (very significant); $p \leq 0.001$ (extremely significant). The correlation between parameters was also evaluated, also considering each period of collection campaigns and covering the seasonal periods, according to the method of the Spearman Correlation Matrix, since this allows the use of data applied in non-parametric tests, such as Friedman. The Spearman matrix has a score for each parameter ranging from -1 to 1 and has the following classification: from $0 \geq r > 0.3$ (weak correlation); of $0.3 \geq r > 0.6$ (regular correlation); of $0.6 \geq r > 9.0$ (strong correlation); of $0.9 \geq r > 1$ (very strong correlation); $r = -1$ or 1 (perfect or full correlation). For the statistical calculations of the data series in question, the following programs were used: MicrosoftExcel 2013, SPSS (version 20, IBM), R statistic and the R STUDIO interface. The data was tabulated in the Microsoft Excel and Word programs, both in the 2013 version, for a better visualization of their results.

RESULTS

None of the parameters presented significance greater than or equal to 0.05, according to Friedman's test. Board 01 and Figure 03 will bring the concentration values of the parameters and their graphical representation, respectively, after the discussion of the results.

Board 1. Monitored parameters's concentration values from september 2015 to july 2016 (Source: Author, 2017)

PARAMETER	POINTS	MONTHS 2015 Sep.	2015 Dec.	2016 Jan.	2016 Mar.	2016 May	2016 Jul.	MPA
Temperature	T1	27	28	28	29	30	28	30 °C
	T2	29	29	29	28	29	28	
	T3	29	29	30	28	30	30	
pH	PH1	7,06	7,42	6,70	5,96	7,32	6,61	6 a 9
	PH2	7,34	7,48	7,14	6,15	7,55	6,61	
	PH3	7,61	7,44	7,28	6,41	7,47	6,48	
DO	DO1	2,4	3,7	5,3	5,2	4,3	2,6	≥ 6 mg.L^{-1}
	DO2	1,9	3,9	5,6	2,5	3,8	2,6	
	DO3	4,5	4,6	6,6	4,8	3,8	3,8	
BDO	BOD1	36,7	39,2	11,8	16,2	3,8	15,3	≤ 3 mg.L^{-1}
	BOD2	12,2	13,8	9,8	22,7	4,3	5,0	
	BOD3	36,7	25,0	23,8	23,8	1,8	5,4	
Total Phosphorus	TP1	0,5	1,5	1,3	0,7	1,3	0,8	≤ 0,02 mg.L^{-1}
	TP2	0,6	1,3	1,1	0,6	1,1	1,1	
	TP3	0,5	1,6	1,0	0,7	1,0	1,0	
Nitrate	N1	1,4	1,5	3,3	0,5	5,0	3,4	≤ 10 mg.L^{-1}
	N2	1,3	1,5	3,2	0,5	3,8	3,6	
	N3	1,4	1,6	3,1	0,4	3,8	3,6	
Total Solids	TS1	436	426	486	186	381	447	≤ 500 mg.L^{-1}
	TS2	434	732	437	160	355	446	
	TS3	436	541	472	160	322	461	
Turbidity	TD1	10,50	10,50	11,05	11,10	38,00	6,30	≤ 100 mg.L^{-1}
	TD2	9,30	9,15	6,05	32,50	8,00	5,30	
	TD3	10,50	11,10	11,05	38,00	10,50	9,00	

DISCUSSION

pH: Most of the mean and point values are within the range according to CONAMA resolution no. 357/2005, which indicates the pH range between 6 and 9 as ideal. The parameter presented higher concentration variations in the rainy season, which may be due to the arrival of the urban washing waters, rainwater, which may have caused a reduction in the value of the parameter concentrations soon after precipitation events. According to Pereira (2004) the acidity in the aquatic environment is caused mainly by the presence of carbonic gas, mineral acids and hydrolyzed salts. Acidification of the aquatic environment can occur due to the release of the hydrogen ion, when an acid reacts with water. Also according to the author, variations in pH in this environment are also related to the dissolution of rocks, absorption of gases from the atmosphere, oxidation of organic matter and photosynthesis.

