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Influence of the Hydrological Regime on the Water Quality from the Lake of the Francesa - Parintins/Amazonas/Brazil

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The objective of this work was to evaluate the quality of the water from the lake of the Francesa in the city of Parintins/AM, taking into account the hydrological regime of the Amazon region. The study was based on analysis of the physiochemical parameters: temperature, pH, electrical conductivity, turbidity, suspended solids, dissolved oxygen, chemical and biochemical oxygen demand, total phosphorus, phosphate, total nitrogen, ammonia and nitrate. The collection periods covered the months of March and July of 2012 and 2013, totaling four collections. The results show that the lake receives a high load of urban wastewater, being evidenced in the high content of nutrients phosphorus, nitrogen compounds and expressive variation in the concentration of dissolved oxygen in the water level. Despite this, the lake has its own characteristics of environments with the ability to maintain the ecological balance in the period of greatest volume of water (July).

1. Introduction

To ensure the life of river dwellers and to ensure the intake of a substance that is not harmful to the health of the population, water quality is assessed through the analysis of some parameters of physical, chemical and biological characteristics described in the 357/2005 Resolution of the National Council of the Environment (Conama).
A large amount of residues is produced by human activities, and has as its final destination its disposal in the environment, mainly in rivers and lakes, causing the increase in environmental problems and diseases in communities exposed to these conditions. Commonly these aquatic ecosystems have the ability to assimilate and neutralize toxic substances through physical, chemical and biological mechanisms. However, when contaminants exceed the capacity to purify these bodies of water, organisms present in the aquatic environment may suffer damages in their life cycle or even in their conduct (Cooney, 1995). Among the environmental problems, the mortality of botanic species and fauna stand out, some of which have great ecological importance in the environment (Goulart and Callisto, 2003). The fish mortality in the aquatic environment, for example, can significantly reduce the availability of employment and food for different riverine communities, especially in places where this economy is strong, in the case of the Amazon.
From this context, it is necessary to study the changes in the water quality of the lake of the Francesa, considering the environmental and economic significance for the municipality of Parintins/Am.

2. Description of place of study

The lake of the Francesa is located in the municipality of Parintins, state of Amazonas (Figure 1), its formation is directly related to the Amazon River and lake of the Macurany. The municipality of Parintins has an area of 5,952 Km^2 and a population of 102,033 inhabitants (IBGE, 2010). It has a tropical, rainy climate, with a small dry period (August to October), relative air humidity around 71 % and annual rainfall of 2,327 mm. The region presents variation in the level of its waters, a natural phenomenon in the Amazon, it is characterized by two very distinct periods throughout the year, high waters (flood) and low waters (ebb/dry). Being that in this last period, the lake disappears completely.

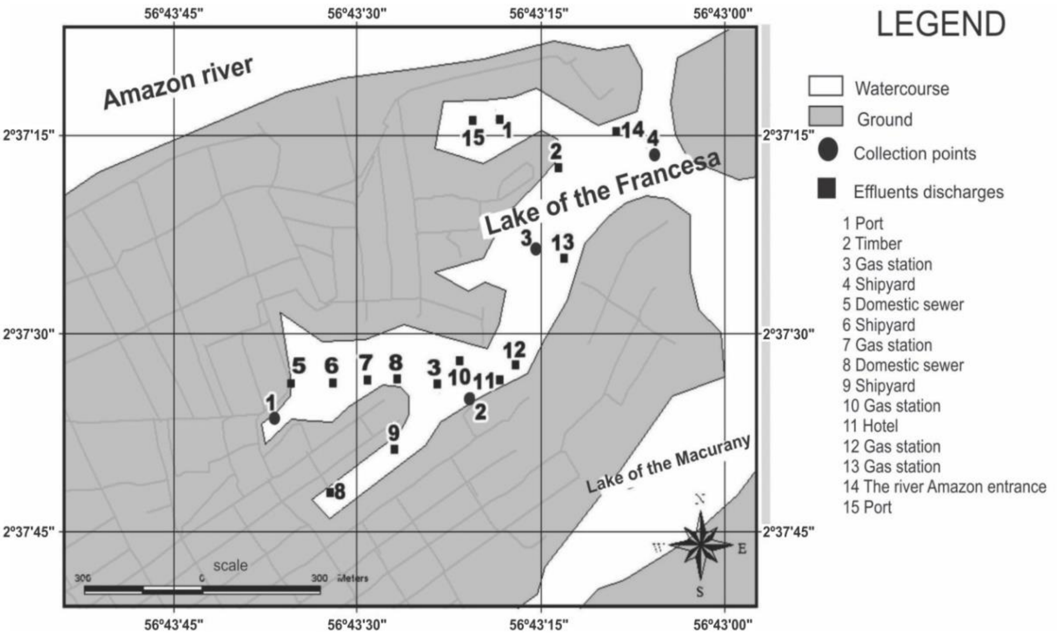

Figure 1 – Location map of the lake of the Francesa with collection points and polluting sources.

