

Physicochemical characterization of Lagoon of the Indians in Macapá-AP-Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JSC, SSMSA, RSR and CBR designed the study, wrote the protocol, involved in writing the first draft, participated in experiments and data collection. Authors FSB, DCB and ACC managed the literature search, analyses of the study and manuscript preparation. Author JSC, ACC and CBRS performed the statistical analysis and also aided in data interpretation and was actively involved in reading the manuscript. All authors read and approved the final manuscript.

ABSTRACT

Aims: Characterize Lagoon of the Indians from physico-chemical parameters with reference to the CONAMA nº357/2005 resolution and recommendations of the EPA, as well as statistical analysis of seasonal and temporal variability and correlation.

Study design: The collections were conducted at five points in the Lagoon of the Indians in Macapá-AP-Brazil, during the wet period (Nov/2010) and dry period (March/2011). Analyses were performed for seventeen physico-chemical parameters according to APHA (1998). The metals were determined by Atomic Absorption Spectrometry (AAS Model 6300) Shimadzu. The pH was determined in situ with ORION pH meter Model 3 STAR, portable pH, trademark THERMO.

Place and Duration of Study/Methodology: The determination of physico-chemical parameters were performed in the Chemistry, Sanitation and Modeling of Environmental Systems Laboratory, and in the General and Analytical Chemistry Laboratory of Federal University of Amapá, between November 2010 and March 2011. Statistical analyzes were performed using BioStat 5.0 software.

Results: Five parameters showed discordance with the reference values: pH, dissolved oxygen (DO), dissolved Fe, dissolved Mn and Colour. Alkalinity showed values outside the EPA standards unlike the hardness that presented accordingly. EC and TSS have no reference values, but the determined values can be considered normal when compared to other existing results in publications about Amazonian waters. The results for biochemical oxygen demand (BOD), dissolved aluminum, ammonia nitrogen, total dissolved solids (TDS), nitrate, chloride and turbidity measurement showed in accordance with the reference values of CONAMA and EPA. The seasonal data analysis (Kruskal Wallis test) showed significant differences between the parameters for the collection points. Significant differences (t-test) were also observed between dry and wet period for alkalinity, EC, TDS

and dissolved iron parameters. Statistical results for the Kruskal Wallis test, t-test and CV show a high level of heterogeneity for the Lagoon of Indians. The correlation matrix shows results expected for the physico-chemical parameters: a positive correlation between pH and alkalinity, EC and pH, alkalinity, TDS, and negative correlation between DO and BOD, and other significant values.

Conclusion: The concentration of physico-chemical constituents showed lower values in the wet period, which may be related to the increase of water level depending the level of rainfall. The Lagoon of the Indians showed normal values for most parameters, however, parameters in disagreement with the CONAMA nº357/2005 resolution and EPA may mean initial changes in the physico-chemical composition of the lagoon. The correlation results allow us to infer that the interaction dynamics of physico-chemical parameters follow normal patterns compared to other results obtained for analysis of the same type in other aquatic environments.

Keywords: Lagoon of the Indians, physico-chemical characterization, CONAMA nº357/2005 resolution, EPA, spectrophotometry.

1. INTRODUCTION

In the Brazilian urban context excessive growth of aggregate population to new patterns of production and consumption, results in huge amounts of toxic waste pollutants with disastrous effects on biodiversity. The lack of planning is a serious problem, which causes large population concentration in a small area, increasing the occupation of the peripheric and risk areas [1]. The situation arises particularly dramatic in urban and metropolitan areas, especially in areas where housing conditions, sanitation and access to leisure and recreations are increasingly precarious. The low sanitation conditions generate problems such as: pollution of rivers, lakes, coastal zones and bays. This has caused continuous environmental degradation by dumping of increasing volumes of organic and inorganic residues. The release of untreated sewage into the Lagoon of the Indians has increased significantly in recent decades, with severe impacts on fauna, flora and human beings [2].

In Amapá state the cities of Macapá and Santana have a high level population improper of the areas of "undertow". The term "undertow" is used regionally to denominate the various lakes in existing floodplains in the state of Amapá. These lakes occur during the wet period (winter) which extends from December to June. Rain water feeds rivers and igarapes inundating these areas. During the dry season (summer), the waters are mainly concentrated in the channels of rivers and the water levels of the hangovers reduce significantly. The term is also used to define the areas which behave as natural water reservoirs, which are characterized by a complex and distinct ecosystem, under the influence of tides and rainfall [3].