Temperature: The CONAMA Resolution no. 357/2005 does not indicate an ideal range of MPA for this parameter, however, CONAMA Resolution no. 430/2011 treats that effluents discharged into water resources must have a temperature below 40ºC, and the temperature variation of the should not exceed 3°C at the boundary of the mixing zone. Therefore, it was considered to evaluate the thermal amplitude between the points of each collection campaign, which are characterized by mixing zones, since they receive occasional releases of effluents. Point 03 presented higher values of temperature, in general, being this place more exposed to sunlight, which may have contributed to this result. The points presented temperatures in the range of 26.5°C to 30°C, the lowest temperatures being identified in the rainy season, mainly in march 2016, during which the harvest occurred in an intense precipitation event. The thermal amplitudes between the points were outside the ideal scenario established by CONAMA Resolution no. 430/2011. The collections occurred between 9:00 a.m. and 12:00 p.m, which characterizes the temperatures as a function of this, which possibly easily changes at the mouth of the MaceióStream, due to its shallow depth. According to IPECE (2016), average Fortaleza temperatures are in the range of 26ºC to 28ºC.

Dissolved Oxygen (OD) and Biochemical Oxygen Demand (BOD): The concentrations of both parameters were mostly outside the maximum permissible values, according to CONAMA Resolution no. 357/2005, where the DO can't have values less than or equal to 6 mg.L^{-1} and the BOD is not greater than or equal to 3 mg.L^{-1}. The high concentrations of BOD are associated to the presence of aerobic bacteria, which consume oxygen during their metabolic activity, thus generating a biochemical demand, which in this case ends up being superior to the recovery capacity of DO concentrations in the water. The contribution of organic sewage entails an increase in nutrient concentrations, such as nitrogen and phosphorus, being one of the factors that can maximize the bacterial activity of organic matter decomposition in water resource and the reductions in DO concentration. The organic matter introduced into the body of water is progressively decomposed by biological activity. The growth of populations of saprobic and detritivorous microorganisms increases in case of eutrophication. The increase in the activity of the microbial saprobic population increases the demand for oxygen and can result in the excessive consumption of DO, which can generate an anoxia condition, which directly affects other organisms due to their respective tolerances to dissolved oxygen depletion (QUEIROZ, SILVA and TRIVINHO-STRIXINO, 2008). Most of the correlations between DO and BOD presented directly proportional results of "regular" classification (r = 0.5), with the exception of points 02 and 03 in the rainy season, where the first presented a regular but indirectly proportional correlation (r= -0.5), and the second very strong correlation was directly proportional (r = 0.9). The high BOD concentrations, added to the lotic flow, may have favored a differentiated scenario in this section, where oxygenation of water is maintained, but there is also a persistence of BOD concentrations. This scenario is confirmed, since when applying the Spearman Correlation to the Silva (2003) and Maia (2010) data, studies already

