

Original Research Article

Physico-chemical characterization of Lagoon of the Indians in Macapá-AP-Brazil

ABSTRACT

Aims: Characterize Lagoon of the Indians from physico-chemical parameters with reference to the CONAMA nº357/2005 resolution.

Study design: The collections were conducted at five points in the Lagoon of the Indians in Macapá-AP-Brazil, during the rainy season (Nov/2010) and dry period (March/2011). Analyses were performed for seventeen physico-chemical parameters according to APHA (1995). The metals were determined by Atomic Absorption [Spectrometry equipment](#) (AAS [Model 6300](#))

Shimadzu. The pH was determined [in-situ on collection location](#) 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 [laboratories of Chemistry, Sanitation and Modeling of Environmental Systems Laboratory](#), and in [the laboratory of General and Analytical Chemistry Laboratory](#) of Federal University of Amapá, between November 2010 and March 2011.

Results: Five parameters showed discordance with the reference values: pH, dissolved oxygen (DO), dissolved Fe, dissolved Mn and Colour. The alkalinity, electrical conductivity, hardness and total suspended solids parameters are not regulated by CONAMA, 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. The parameters presented larger values for the dry season and lower values during the rainy season. Statistical results for mean and standard deviation show a high degree of heterogeneity of Lagoon of the Indians.

Conclusion: The concentration of physico-chemical constituents showed lower values in the rainy season, which may be related to the increase of water level [in](#)-depending on [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 may mean initial changes in the physico-chemical composition of the lagoon.

Keywords: Lagoon of the Indians, physico-chemical characterization, CONAMA nº357/2005 resolution, 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. Failure to [planning](#) is one of the main problems related [to with](#) lack of infrastructure, which causes large population concentration in a small area, increasing the periphery and occupation of 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

24 and bays. This has caused continuous environmental degradation by dumping of increasing
 25 volumes of organic and inorganic residues. The release of untreated sewage [into the Lagoon](#)
 26 [of Indians](#) has increased
 27 significantly in recent decades, with severe impacts on fauna, flora and human beings
 28 ~~themselves~~ [2].
 29 In Amapá state the cities of Macapá and Santana have a high [population level of](#)
 30 [occupancy](#)
 31 improper of the areas of "undertow". The term "undertow" is used regionally to denominate
 32 the various lakes [in](#) of existing floodplains in the state of Amapá. These lakes occur during the
 33 rainy season (winter) which extends from December to June. Rain water feeds rivers and
 34 igarapes inundating these areas. During the dry season (summer), the waters are mainly
 35 concentrated in the channels of rivers [forming](#) and the water levels of the hangovers reduce
 36 significantly. The term is also used to define the areas which behave as natural water
 37 reservoirs, which [are](#) characterized by a complex and distinct ecosystem, ~~suffering from~~
 38 ~~effects~~
 39 ~~of the action of the under the influence of~~ tides and rainfall, ~~temporary manner~~ [3].
 40 Areas of hangovers are predominant in almost all the urban perimeter of Macapá.
 41 The decharacterization of some of these areas due to human occupation, ~~it~~ is already
 42 evident, even without formal diagnosis. The occupation of hangovers turns out to influence
 43 these ecosystems due to lack of minimum housing conditions (such as sanitation, for
 44 example) resulting in [indiscriminate](#) waste disposal ~~from waste disposal~~, livestock [rearing](#)
 45 ~~and recreation, and other factors~~
 46 that eventually degrade and disfigure the nature of these environments. The Lagoon of
 47 Indians located in the city of Macapá-AP is an area of hangover that in recent years has
 48 suffered from ~~various~~ the environmental problems [as a result of over-population and siting of](#)
 49 [unplanned settlements caused by improper occupation](#) [4, 5].
 50 The principal objective of this work was the characterization of the Lagoon of the
 51 Indians from physico-chemical parameters [with](#) based on CONAMA nº357/2005 resolution
 52 [6] ~~in the face of occupation~~ [with respect to urbanization and industrialization](#) around this water
 53 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 rainy
 (March/2011), at five points in Lagoon of the Indians (Figure 1) defined with the aid of [brand](#)
 Garmin GPS device.

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) [7].



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 with-to Standard Methods recommended by- APHA [8]. Analyses of Biochemical Oxygen Demand (BOD) were performed according-withusing the Winkler method. The analysis relating to determinations of metals (aluminum, iron and manganese) were performed-withconducted using atomic absorption equipment 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 immediate-analyzesphysical parameters such as (temperature, pH, conductivity and dissolved

oxygen - DO) were ~~taken in-situ-performed in loco~~ by the use of probe YSI multiparameter model 556MPS trademark and ORION pHmeter Model 3 STAR, portable pH, trademark THERMO. Statistical analyzes were ~~performed with~~conducted using BioEstat 5.0 software.