Areas of hangovers are predominant in almost all the urban perimeter of Macapá. The decharacterization of some of these areas due to human occupation, is already evident, even without formal diagnosis. The occupation of hangovers turns out to influence these ecosystems due to lack of minimum housing conditions (such as sanitation, for example) resulting in indiscriminate waste disposal from livestock rearing and recreation that eventually degrade and disfigure the nature of these environments. The Lagoon of Indians located in the city of Macapá-AP is an area of hangover that in recent years has suffered from various environmental problems as a result of over-population and siting of unplanned settlements [4, 5].

The main objective of this work was the characterization of the Lagoon of the Indians from physicochemical parameters with based on statistical analysis, the CONAMA Resolution 357/2005 [6] and regulations of the U.S. Environmental Protection Agency - EPA [7] with respect to urbanization and industrialization around this water body.

2. MATERIAL AND METHODS

2.1 Location of Lagoon of the Indians, collection and analysis of samples

The samples were collected in two periods: Dry (November, 2010) and wet (March/2011), at five points in Lagoon of the Indians (Figure 1) defined with the aid of Garmin GPS device. The depth of the Lagoon of the Indians presents, on average, 1.5m in the dry season and 3m deep in the wet season.

The collection and preservation of samples were carried out in accordance with the Manual of Procedures and Laboratory Techniques aimed at Analysis of Water and Sanitary Sewage and Industrial of University of São Paulo-Brazil (USP/Brazil) [8].



Fig. 1. Satellite image of Lagoon of the Indians, Macapá-AP.

Source: Google, 2014

Laboratory analyzes were performed in triplicate at the laboratory of chemistry, sanitation and modeling of environmental systems of Federal University of Amapá. The

determination of chloride, alkalinity, nitrates, ammonium nitrogen were performed according to Standard Methods recommended by - APHA [9]. Analyses of Biochemical Oxygen Demand (BOD) were performed using the Winkler method. The analysis relating to determinations of metals (aluminum, iron and manganese) were conducted using Atomic Absorption Spectrometry AAS Model 6300 Shimadzu at the Laboratory of Atomic Absorption and Bioprospecting (LAAB). The determination of the parameters total hardness, colour, total suspended solids (TSS) and total dissolved solids (TDS) were performed with model DR2800 spectrophotometer HACH trademark and turbidity determinations were obtained from the American Home turbidimeter AP2000. The physical parameters such as (temperature, pH, conductivity and dissolved oxygen - DO) were taken in-situ by the use of probe YSI multiparameter model 556MPS trademark and ORION pHmeter Model 3 STAR, portable pH, trademark THERMO. As análises estatísticas de correlação, teste de Kruskal-Wallis e t-test foram realizadas com auxílio do software BioEstat 5.0.

In Brazil the law which serves as reference standard to compare changes in freshwaters is the CONAMA Resolution 357/2005, is a resolution of the National Council on the Environment (Portuguese acronym for the Conselho Nacional do Meio Ambiente - CONAMA), agency under the Ministry of Environment. In the United States this function is the U.S. Environmental Protection Agency - EPA.

Table 1 shows that the limit values available by CONAMA Resolution 357/2005 and by the EPA.

Table 1. Limit values for the physicochemical parameters.

Parameter	Limit values	
	Brazil	USA
Temperature	–	–
pH	between 6 and 9	Between 6.5 and 9
Alkalinity	–	Min 20 mg/l
Electrical Conductivity (EC)	–	–
DO	Max 5 mg/l	Max 4 mg/l
BOD	Max 5 mg/l	mg/l
		0 - 75 soft
Hardness (mg/l Ca or Mg CaCO ₃)	–	75 - 150 moderately hard
		150 - 300 Hard
		300 and up very hard
Iron dissolved	Max 0.3 mg/l	Max 0.1 mg/l
Aluminium dissolved	Max 0.1 mg/l	Max 0.087 mg/l
Manganese dissolved	Max 0.1 mg/l	Max 0.1 mg/l
Ammonia nitrogen (mg/l NH ₃ -N)	3.0 mg/l N, to pH ≤ 7.566 2.0 mg/l N, to 7.5 < pH ≤ 8.0 1.0 mg/l N, to 8.0 < pH ≤ 8.5 0.5 mg/l N, to pH > 8.5	3.48 mg/l N, to pH ≤ 6.5 3.0 mg/l N, to 6.5 < pH ≤ 7.0 1.0 mg/l N, to 7.0 < pH ≤ 8.0 0.25 mg/l N, to pH > 8.0
Colour	Max 75 mg/l PtCo	Max 75 mg/l PtCo
TSS	–	–
TDS	Max 500 mg/l	Max 500 mg/l
Nitrate	Max 10 mg/l NO ₃ - N	Max 10 mg/l NO ₃ - N
Chloride	Max 250 mg/l Cl	Max 250 mg/l Cl
Turbidity	Max 100 NTU	–

The electrical conductivity and TSS parameters not regulated by CONAMA Resolution 357/2005 and the EPA, was analyzed to assist in better characterization of water

body studied, because present strong correlation with other parameters in aquatic environments.