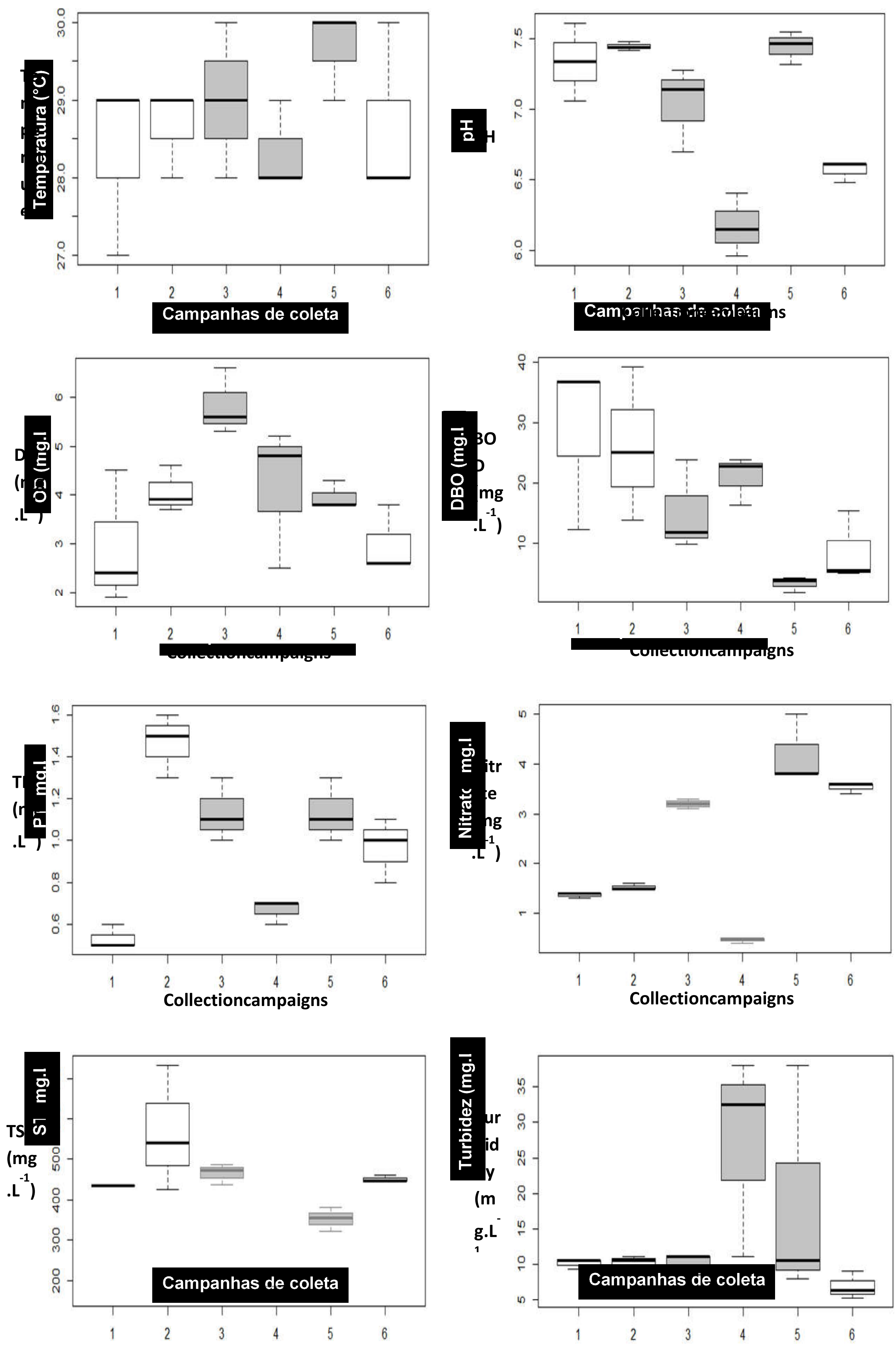

Figure 3. Box plots representations of the monitored parameter's concentrations (Source: Author, 2017)

performed in Maceió Stream, both presented the same type of correlation. The correlation between BOD and rainfall was equal to -0.086, since the correlation between DO and precipitation was equal to 0.829, that is, with the renewal of the water volume, there is a greater influence of the change of the net mass and the exchange surface gas with atmospheric air, which leads to the belief that these factors positively influence the recovery of DO concentrations, a factor favored by the lotic regime of the water body. The water lotic flow regime could have a better positive influence on the recovery of DO's concentration, however, there are a number of local factors that hinder the efficiency of this process, such as: deposition of solid waste in the banks and channel; evident silting of the stream bed; artificial structures that are part of the channeled bed; the excessive growth of plants in sediments deposited in the banks and channel bed, among other factors. Silva (2003) reported problems related to the degradation of the stream, alerting to the growth of negative impacts. The author reported that the substances present in the sewage exert a deleterious action on the bodies of water, where the organic matter would cause exhaustion of the dissolved oxygen, leading to the mortality of fish and other aquatic organisms, and until the darkening of the water and the appearance of stink.