In order to assess the water quality of the lake of the Francesa, four collections were committed in the periods of March and July in the years of 2012 and 2013, which comprehends different water levels of the lake under study. The water samples were collected at strategic points of the lake considering the urban areas and a less urbanized area. Table 1 shows the collection sites, the anthropic interventions observed at the sites and their geographic coordinates.

Table 1: Location and description of sampling areas and their geographical coordinates.

Period	Description	Geographic coordinates	
F1	Pond staircase - strong influence of domestic sewage, ship dumping	Latitude Longitude	02º 37.604 56º 43.610
F2	Hotel/Floating fuel station, influence of domestic sewage	Latitude Longitude	02º 37.577 56º 43.343
F3	Logging company/Floating fuel station	Latitude Longitude	02º 37.391 56º 43.255
F4	Entrance/exit of the lake - area of less urbanization	Latitude Longitude	02º 37.278 56º 43.112

3. Sampling and determination of physic-chemical parameters of water

The collection periods were determined according to the hydrological regime of the Amazon region, thus comprising different water levels of the lake, 1.5 liters of water sample were collected with a Van Dorn type of collection bottle, placed in polyethylene bottles to determine the water quality parameters in laboratory. The physic-chemical parameters pH, conductivity, dissolved oxygen and temperature were measured at the time of sample collection with the aid of portable equipment. A pH-meter of the Quimis brand was used for pH and a Lutron CD-4303 conductivity meter was used for conductivity. The dissolved oxygen was determined by the modified Winkler method, as described in Golterman et al. (1971). For the other parameters, conservation and storage were carried out according to the parameter to be determined and sent to INPA's environmental chemistry laboratory. In the laboratory, the BOD_5 described in Golterman et al. (1971) was established. COD by the titration method according to APHA (2003), solid in suspension by gravimeter, turbidity, nitrogen and total phosphorus by spectrophotometry in the FIA – Flow Injection Analysis. The concentrations of ammonia, nitrate and phosphate were determined by ion chromatography (Dionex, ICS 2500).

4. Results and discussion

The results obtained for the physic-chemical parameters are described in Table 2 and 3 for the samples performed in the year 2012 and 2013 respectively.
In the 2012 collections (Table 2), the water temperature ranged from 29.9 °C (F4 in March) to 34 °C (F1 in July). In 2013, there was variation between 30.2 ºC (F2 and F3 in March) and 33.9 ºC (F3 in July). It was observed an increase in the period of July, which is characteristic of the Amazonian environments and are consistent with the air temperature in the period. According to Alves et al. (2012), the lower water temperatures occur due to the cloud cover, which does not allow the incidence of solar rays on the surface of the water, whereas in the less rainy period more hours of solar incidence occur and allows the increase of temperature.
The pH did not show large variations, they remained close to neutrality, Kimura (2011) observed this behavior in previous periods, with values ranging from 6.36 to 6.92 (in 2012) and from 6.03 to 7.10 (in 2013). It should be noted that the maximum value (7.10) is very punctual differing from the others and was only observed in the collections of 2013. This increase is attributed to the discharge / sewage of the hotel located in the sampled site.

Table 2: Physicochemical parameters for the periods of March and July of 2012.

Parameters	Period	F1	F2	F3	F4
Temperature ºC	March	30.4	30.6	30.5	29.9
	July	34.0	33.4	32.9	32.4
pH	March	6.5	6.5	6.6	6.5
	July	6,6	6,7	6,7	6,8
Electrical conduction (µs/cm)	March	63,6	50,2	50,0	46,6
	July	119,7	60,6	46,9	38,8
Turbidity (UNT)	March	3,6	5,9	5,9	7,8
	July	16,8	22,1	21,1	21,8
Suspended Solids (mg/L)	March	2,4	4,0	2,8	4,6
	July	19,7	32,3	28,7	25,3
DO (mg/L)	March	1,1	3,4	3,5	2,9
	July	5,5	5,3	6,9	6,3
BOD (mg/L)	March	0,01	2,0	0.5	0.07
	July	5.3	4.4	3.3	1.09
COD (mg/L)	March	36.8	35.5	35.5	36.1
	July	30.9	29.7	27.1	27.1
Ptotal (mg/L)	March	0.2	0.14	0.09	0.11
	July	0.09	0.16	0.13	0.07
Phosphate (mg/L)	March	ND	ND	ND	0.01
	July	ND	ND	ND	0.007
Ntotal (mg/L)	March	0.18	0.38	0.3	0.21
	July	3.3	1.06	0.5	0.37
NH_4^+ (mg/L)	March	0.78	0.20	0.19	0.19
	July	2.2	0.41	0.23	0.27
Nitrate (mg/L)	July	0.02	0.06	0.02	0.02
	March	0.4	0.63	0.30	0.06