3. RESULTS E DISCUSSION

3.1 Seasonal variability of physico-chemical parameters and compared with values CONAMA and EPA

Table 2 shows the results obtained for the parameters analyzed in five sampling points and their differences with the Kruskal-Wallis test. It is possible to verify that at least three points for the parameters analyzed, have significant differences. The results presented in the table below have their values compared to the values normalized by CONAMA and EPA.

Table 2. Mean concentrations of analyzed parameters for the Lagoon of the Indians in Macapá-AP-Brazil in Dry and Wet period.

Parameter	Period	Point 1	Point 2	Point 3	Point 4	Point 5
Temperature (°C)	Dry	25.90 ^{A,B}	28.21 ^A	26.83 ^C	28.97 ^{B,C}	27.84 ^C
	Wet	26.98	25.99 ^A	25.98 ^{B,C}	28.16 ^{A,B}	27.18 ^C
pH	Dry	4.726 ^{A,C}	5.486 ^B	5.791 ^A	5.625	6.101 ^{B,C}
	Wet	5.635	5.585 ^{A,B}	6.445 ^{A,C}	5.872 ^B	5.611 ^C
Alkalinity (mg/l CaCO ₃)	Dry	10.0	8.0 ^{A,B}	34.0 ^{A,C}	18.0 ^{B,D}	8.0 ^{C,D}
	Wet	6.0	6.0 ^A	32.0 ^{A,B}	14.0	6.0 ^B
Electrical conductivity (µS/cm)	Dry	58 ^{A,C}	160	165 ^A	76 ^B	232 ^{B,C}
	Wet	19 ^A	14 ^{B,C}	83 ^{A,B}	29 ^C	27
DO (mg/l)	Dry	1.31 ^{A,B}	4.24 ^{A,C}	1.49	2.14 ^B	1.47 ^C
	Wet	1.55	4.22 ^{A,B}	1.14 ^A	1.03 ^{B,C}	2.21 ^C
BOD (mg/l)	Dry	1.71 ^{A,B}	4.53 ^{A,C}	1.79 ^C	1.97 ^B	1.84
	Wet	1.52 ^{A,B}	1.42 ^C	0.9 ^A	0.46 ^B	1.38 ^C
Hardness Mg CaCO ₃ (mg/l)	Dry	0.57 ^A	2.67 ^{A,B}	2.12	0.56 ^{B,C}	2.33 ^C
	Wet	0.43	0.25 ^{A,B}	0.83 ^{A,C}	0.30 ^C	0.57 ^B
Hardness Ca CaCO ₃ (mg/L)	Dry	0.85 ^A	0.15 ^{A,B}	0.81	1.03 ^{B,C}	0.77 ^C
	Wet	0.99 ^A	1.02 ^{B,C}	0.98	0.66 ^B	0.65 ^{A,C}
Iron dissolved (mg/l Fe)	Dry	4.51 ^A	3.38 ^B	2.66 ^{A,C}	4.00	5.73 ^{B,C}
	Wet	1.76 ^A	2.56 ^{B,C}	0.90 ^B	0.88 ^{A,C}	1.16
Aluminium dissolved (mg/l Al)	Dry	0.030 ^{A,B}	0.051 ^A	0.039 ^C	0.05	0.091 ^{B,C}
	Wet	0.020 ^A	0.059 ^{A,B}	0.002 ^{B,C}	0.022	0.033 ^C
Manganese dissolved (mg/l Mn)	Dry	0.055 ^{A,B}	0.105 ^A	0.070 ^C	0.100	0.219 ^{B,C}
	Wet	0.049 ^A	0.075 ^{A,B}	0.062 ^C	0.033 ^{B,C}	0.054
Ammonia nitrogen (mg/l NH ₃ -N)	Dry	0.26 ^{A,B}	0.53 ^{A,C}	0.53 ^{B,D}	0.37 ^{C,D}	0.51
	Wet	0.13	0.04 ^{A,B}	0.69 ^{A,C}	0.07 ^C	0.14 ^B
Nitrate (mg/l NO ₃ -N)	Dry	1.70	0.80 ^A	0.70 ^{B,C}	1.80 ^B	2.50 ^{A,C}
	Wet	1.30 ^{A,B}	0.80 ^A	1.00	0.80 ^B	1.00
Colour (mg/l PtCo)	Dry	207 ^A	185 ^B	144 ^{A,C}	189	368 ^{B,C}
	Wet	111	164 ^{A,B}	120 ^C	72 ^{A,C}	107 ^B
TSS (mg/l)	Dry	16,0 ^{A,B}	21,0 ^C	22,0 ^A	26,0 ^{B,C,D}	21,0 ^D
	Wet	9,0 ^A	39,0 ^{A,B}	12,0	8,0 ^{B,C}	21,0 ^C
TDS (mg/l)	Dry	0.028 ^{A,B}	0.075	0.08 ^A	0.035 ^C	0.11 ^{B,C}
	Wet	0.009 ^A	0.007 ^{B,C,D}	0.041 ^{A,B}	0.013 ^C	0.013 ^D
Chloride (mg/l Cl)	Dry	62.98 ^{A,B}	54.56 ^C	21.88 ^A	24.65	17.48 ^{B,C}
	Wet	59.98 ^{A,B}	53.98 ^C	18.95	18.69 ^A	17.52 ^{B,C}
Turbidity (NTU)	Dry	10.6 ^A	6.6 ^{A,B}	7.44 ^C	9.3	14.8 ^{B,C}
	Wet	3.13 ^A	30 ^{A,B}	7.48 ^C	1.21 ^{B,C}	5.02