Phosphorus: All values found are outside of the maximum permitted values, according to CONAMA's No. 357/05 resolution, which establishes the concentration of 0.1 $mg.L^{-1}$ for freshwater lotic water, Class II. In general, Point 01 presented the highest values of TP concentration, which may be related to the receipt of the upstream flow that comes from the creek channel and receives a series of occasional releases, which add to the gallery's own launch located at this point. In addition to the reduction of water flow by barriers formed by sediment and vegetation that accumulate at this point. In all the channelized section of the microbasin there is the presence of rainwater galleries, which in turn end up carrying effluents from the rains and also receive clandestine sewage, events that had already been approached in the studies of Silva (2003) and Maia (2010), proved situation on field visits. The correlation between DO and TP was perfect in most of the studied section, for the dry season (P1: r = 1, P2: r = 1, P3 r = 0.5), and regular for the rainy season (P1: r = -0.5, P2: r = 0.5, P3: r = -0.5). The predominance of the directly proportional relations in the dry period is related to the constant effluent release in the monitored section, as well as to the lotic flow regime. In the rainy season, there is an increase in water volume and flow velocity, which leads to a large amount of effluent released into the watershed.

In the aquatic environment, phosphorus consumption may be related to the activity of aerobic heterotrophic microorganisms. To study such behavior, the Spearman correlation was performed between BOD and TP. Where: Dry period (P1: r = 0.5, P2: r = 0.5, P3 r = -0.5) and Rainy Period (P1: r = -1, P2: r = -1, P3 r = -0.9). For the dry period, Points 01 and 02 presented a directly proportional correlation, indicating that, with the increase of the TP concentrations, initially, there is the consumption by the heterotrophic microorganisms, which increases the BOD concentration. At Point 03, there was an inverse correlation, probably due to the growth of BOD concentration, about four times higher than the previous one. In the rainy season, the three points presented an inversely proportional correlation, Points 01 and 02 underwent a considerable change after the precipitations from january to may 2016, due to the reduction in BOD concentrations and increase in TP concentrations. The high concentrations of TP in the aquatic environment can lead to the growth of algae, some of which are toxic, and also macrophytes, which occupy a large part of the water surface, or even its totality, mainly in small water bodies, for example, *Maceió* Stream's case, thus initiating the process of incoming blocks of the solar rays in the water and impeding the photosynthetic processes in the lower water body layers, degrading factors to the quality of the aquatic environment, the ecosystem and even the health of those who use this water. The presence of excessive phosphorus has as a characteristic the increase of algae and other aquatic plants such as macrophytes causing eutrophication of water bodies, making it impossible to use and experience their natural biota (QUEVEDO and PAGANINI, 2011). Consequently, there is a reduction in DO concentrations, which impairs other life forms, such as fish, benthic macroinvertebrates, algae that are located in the lower water bodies layers, among others, from that point a predominantly anaerobic-optional process, in which the decomposition of organic matter results in the release of toxins that cause even greater damage to water quality, such as hydrogen sulphide gas, harmful to human health. Eutrophication can enable more intense growth of living things that use nutrients, especially algae. These large concentrations of algae can damage the multiple uses of these water resources, seriously damaging the public supply or causing pollution resulting from the death and decomposition of these organisms (CETESB, 2009).

Nitrate: No concentration values of NO_3^- were found in disagreement with the limits established in CONAMA Resolution No. 357/05, for Class II fresh waters, equal to 10 $mg.L^{-1}$ of NO_3^-. The 2015's months of September and december and 2016's march presented the lowest average values and punctual of concentration. The month 2016's march presented the lowest point values, where: P1 = 0.54 $mg.L^{-1}$; P2 = 0.51 $mg.L^{-1}$ and P3 = 0.42 $mg.L^{-1}$. In 2016's may, the highest point values (4.95 $mg.L^{-1}$, 3.84 $mg.L^{-1}$ and 3.77 $mg.L^{-1}$) and medium (4.18 $mg.L^{-1}$). Although there are reductions in concentrations, after precipitationss, there is an increase in rainfall, since the sewage, as well as the domestic and industrial effluents, is one of the main sources of macronutrients in polluted waters. In order to identify the influence of these effluents on the water body, the correlation between the Nitrate and BOD parameters was calculated, where: Dry Period (P1: r = -0.5, P2: r = -0.5, P3 r = -1) and Rainy Period (P1: r = -1, P2: r = -1, P3: r = -0.9). The indirect correlations between the parameters characterize some factors, such as the consumption of macronutrients by aerobic organisms, a commonly cited factor, however, it is important to point out that nitrate can be fixed by the plants that grow next to the sediment banks present in the stream's channel bed, besides the permeability of the local soil.