3. RESULTS E DISCUSSION

Table 1 show that the 17 analyzed parameters, only 12 have values made available by CONAMA nº357/2005 resolution. Figure 2 shows values not regulated by CONAMA. In Figure 3 are shown results for the parameters in disagreement with CONAMA resolution, and in Figure 4 are presented results within established standards.

Table 1: Parameters analyzed and values of CONAMA nº357/2005 resolution.

Parameter	Limit value established
Temperature	
pH	between 6 and 9
Alkalinity (mg/L CaCO ₃)	
Electrical conductivity (µS/cm)	
DO (mg/L)	Minimum 5
BOD (mg/L)	Maximum 5
Hardness mg/L (Ca CaCO ₃ and Mg CaCO ₃)	
Iron dissolved (mg/L Fe)	Maximum 0,3
Aluminium dissolved (mg/L Al ³⁺)	Maximum 0,1
Manganese dissolved (mg/L Mn)	Maximum 0,1
Ammonia nitrogen (mg/L NH ₃ -N)	Maximum 3,7mg/L N, <u>ate</u> pH ≤ 7,566 Maximum 2,0 mg/L N, <u>ate</u> 7,5 < pH ≤ 8,0 Maximum 1,0 mg/L N, <u>ate</u> 8,0 < pH ≤ 8,5 Maximum 0,5 mg/L N, <u>ate</u> pH > 8,5
Colour (mg/L PtCo)	Maximum 75
TSS (mg/L)	
TDS (mg/L)	Maximum 500
Nitrate (NO ₃ ⁻ - N)	Maximum 10
Chloride (mg/L Cl ⁻)	Maximum 250
Turbidity (NTU)	Maximum 100

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3.1 Parameters not regulated by CONAMA nº357/2005 Resolution

Figure 2 shows the results for the parameters that have no values reference standards: alkalinity, electrical conductivity, hardness and TSS.

The alkalinity showed high levels only in point 3, being in the dry period equal to 32 mg/L CaCO₃ and ~~during on~~ the rainy season 34 mg/L CaCO₃. A measure of the ability of water of

neutralize acids is called alkalinity. In natural waters ~~is~~ salts consists mainly of weak acids and bases or strong bases, such as phosphates, silicates, bromates, carbonates and bicarbonates [8]. Physical and chemical analyzes carried out in waters of igarapes of city Manaus-AM-Brazil [9], showed low values of alkalinity in preserved areas. This may mean that the waters at point 3 may be in the initial stage of change for this parameter.

Significant differences are observed for values of electrical conductivity in the dry season (higher values) and in the rainy season (lower values). The electrical conductivity expresses the ability of a liquid to conduct electrical current, depends on the type, amount, concentration, mobility and valence of the ionic species in dispersal beyond of solution temperature [10]. The results for electrical conductivity with high values in the dry season and low values during the rainy season were found on research conducted on the Ribeirão Salgadinho in Xavantina-MT-Brazil [11]. The lowest values in the rainy season may be

related to a reduction in the concentration of electrolytic substances due to the increased volume of water.

The hardness with low values (less than 3 mg/L) to Ca and Mg in the dry season and the rainy season the water features of all points like soft. The hardness represents the capacity of the water of precipitate soap and is described as the sum of polyvalent cations such as iron, barium, strontium, magnesium, calcium and others. These cations react with soap forming precipitates or react with anions forming crusts [12]. According to Environmental Protection Agency, water with hardness values to 75 mg/L is considered soft [13].

The TSS values were below 40 mg/L for dry and rainy seasons. The suspended solids may contain toxic components such as heavy metals and pesticides and other pollutants. this parameter has direct proportional relationship with turbidity, the greater the amount of SST greater turbidity and reduced transparency of the water, which hampersdisfavors the penetrationpassage of light and reduces the photosynthetic rate of aquatic plants, in addition to harming the search for food from aquatic animals [14,15].