Means followed by the same letters in the horizontal differ significantly (Kruskal-Wallis p<0.05).

The parameters that had values outside the standards for both Brazilian regulations as to the American were pH, DO, Fe, Mn and colour.

The pH values show results according to the standards in point 5 in the dry period (pH = 6.101) and point 3 in the wet period (pH = 6.445). Even presenting values less than the standards, values are considered normal for Amazonian waters, which are slightly acidic [10], and are in agreement with results presented in studies conducted with waters of the Brazilian Amazon region [11,12,13,14]. The natural acidity characteristic of these waters may be related to the presence of potentially acidic substances, derived from various natural sources, which are carried from the soil to the waters of rivers and lakes [13,14,15].

The DO values were below the allowed for all the points in both the dry and wet period (highest value = 4.24 mg/l). The low DO concentration is due to the oxygen consumption caused by the decomposition of organic matter (oxidation) by microorganisms, material possibly originated from the release of waste dumped in water [16,17].

The results for dissolved iron showed values well above permitted at all points in both the dry and in the wet period (lower value = 0.90 mg/l and highest value = 5.73 mg/l) and the values of dissolved manganese were above the permitted only in points 2 and 5 in the dry period (point 2 = 0.105 mg/l and 5 point = 0.219 mg/l). These parameters can be naturally related to the geological characteristics of the region, where minerals are leached from soil to water [18]. And the high values can be attributed the dumping of waste as a result of anthropogenic influence. Metals in high concentrations can cause serious damage to animals and aquatic plants [19,20,21].

The colour parameter values presented in accordance with the permitted only at point 4 in the wet period (72 mg/l PtCo). Substances dissolved in the water can cause characteristic colour in water, some of these substances may be of organic origin (plankton, plant and animal) and inorganic origin (Fe and Mn ions, for example) [22].

The hardness and has no values standardized by the Brazilian environmental legislation, but has values regulated by EPA. Low values (less than 3 mg/l) for Ca and Mg in the dry and the wet period characterized as soft waters of all points. The hardness is the ability of water to precipitate soap and is described as the sum of polyvalent cations such as iron, barium, strontium, magnesium, calcium. These cations react with soap to form precipitates or react with anions forming crusts [23]. According to EPA, water with hardness values up to 75 mg/l are considered soft.

The EC has not values normalized by CONAMA and EPA. Significant differences are observed for values of EC in the dry period (higher values) and in the wet period (lower values). Results of electrical conductivity with high values in the dry period and low values during the wet period were determined in study conducted in Ribeirão Salgadinho in Xavantina-MT-Brazil [24]. The low values in the wet period may be related to a reduction in the concentration of electrolytic substances due to the increased volume of water.