The quartz sand, a soil that composes the pedology of the studied section, presents great potential of porosity and permeability, which allows substances, such as nitrate, to reach the groundwater, the level of which, in the area, even perpetuates themicrobasin flow. According to EMBRAPA publication (2017), although phosphorus adsorption is small in these soils, there are serious problems with nitrogen leaching and rapid decomposition of organic matter. The leaching of nitrates and sulphates is intense because of the great macroporosity and permeability of sandy soils. Although nitrate as a nitrogen compound represents one of the main macronutrients present in polluted waters along with phosphorus, it is necessary to evaluate the geological, vegetative and other aspects that may interfere with the nutrient cycle in the aquatic environment. According to PHA (2017): "The control of eutrophication, through the reduction of the nitrogen supply, is compromised by the multiplicity of sources, some very difficult to be controlled as the fixation of the atmospheric nitrogen, by some genera of algae. Therefore, it is preferable to invest in the control of phosphorus sources ". The photosynthetic activity of the algae can reduce the concentrations of DO and nitrogen, due to the consumption required in the transformation processes of the nitrogenous forms (CETESB, 2009).

Turbidity: The rainy period had a considerable influence on the parameter concentrations, since with higher rainfall volumes, there was an increase in its, the sediments deposited in the banks and channel bed of the watershed are carried by the flow of the liquid mass, or even retained in the banks of sand and vegetation already consolidated in the channel of the creek, facts that can justify the decrease of the values of concentration occurred, more markedly, in the period of March to July of 2016, soon after the reduction of the volume of the rains. Point 03 presented the highest values of concentration in the collections of 2015's september and december, a result that may be related to the punctual launch of sewage, as already discussed, since there are discharges of sewage at all points in the monitored area. Subsequently, Point 01 presented the highest values of concentration, which is justified by the volume of sediment already accumulated in this stretch and also the high growth of vegetation, which retain sediments drained from the amount and point release. In the dry period, the minimum values of Turbidity are recorded, since at this time the main sources of feed of the superficial water bodies are the groundwater, which undergo a natural process of filtration, appearing with very low values of turbidity (ANA, 2011). Silva (2003) reported that the area where streams flows from the *VertenteMarítima* Basin, consists of sandy sediments of old dunes, which favors the superficial percolation of the water table that feeds these springs and thus is more significant the ease of infiltration of water flows.

The urban expansion and its interventions together with the absence of planning radically altered the dynamics of the *Maceió/Papicu* Hydrographic System. Despite the implementation of a large infrastructural contribution in the east coast of the city, the consequences were harmful to the environment and to the populations that live close to the water courses (MAIA, 2010). The creek has been degraded by the deposition of solid waste and civil construction, real estate speculation, irregular constructions, among other urban aggravating factors. Carvalho et al. (2014) pointed out that when generated in urban areas the sediments are fruit of the lack of planning in the occupation and use of the soil. The solid particles can serve as shelter and support for microorganisms, in this sense, it was chosen to evaluate the correlation between Turbidity and BOD (P1: r = -0.5, P2: r = 0.5, P3 = 0.5, P3 = 0.5) and the rainy season r = 0.9). The predominance of directly proportional correlation was observed, which may reiterate the approach of Von Sperling (2005): "... suspended solids can serve as shelter for pathogenic organisms". It is important to remember that the studied section receives contributions of effluents of varied nature, which can increase the chance of the presence of pathogens in the liquid mass and consequently in the suspended sediments. These sediments are also responsible for changes in the pH of the water, since the dissolutions of mineral matter influence the equilibrium of the acidity of the water. Therefore, the correlation between Turbidity and pH was evaluated, resulting in: Dry Period (P1: r = 0.9, P2: r = 0.5, P3 r = 0.5) and Rainy Period (P1: r = 0 , 5; P2: r = -0.5; P3: r = -1). The lower mean concentrations of pH in the rainy season, tendency to acidity, may justify the inversely proportional correlations observed in Points 02 and 03, since the acidity leads to the degradation of the solid particles suspended in the water. The reduction of the pH, tendency to acidity, can cause the dissolution of suspended particles that impart turbidity to the water, which can reduce the concentration values of the parameter (FUNASA, 2014).