The conductivity showed a similar behavior in both years, its maximum values were observed in the months of July for both years. There was a decrease of concentration in relation to areas F1 and F4, which is due to the location of collection areas in relation to the urban impact, that is, F1 is in the most urbanized area while F4 is less urbanized, demonstrating that the sewage originated from the urban area contributes to the degradation of the water of the lake of the Francesa. According to Guimarães and Nour (2001), such sewage, mostly from residences consists, basically, of urine, feces, food waste, soap, detergents and washing waters, containing a high amount of organic matter, which contribute to the entrance, in the body of water of ionic species.
Regarding to suspended solids, this variable, in addition to discriminating the quality of the rivers, according to Silva et al. (2008), is the one that is most influenced by the seasons, and also directly influences the turbidity

values, and this condition was observed in the annual collections. The values were in the range of 32.33 and 47.0 mg/L (maximum suspended solids) and 22.1 and 25.22 UNT (turbidity maxima) both observed in the month of July, demonstrating that these parameters have higher loads in this period

The levels of dissolved oxygen for the collections of 2012 presented low concentrations in March with a minimum of 1.10 mg/L and a maximum of 3.53 mg/L. These values are all lower than the limit established by CONAMA Resolution 357/05 that says not to be less than 4 mg/L of O_2. However, the values referring to July of the same year had values with a maximum of 6.96 mg/L and a minimum of 5.24 mg/L. The reduction of oxygen in the water is associated with a high load of organic matter, in which the microorganisms withdraw the oxygen from the water to its metabolism in the degradation of the organic matter. However, there was no association with high BOD indices in the same period, which would be expected. Although the decrease in DO can be attributed to natural conditions, such as high temperatures, it is worth mentioning that the lagoon receives a heavy load of sewage from the urban area, which, associated with the low level of water, creates conditions of a practically anoxic environment.

In general, in the 2013 collections, the DO was similar to 2012, with values below the CONAMA 357/05 limit, with the exception of area F2.

Table 3: Physicochemical parameters for the periods of March and July 2013.

Parameters	Period	F1	F2	F3	F4
Temperature ºC	March	30.9	30.2	30.2	30.3
	July	31.5	33.6	33.9	32.7
pH	March	6.6	7.1	6.6	6.03
	July	6,5	6,7	6,7	6,9
Electrical conduction (µs/cm)	March	60,9	57,2	43,7	38,4
	July	75,2	54,7	40,8	34,1
Turbidity (UNT)	March	1,0	5,5	6,2	5,7
	July	25,2	15,1	12,7	15,3
Suspended Solids (mg/L)	March	2,6	1,0	11,0	7,7
	July	47,0	25,7	18,3	16,0
DO (mg/L)	March	2,9	8,4	3,9	3,4
	July	3,5	6,01	7,1	7,4
BOD (mg/L)	March	0,01	0,01	2.5	0.6
	July	0.01	0.01	2.3	1.1
COD (mg/L)	March	24.6	23.4	24.1	22.7
	July	35.2	25.1	20.1	21.3
Ptotal (mg/L)	March	0.2	0.18	0.16	0.05
	July	0.15	0.13	0.07	0.05
Phosphate (mg/L)	March	0.01	0.008	0.001	0.01
	July	0.05	0.01	0.005	0.007
Ntotal (mg/L)	March	1.5	1.98	0.6	0.4
	July	2.9	1.39	0.78	0.44
NH_4^+ (mg/L)	March	0.4	0.09	0.1	0.07
	July	1.47	0.2	0.2	0.2
Nitrate (mg/L)	July	0.2	0.008	0.05	0.02
	March	2.6	1.18	0.39	0.09

Regarding phosphorus, all the areas had their concentrations above the established limit (0.05 mg/L P) by resolution CONAMA 357/05 (class 3). In both years, the highest concentrations are in the month of March, and this is due to the low water level. Following the hydrological cycle of the Amazon region, in March the water levels are rising, so the high levels of this and other nutrients such as nitrogen tend to concentrate. However, July is the highest level of water, the reduction of concentration is associated with the capacity of dilution of the pond as a function of the volume of water.