The values of the parameters BOD, dissolved aluminum, ammonia nitrogen, STD, nitrate, chloride and Turbidity shown are all in agreement with both the CONAMA Resolution 357/2005 and with the values normalized by the EPA.

The BOD parameter value presented (4.53 mg/l), close to the reference values only at point 4 in the dry period. The value close of limit can be related to the creation of buffalo cattle near this point.

The value parameter of aluminum (0.091 mg / L) in Section 3 dry period showed values close to the limit values. The presence of dissolved aluminum in the soil can be extremely toxic to vegetation, especially in the wet period when the metal can react with acids precipitated with the rains, can also be carried to water bodies [21]. The existence of several homes near the point 3 (see Figure 1), as a source of waste disposal, can be related to the value obtained.

Ammonia Nitrogen and nitrate parameters showed low values (highest value 0.69 mg/l for NH₃-N and 2.5 mg/l NO₃-N) for all points in both the dry and wet period. Organic nitrogen is converted to ammonia by ammonification, ammonia is converted into nitrite by

nitrification, which is converted to nitrate by denitrification. The existence of ammonia nitrogen (mainly in large concentrations) indicates recent dumping of waste of animal and vegetable origin, therefore not yet occurred nitrification and denitrification [25,26]. The nitrate is end product of nitrogenous organic matter mineralization. Trace amounts of nitrate are present in natural waters and its increase may occur as a result of waste disposal or use of fertilizers in agricultural activities near rivers and lakes [27]. The low values of $\text{NH}_3\text{-N}$ indicate two possibilities: either there is low levels of waste of animal and vegetable origin, or ammonia would have been converted to nitrate (with higher values).

Measurements of TDS showed lower values in the dry period (higher value 0.110 mg/l) and in the wet period (higher value 0.041). Inorganic salts are the main constituents of dissolved solids, but may also contain dissolved gases and small amounts of organic [27]. Low values for TDS were also determined in research with the waters of the Rio Araguari, Amapá-Brazil [28].

The alkalinity reported higher only in point 3, with the dry period 32 mg / L CaCO_3 and wet period 34mg/L CaCO_3 . Physicochemical analyzes performed with water streams in Manaus-AM-Brazil [16], showed low levels of alkalinity in preserved areas. This may mean that the waters in point 3 may be in the early stages of change for this parameter. And the values provided by the EPA for alkalinity, cannot be considerable standards for Amazonian waters.

Chloride parameter showed low values compared to the reference values (maximum of 62.98 mg/l in the dry period and maximum of 59.98 mg/l in the wet period). In natural waters Cl^- ions originates from leaching of soil and rocks composed of chlorine salts, their values can be increased by the influence of waste disposal of households, industries and agricultural activities [22,29]. The low values can be attributed to the absence of agricultural activities near the sampling sites. And naturally absence of rocky soils near the Lagoon of the Indians [22].

Turbidity showed a higher value in point 2 in the wet period (30 NTU). The turbidity is related to the presence of organic and inorganic finely divided material, microscopic organisms, as well clay and silica in water. Its increase may be caused naturally by soil leaching and by anthropogenic influence from the dumping of waste [27]. The low turbidity values show that this parameter shows good results for Lake of the Indians. The increase in turbidity at point 2 in relation to the other points can be related to the presence of residences near this point (see Figure 1), which can result in dumping of waste organic and mineral origin.

The TSS parameter are not regulated by CONAMA and not by EPA. The values are below 40 mg/l for the dry and wet period. The suspended solids may contain toxic components such as heavy metals and pesticides and other pollutants originating from industrial waste, fertilizer, drainage of roads, drains, and soil erosion. [30]

3.2 Temporal variability and heterogeneity of the Lagoon of the Indians

Table 3 shows the results for t-test, where only the alkalinity, dissolved iron, electrical conductivity and TDS parameters showed significant differences relative temporal variability. Exists trend of these parameters, which in general, their values are higher in the dry season and lower in the wet period. These results allow us to infer that pluviosity significantly interfere in the dynamics hydrochemical of Lagoon of the Indians reducing the concentration of existing chemical constituents in relation to the increased volume of water in the wet period. Similar results were determined in research conducted in the waters of the basins of hangovers Igarapé of Fortaleza and Rio Curiaú in Macapá-Amapá-Brazil [4].

The data disposed in Table 3 shows the values of mean and Coefficient of Variation (CV) in relation to sampling points in dry and wet period. These results show that the Lagoon of the Indians have a high level of heterogeneity (high CV values). The extent of the lagoon and the different types of vegetation communities and existing animals and levels of human

227 occupation in their environment can be the causes for the large variations of the CV for most
 228 of parameters.