Total Solids: Most of the values found in the monitoring met the VMPs established by the CONAMA Resolution No. 357/05, which is 500 $mg.L^{-1}$ of ST. However, points 02 and 03 presented results higher than the value established by law, 732 $mg.L^{-1}$ and 541 $mg.L^{-1}$, respectively, both in the campaign of December 2015, month that enters the dry period and that also has the highest monthly average value of the parameter, 566 $mg.L^{-1}$. Another considerable fact, many of the concentrations of this parameter already approach the maximum allowed value, which reinforces the tendency of silting of the estuary, fact visible in the place. The accumulation of litter and sediment is visible in the place, where they accumulate in the bed, mainly in points 02 and 03. Due to the fact that it is the lowest point in the topography, this area has natural factors favorable to the accumulation of sediments, such as sediment transport by gravity and natural water flow and wind transport, which adds to the anthropic impacts, such as (2003) and Maia (2010), such as the removal of vegetation from the dunes near the Papicu Lagoon, which exerted an important factor of reduction of the wind action on the sediments of the Maritime Basin. In the rainy season there is a reduction in the average concentrations of the parameter, a fact that can be justified by the increase of water flow velocities, leading to the transport of solids towards the sea. With the reduction of rainfall volume, from 476 mm in March 2016 to 123 mm and 3.3 mm in May and July 2016, respectively, an increase in mean concentrations (352.67 mg.L-1 and 451.17 mg.L-1) and point of the parameter, a scenario similar to that of the first collections, which also occurred in periods of low rainfall indexes. Total solids can interfere with the penetrability of light, making it impossible for the microorganisms' physiological activities, as well as retaining bacteria and organic residues (CETESB, 2017). In order to understand this dynamics, it was chosen to correlate ST and DBO, where: Dry Period (P1: r = -1, P2: r = 0.5, P3 r = -0.5) and Rainy Period (P1: r = -0.5; P2: r = -0.5; P3: r = 0). The lotic environments present a complex character in the total solids dynamics, since the flow forces, rainfall, erosion processes, soil sealing, urban drainage, among other factors, generate instability in the parameter concentration values. makes it difficult to establish a determining factor that justifies the correlations.

However, if the concentration of organic matter present in the total solids is considered, it is degraded by the organisms that generate the biochemical oxygen demand. In lotic environments, under organic conditions, organic matter, such as leaves and other materials of plant or animal origin, penetrate the system due to the erosion of the river banks, as well as the fall of the foliage of the riparian forest. In addition, the discharge of organic effluents, such as domestic sewage and those resulting from the processing of food and other biological materials, also increases the amount of organic matter (CPOM and fine particulate - FPOM) naturally present in a river (Queiroz, SILVA and TRIVINHO-STRIXINO, 2008). Von Sperling (2005) reports that phosphorus presents two types of natural and anthropogenic origin, from which various sources of this nutrient are subdivided, such as organic matter decomposition, cellular composition of organisms, household and industrial waste, detergents, excrement animals, fertilizers, dissolution of soil compounds. The correlation between ST and PT showed a predominance of directly proportional values: Dry Period (P1: r = -1, P2: r = 1, P3 r = 1) and Rainy Period (P1: r = 0.5, P2: r = 0.5, P3: r = 0.5) Point 01 proved to be an exception in the dry period, a result that can be justified by the intense accumulation of solids in the sandbanks and vegetation at this point, a factor that reduces the solids concentration in the net mass, which does not occur with the phosphorus, since there is a frequent increase of the punctual launching of effluents, causing the perenniality of the PT concentration. In the beds of the Papicu and Maceió Riachos, the sediments are of average biodetritic sand, presenting good amount of organic matter. The confluence of the Papicu and Maceió streams presents sediments composed of fine, finely selected biodetritic sand, characterized by a high concentration of organic matter, probably due to the large discharge of domestic effluents in the area (SILVA, 2003).