Phosphate was practically absent in 2012, values were only found at F4 areas. In 2013, there was an increase in all areas, indicating the presence of anthropogenic source. The phosphate, besides being related to the oxidation of the urban sewage, can come from the chemical decomposition of the polyphosphates used in the manufacture of detergents. The highest concentrations can be observed in the area of the lake of the Francesa, mainly in the local F1 area of greatest urban interference.

The correlation matrix composed of water quality variables can be seen in Table 4. According to Helena et al. (2000), coefficients with correlation higher than 0.5 express a strong relation. There was a very strong correlation between SS and Turbidity (r=0.90), NH_4^+ and conductivity (r=0.91). Correlations between nitrogenates were expected, as well as NH_4^+ conductivity since this, expressed presence of salts in water. The strong and negative correlation between DO and COD expresses an expected behavior for these variables.

Table 4: Correlation matrix of the water quality indicator variables of the lake of the Francesa.

Variable	Temp	pH	Cond	Turb	SS	DO	BOD	COD	Ptotal	PO_4^-	N_{total}	NH_4^+	NO_3^-
Temp	1.00												
pH	-0.05	1.00											
Cond	0.25	-0.02	1.00										
Turb	0.67	0.22	-0.09	1.00									
SS	0.79	0.06	0.14	0.90	1.00								
DO	0.40	0.72	-0.18	0.43	0.32	1.00							
BOD	0.42	0.13	0.18	0.11	0.30	0.33	1.00						
COD	-0.30	-0.28	0.40	-0.12	-0.10	-0.71	-0.24	1.00					
Ptotal	-0.46	0.21	0.27	-0.13	-0.10	-0.27	-0.28	0.36	1.00				
PO_4^-	0.25	-0.04	0.16	0.21	0.36	-0.08	-0.12	0.06	-0.06	1.00			
N_{total}	0.45	0.22	0.76	0.16	0.41	0.26	0.21	-0.08	0.16	0.50	1.00		
NH_4^+	0.41	-0.13	0.91	0.12	0.37	-0.17	0.18	0.37	0.08	0.24	0.72	1.00	
NO_3^-	0.57	-0.04	0.33	0.57	0.74	0.00	-0.09	0.12	0.12	0.76	0.62	0.46	1.00

The factorial weights attributed to each component, as well as the percentage of the total variance explained by each component, can be observed in Table 5. The first three components explained respectively 33.9, and 23.20 and 13.2 % of the total data variance, concentrating on three dimensions 70.30 % of information. The values of the factorial weights are expressed for the components CP1, CP2 and CP3, which express the relation between factors and variables allowing the identification of the variables with the highest interrelationships in each component.

Table 5: Matrix of the factorial weight of water quality variables in the three main components.

Parameters	CP1	CP2	CP3
Temperature	-0.83	-0.30	-0.16
Suspended solids	-0.86	-0.21	-0.29
Total Nitrogen	-0.78	0.27	0.43
NH_4^+	-0.65	0.58	0.27
NO_3^-	-0.82	0.24	-0.34
Turbidity	-0.68	-0.38	-0.35
Phosphate	-0.54	0.23	-0.34
Ptotal	0.10	0.49	0.29
Electrical conduction	-0.51	0.65	0.49
COD	0.09	0.79	-0.16
DO	-0.34	-0.80	0.39
BOD	-0.32	-0.32	0.55
pH	-0.14	-0.43	0.59
% explained variance	33.90	23.20	13.20
% accumulated variance	33.90	57.10	70.30

5. Conclusions

The hydrological regime of the region contributes to the variation of the water quality parameters of the lake of the Francesa. In the low water period (March) turbidity, suspended solids and nitrogen compounds presented high levels. The dissolved oxygen presented lower concentrations always in the month of March without presenting relation with the BOD. The use of the Principal Component Analysis (PCA) promoted the reduction of the surface water variables of the lake of the Francesa to three components, which account for 70.30 % of the total variance. The rotation of the factors showed that the water quality parameters of the lakes are mainly related to nutrients (anthropic action). The lake still maintains its capacity to dilute the pollutants, especially in the period of greatest volume of water (July). However, some parameters are close to the legal limits (CONAMA 357/05) indicating the need to implement an environmental management program to avoid problems with pollutants in the short term.

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