229
 230 Table 3. Variation in parameters values analyzed for the Lagoon of the Indians in Macapá-
 231 AP-Brazil in Dry and Wet period.

Parameters	Dry period			Wet period		
	Mean±se	Range	CV	Mean±se	Range	CV
Temperature (°C)	27.55±0.53	25.90-28.97	4.36%	26.85±0.41	25.98-28.16	3.40%
pH ^{ns}	5.54±0.23	4.72-6.10	9.28%	5.83±0.16	5.58-6.44	6.22%
Alkalinity** (mg/l CaCO ₃)	15.6±4.95	8-34	71.04%	12.8±5.04	6-32	88.11%
Electrical conductivity* (µS/cm)	138.2±31.8	58-232	51.54%	34.4±12.44	14-83	80.92%
DO ^{ns} (mg/l)	2.13±0.54	1.31-4.24	57.35%	2.03±0.58	1.03-4.22	64.47%
BOD ^{ns} (mg/l)	2.38±0.56	1.71-4.63	52.63%	1.13±0.2	0.46-1.52	39.38%
Hardness MgCaCO ₃ ^{ns} (mg/l)	1.65±0.45	0.56-2.57	60.97%	0.47±0.10	0.25-0.83	49.08%
Hardness ^{ns} Ca CaCO ₃	0.72±0.14	0.15-1.03	46.40%	0.86±0.08	0.65-1.02	21.83%
Iron dissolved** (mg/l Fe)	4.05±0.52	2.66-5.73	28.69%	1.45±0.31	0.88-2.56	41.12%
Aluminium dissolved ^{ns} (mg/l Al)	0.052±0.01	0.03-0.091	66.01%	0.027±0.009	0.002-0.059	41.12%
Nitrate ^{ns} (mg/l NO ₃ -N)	1.50±0.33	0.70-2.50	50.11%	0.98±0.09	0.80-1.30	20.91%
Manganese dissolved ^{ns} (mg/l Mn)	0.11±0.03	0.05-0.219	58.73%	0.05 ±0.007	0.033-0.075	28.51%
Ammonia nitrogen ^{ns} (mg/l NH ₃ -N)	0.44±0.05	0.26-0.53	27.46%	0.21±0.12	0.04-0.69	125.85%
Colour ^{ns} (mg/l PtCo)	218.6±38.7	144-368	39.63%	114.8±14.75	72-164	28,74%
TSS ^{ns} (mg/l)	21.2±1.6	16-26	16.81%	17,8±5.8	8-39	72.54%
TDS* (mg/l)	0.065±0.015	0.02-0.11	51.79%	0.016±0.006	0.007-0.04	83.65%
Chloride ^{ns} (mg/l Cl)	36.31±9.33	17.4-62.98	57.49%	33.82±9.50	17.52-59.98	64.57%
Turbidity ^{ns} (NTU)	9.75±1.44	6.60-14.80	33.12%	9.36±5.26	1.21-30.0	125.71%

232 (T-test) ns = Non significant, p<0.05, * = Significant, at 0.05, ** = Significant at 0.01

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 234

235 3.3 Correlation between physicochemical parameters

236 The Pearson correlation analyzes were performed individually for the dry period and
 237 the wet period and their values are shown in Table 4.

238 The pH and alkalinity showed a strong positive correlation in the wet period. The pH
 239 can be described as the measurement of the concentration of free water protons. The
 240 constituents of natural waters that influence pH are solid and dissolved gases, originated
 241 from the dissolution of rock materials, oxidation of organic matter and photosynthetic
 242 interactions, and also effluents of anthropogenic origin [31].