The Papicu / Maceió water system presents a very compromising picture regarding environmental conditions. In this sense, several impacts were identified in the general context of the area, such as: water contamination associated with erosion and silting processes, as well as the reduction of the water table of the Papicu lagoon (SILVA, MEIRELES and PEREIRA, 2011). The dissolution of solid particles can alter the water quality, as already noted, as well as the pH concentrations. Von Sperling (2005) reports that the constituent forms of pH are: dissolved solids and dissolved gases. The author also highlights the natural dissolution of rocks and solid material. In order to understand the dynamics of this event in the studied section, we chose to apply the Spearman correlation between ST and pH, resulting in: Dry Period (P1: r = -1, P2: r = 0.5, P3 r = -0,5) and Rainy Period (P1: r = 0.5, P2: r = 0.5, P3: r = 0.5). After the precipitations of March 2016, the highest volume (476 mm), pH tended to acidity, a period in which there was a reduction in ST concentration, which may be related to the formation of weak acids by the reaction between the dioxide of carbon and water, forming carbonic acid, a substance that degrades solid materials, especially those rich in organic matter. The predominant soil of the stretch is of low fertility and high propensity to erosion and weathering.

CONCLUSION

Most of the evaluated parameters were within the maximum values allowed by the current legislation. However, parameters such as OD, BOD and PT presented most or all concentration values in disagreement with the laws, which are some of the main responsible for the health of aquatic environments. The statistical method of correlations proved to be efficient in the understanding of the local reality, since its point variation reiterates the dynamic character of the lotic water resources, as well as, it enabled the recognition of deficiencies and potentialities of the monitored environment. The mouth of the Maceió Creek presents a clear picture of degradation of the water quality, with deposition of solid waste in the banks and channel bed, fish mortality, proliferation of macrophytes and vegetation in its bed, silting up, launching of underground sewage, among others factors that have led to water pollution and the loss of the quality of the water ecosystem.

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REFERENCES

BRASIL – Agência Nacional das Águas (ANA). Parâmetros de Qualidade de água. Superintendência de Gestão da Rede Hidrometeorológica, 2011;

BRASIL. Ministério da Cultura, Agropecuária e Abastecimento. Areia Quartzosa /NeossoloQuartzarênico. Disponível em: <http://www.agencia.cnptia.embrapa.br/Agencia16/AG01/arvore/AG01_2_10112005101955.html> Acesso em: 26/03/2017;

BRASIL. Conselho Nacional do Meio Ambiente. Resolução CONAMA nº 357/2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Brasília-DF, 2005;

BRASIL. Conselho Nacional do Meio Ambiente. Resolução CONAMA nº 430/2011. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução N° 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente-CONAMA. Brasília-DF, 2011;

BRASIL. Ministério da Saúde. Fundação Nacional de Saúde. Manual de controle da qualidade da água para técnicos que trabalham em ETAS / Ministério da Saúde, Fundação Nacional de Saúde. – Brasília: Funasa, 2014. 112 p;

BRASIL. Ministério do Meio Ambiente – Projeto Orla, Fortaleza-CE. PLANO DE GESTÃO INTEGRADA DA ORLA MARÍTIMA. Fortaleza-CE, agosto de 2006;

CARVALHO, J. C. de; SALES, M. M.; SANTOS JÚNIOR, O. F.; MAROT, D.; CAMPOS, L. E. Um paralelo quanto aos mecanismos de surgimento e evolução de erosões continentais, fluviais, de bordo de reservatório e costeiras. VII Congresso Luso-Brasileiro de Geotecnia, Goiânia – GO, setembro de 2014;

CEARÁ - Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE); Perfil Básico Municipal – Fortaleza, Fortaleza – CE, 2016;

CHAPMAN, D. WATER QUALITY ASSESSMENTS - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition. Disponível em: <http://www.who.int/water_sanitation_health/resourcesquality/watqualassess.pdf>Acessed in: 11/12/2016;