243 Tabela 4: Correlation between physico-chemical parameters

Parameter	Temperature	pH	Alkalinity	EC	DO	BOD	Hardness Mg CaCO ₃	Hardness Ca CaCO ₃	Iron dissolved	Al dissolved	Mn dissolved	Ammonia nitrogen	Nitrate	Colour	TSS	TDS	Chloride	Turbidity
Temperature	-	-0.28	-0.30	-0.35	-0.50	-0.48	-0.37	-0.81	-0.48	-0.14	-0.93	-0.49	-0.06	-0.87	-0.55	-0.39	-0.33	-0.66
pH	0.57	-	<u>0.99</u>	<u>0.97</u>	-0.56	-0.57	0.74	0.17	-0.60	-0.76	0.005	<u>0.92</u>	-0.06	-0.17	-0.43	<u>0.96</u>	-0.50	-0.26
Alkalinity	-0.14	0.24	-	<u>0.97</u>	-0.52	-0.57	0.73	0.17	-0.58	-0.73	0.02	<u>0.92</u>	-0.09	-0.13	-0.39	<u>-0.96</u>	-0.50	-0.22
EC	0.19	0.80	-0.02	-	-0.52	-0.42	<u>0.87</u>	0.15	-0.61	-0.76	-0.08	<u>0.97</u>	0.02	-0.10	-0.38	<u>0.99</u>	-0.54	-0.27
DO	0.51	0.009	-0.33	0.09	-	0.58	-0.48	0.34	<u>0.88</u>	<u>0.92</u>	0.76	-0.44	-0.35	0.84	0.97	-0.49	0.50	<u>0.93</u>
BOD	0.37	-0.02	-0.37	0.17	<u>-0.98</u>	-	-0.05	0.44	0.68	0.45	0.58	-0.23	0.52	0.64	0.49	-0.39	0.64	0.40
Hardness Mg CaCO ₃	0.15	0.57	0.001	0.86	0.48	0.57	-	0.09	-0.57	-0.73	0.13	<u>0.91</u>	0.34	-0.07	-0.36	0.88	-0.49	-0.37
Hardness Ca CaCO ₃	-0.16	0.03	0.48	-0.32	<u>-0.86</u>	<u>-0.94</u>	-0.68	-	0.60	0.06	0.67	0.31	0.30	0.73	0.29	0.18	0.71	0.53
Iron dissolved	0.03	0.10	-0.69	0.21	-0.35	-0.32	-0.17	0.15	-	0.80	0.65	-0.49	-0.02	0.81	0.77	-0.58	0.85	0.83
Al dissolved	0.47	0.76	-0.39	0.77	-0.01	-0.007	0.44	-0.10	0.68	-	0.46	-0.73	-0.43	0.59	<u>0.88</u>	-0.74	0.44	0.78
Mn dissolved	0.43	0.72	-0.43	0.76	-0.03	-0.01	0.42	-0.10	0.72	<u>0.99</u>	-	0.21	-0.11	<u>0.97</u>	0.80	0.12	0.36	0.84
Ammonia nitrogen	0.36	0.79	0.23	<u>0.86</u>	0.39	0.42	<u>0.92</u>	-0.45	-0.26	0.49	0.45	-	0.17	0.02	-0.32	<u>0.98</u>	-0.39	-0.20
Nitrate	0.13	0.16	-0.52	0.10	-0.48	-0.50	-0.35	0.40	<u>0.95</u>	<u>0.88</u>	0.67	-0.33	-	-0.08	-0.46	0.03	0.38	-0.45
Colour	0.12	0.41	-0.58	0.56	-0.26	-0.21	0.18	0.01	<u>0.92</u>	0.64	<u>0.91</u>	0.11	0.84	-	0.84	-0.07	0.56	<u>0.90</u>
TSS	0.85	0.64	0.36	0.11	0.20	0.03	0.03	0.21	-0.23	0.26	0.20	0.37	-0.02	-0.13	-	-0.35	0.33	<u>0.93</u>
TDS	0.16	0.80	-0.04	<u>0.99</u>	0.07	0.15	0.85	-0.31	0.20	0.76	0.75	0.86	0.09	0.55	0.10	-	-0.52	-0.24
Chloride	-0.43	-0.88	-0.47	-0.53	0.37	0.44	-0.18	-0.49	-0.11	-0.57	-0.54	-0.49	-0.29	-0.31	-0.69	-0.53	-	0.47
Turbidity	-0.06	0.25	-0.43	0.32	-0.58	-0.54	-0.14	0.35	<u>0.94</u>	0.70	0.74	-0.16	-0.19	<u>0.92</u>	<u>0.94</u>	0.32	-0.33	-

- The dark area corresponds to the values in the wet period and the bright area corresponds to the values in the dry period.

- Highlighted values are significant for Pearson correlation with P <0.05.

Alkalinity is described as a measure of capacity of water to neutralize acids. Alkalinity is described as a measure of capacity of water to neutralize acids. In natural waters it is constituted mainly of salts of acids and weak bases or strong bases, such as phosphates, silicates, bromates, carbonates and bicarbonates [9,32]. For pH below 4.3 the water has strong mineral acidity, pH values between 4.3 and 8.3 is related to water that presents bicarbonates and some weak acids [32, 33, 34]

Positive correlations occurred between EC and pH, EC and alkalinity in the wet period and between EC and Ammonia Nitrogen, EC and TDS, EC and hardness in the dry period. The EC expresses the ability of a liquid to conduct electrical current, and can be influenced by the type, amount, concentration, mobility and valence of the ionic species in dispersal beyond the temperature of the solution [9,27]. There existence of ions, also in the cited parameters, such as the presence of ions which influence the pH (H^+ or OH^-), alkalinity (CO_3^{2-}), the Nitrogen ammonia (NH_4^+) and TDS, which as the name suggests, has dissolved materials [32,35]. This also justifies the positive correlations presented in the wet period between TDS and pH, TDS and alkalinity, TDS and EC, TDS and Ammonia Nitrogen, since the inorganic salts are major constituents of dissolved solids, but they may also contain ions, dissolved gases and small quantities of organic material [36]

Also occurs, positive correlation between DO and dissolved iron, and between DO and dissolved aluminum, which may be related to increased dissolution of iron and aluminum compounds, especially the oxides of these metals, which release oxygen in water increases the concentration of dissolved oxygen [37]. The results show negative correlations between DO and hardness $CaCO_3$, and BOD and hardness $CaCO_3$ in the dry period. The consumption of dissolved oxygen in reactions of formation of carbonates explain the inverse relationship demonstrated by the correlation [38]. Occurs negative correlation between DO and BOD in the dry season, which occurs due to the consumption of DO for the existing organisms in the water and consequently increased the BOD [39]. The concentration of the Indicates capacity that particular water body has to promote depuration of organic materials. The OD can be influenced by temperature, atmospheric pressure, photosynthesis, respiration of aquatic plants and oxygen demands by some microorganisms. The BOD represents the potential of biodegradable organic matter in aquatic environments. Corresponds to the amount of dissolved oxygen removed from the water by respiration of microorganisms, the greater the amount of biodegradable organic matter oxidizable (which may be increased by the discharge of waste) greater demand for oxygen [40]

Turbidity was positively correlated with the colour and TSS in the dry season and the wet period, these parameters have direct proportional relationship with the turbidity, the greater the amount of TSS higher turbidity and lower water clarity. That disfavors the passage of light and reduces the photosynthetic rate of aquatic plants, and further prejudice search for food of aquatic animals [19,41]. Positive correlations between colour and turbidity and colour and TSS were also evident in a study conducted in the Basin of high Acaraú, CE, Brazil [42]

Positive correlations occurred between colour and dissolved iron, dissolved manganese and colour. The salts of Fe and Mn have similar characteristics in their interactions with natural waters, they are easily oxidized to form insoluble hydroxides. Waters with these metals have low turbidity and high colour [25,43]. Ions dissolved iron and manganese, added organic matter results in increased values of colour [22].

291

292 4. CONCLUSION

The laboratorial analyzes showed that five parameters have values outside the established standards. The case of the pH parameter has peculiar, since water amazonian present tendency to acidity and even with values below allowed by CONAMA Resolution 357/2005 and EPA can be considered normal. The results for DO, dissolved iron, dissolved manganese and colour show that these parameters are in the initial state of change in

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Lagoon of the Indians. Dumping of waste generated by households and establishments engaged in commercial activity around the lagoon may be the cause of changes.

The results for parameters that do not have CONAMA and EPA regulations can be considered normal compared to other existing results in the literature for Amazonian waters.

Regarding the temporal variability, parameter values were lower in the wet period and higher in the dry season, a fact that can be attributed to decreased concentration of physicochemical constituents due to the increased volume of water from the rains.

Seasonal variability data: Kruskal-Wallis test mean and CV, and also the t-test (Tables 1, 2 and 3) show that the Lagoon of the Indians has a high degree of heterogeneity to majority parameters. The great extension area of the lagoon and the different characteristics of the flora and fauna that compose it, and further of different anthropogenic influences in the region may be related to the heterogeneity of water.

Correlation analysis showed values expected for the dynamics of the water body compared to existing studies on the interrelation of physicochemical parameters as in the case of positive correlation between pH and alkalinity, pH and EC, EC and TDS, EC and alkalinity, negative correlation between DO and BOD due to consumption of DO and increased demand for this gas (BOD). And other significant relationships also appear in the matrix.

CONSENT

Not Applicable

COMPETING INTERESTS

Authors hereby declare that there are no competing interests.

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