CONTRI CAMPANELLI, L.; LORANDI, R..Importance of aquifer unit chart to the preparation of (geo)environmental zoning - case study of the Monjolinho river watershed (São Carlos, SP, Brazil). In: Revista de Geología Aplicada a laIngeniería y al Ambiente, nº 29, p. 83 – 90, 2012;

GOOGLE EARTH. Programa de Visualização de Imagens de Satélite, 2017;

MAIA, A. A. D.; CARVALHO, S. L. de; CARVALHO, F. T. de. Comparação de dois índices de determinação do grau de trofia nas águas do Baixo Rio São José dos Dourados, São Paulo, Brasil. In: EngSanitAmbient., v.20, nº 4, 613-622, out/dez 2015;

MAIA, E. B. DINÂMICA GEOAMBIENTAL DO SISTEMA HÍDRICO MACEIÓ/PAPICU, FORTALEZA –CEARÁ. Mestrado em Desenvolvimento e Meio Ambiente da Universidade Federal do Ceará. Fortaleza-CE, 2010;

OGATA, I. S.; OLIVEIRA, R. de; MEIRA, C. M. B. S.; NASCIMENTO, R. S. de; HENRIQUES, J. A. Avaliação de Risco à saúde associada à qualidade da água para consumo humano em Campina Grande, Paraíba. In: RBCIAMB, nº 40, p. 1-15, junho de 2016;

PEREIRA, R. S. Identificação e caracterização das fontes de poluição em sistemas hídricos. Revista Eletrônica de Recursos Hídricos. IPH – UFGRS. V.1, nº 1, p. 20-36, 2004. Disponível em:<http://www.abrh.org.br/informacoes/rerh.pdf>. Acesso em: 09/11/2017;

QUEIROZ, J. F. de; SILVA, M. S. G. M. e; TRIVINHO-STRIXINO, S. Organismos bentônicos: biomonitoramento de qualidade de água. Embrapa Meio Ambiente, Jaguariúna – 2008;

QUEVEDO. C.M.G.; PAGANINI. W. S. Impactos das atividades humanas sobre a dinâmica do fósforo no meio ambiente e seus reflexos na saúde pública. - Universidade de São Paulo - Departamento de Saúde Ambiental - FSP/HSA. 2011;

SÃO PAULO. PHA-USP. CARACTERÍSTICAS FÍSICAS DAS ÁGUAS: COR, TURBIDEZ, SÓLIDOS, TEMPERATURA, SABOR E ODOR. Disponível em: <http://www.pha.poli.usp.br/LeArq.aspx?id_arq=731> Acesso em: 09/11/2017;

SÃO PAULO. PHA-USP. NUTRIENTES: COMPOSTOS DE NITROGÊNIO E FÓSFORO EM ÁGUAS. Disponível em: <http://www.pha.poli.usp.br/LeArq.aspx?id_arq=1807> Acesso em: 09/11/2017;

SILVA, P. R. F. G.da; MEIRELES, A. J. de A., PEREIRA, J. S. DIAGNÓSTICO DA QUALIDADE DA ÁGUA DO SISTEMA HÍDRICO PAPICU/MACEIÓ, FORTALEZA, CEARÁ, BRASIL. Arq. Ciên. Mar, Fortaleza, 2011, 44(3): 81 – 86;

SILVA, P. R. F. G.. Indicadores ambientais do complexo hídrico Papicu/Maceió, Foretaleza-CE. Dissertação de mestrado em Desenvolvimento e Meio Ambiente, UFC. Fortaleza-CE, 2003;

SILVA, S. A. Manual de analises físico-químico de aguas de abastecimento e residuárias. Rui de Oliveira – Campina Grande, Paraíba. 2001;

TUCCI, C. E. M. Desenvolvimento dos Recursos Hídricos no Brasil. Global WaterPartnership (South America). Associação Mundial da Água – SAMTAC. Janeiro, 2004;

VON SPERLING, M.Introdução à Qualidade das Águas e ao Tratamento de Esgotos(Princípios do Tratamento Biológico de Águas Residuárias; vol. 1). Belo Horizonte: DESA-UFMG, 452p. 2005;

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