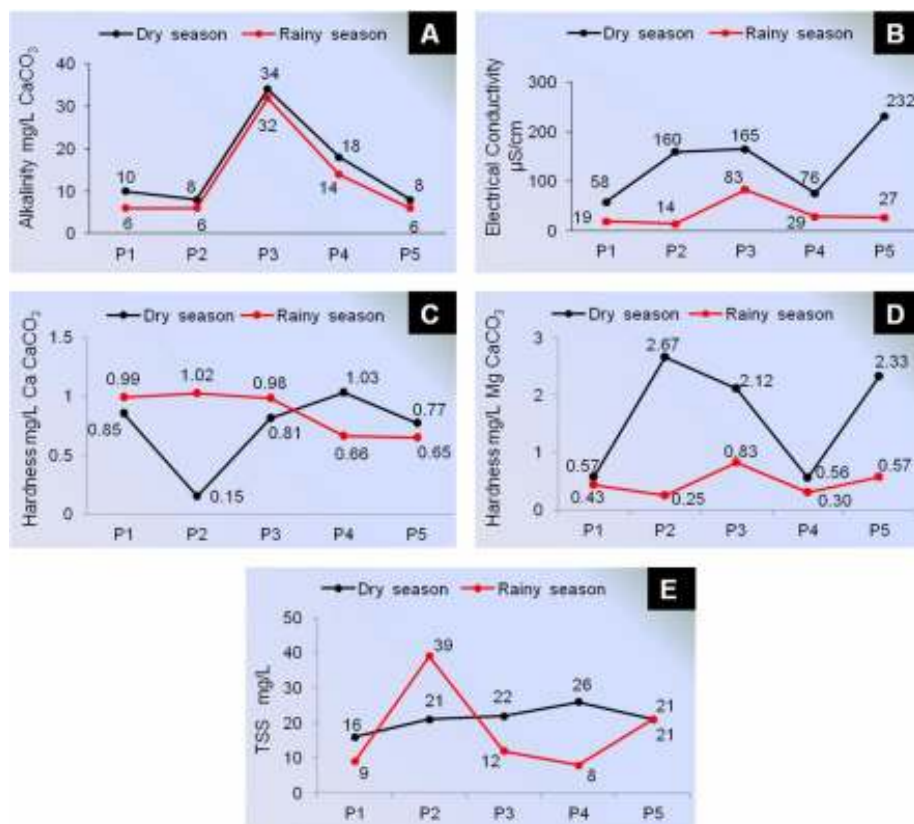


Figure 2. Results of the parameters that have no regulation by CONAMA n°357/2005 resolution. Data relating to: Alkalinity Ca CaCO₃ (A); Electrical conductivity (B); Hardness Ca CaCO₃ (C) and Mg CaCO₃ (D); TSS (E). The collection points are represented by P1, P2, P3, P4 and P5.

3.2 Parameters in disagreement with the CONAMA n°357/2005 resolution

In Figure 3 are shown parameters that showed values nonstandard: pH, DO, Fe, Mn and Colour. The pH values show results within the standards only to point 5 in the dry season (pH = 6.101) and point 3 in the rainy season (pH = 6.445). The pH can be described as a measure of the concentration of hydrogens free in the waters. The constituents of natural waters that pH influencing are solid and dissolved gases originated from the dissolution of rock materials, oxidation of organic matter and photosynthetic interactions, besides, of anthropogenic effluents [16]. Even presenting lower values that willing in CONAMA n°357/2005 resolution, values are considered normal for Amazonian waters, which are lightly acidic and according to results presented in studies performed with waters of the Brazilian Amazon region [17-21]. The natural acidity characteristic of these waters may be related to the presence of potentially acidic substances, from diverse natural sources, which are carried from the soil to the waters of rivers and lakes [20, 21].

The DO values were below the allowed for all the points in both the dry season and in the rainy season (higher value = 4.24 mg/L). The concentration of DO indicates the ability that determined water body has to promote the auto-depuration of existing organic materials. The DO can be influenced by temperature, atmospheric pressure, photosynthesis, respiration of aquatic plants and demands for oxygen of some microorganisms [22]. The low DO concentration is due to its consumption can be caused by decomposition of organic matter (oxidation) of microorganisms, possibly originating material of release of waste dumped in the water [9, 23].

The results for dissolved iron showed values well above permitted at all points in both the dry season and in the rainy season (lower value=0.90 mg/L and higher value=5.73mg/L) and dissolved manganese values were above the allowed only in points 2 and 5 in the dry season (point 2=0.105 mg/L and point 5=0.219 mg/L). The salts of Fe and Mn have similar characteristics in their interactions with natural waters, are easily oxidized and forming insoluble hydroxides. The water with these metals have low turbidity and high colour [14, 24]. These parameters can be naturally related to the geological characteristics of the region where minerals are leached from soil to waters [25]. And the high values can be attributed to the dumping of waste as a result of anthropogenic influence. Metals in high concentrations can cause serious damage to aquatic plants and animals [26, 27, 28].

The colour parameter presented values within the allowed only at point 4 in the rainy season (72 mg/L PtCo). Substances dissolved in the water can cause characteristic color in the water, some of these substances may be of organic origin (plankton, animal and vegetable) and inorganic origin (Ion Fe and Mn, for example). The iron and manganese ions dissolved, together organic matter results in increased values of Colour [29].

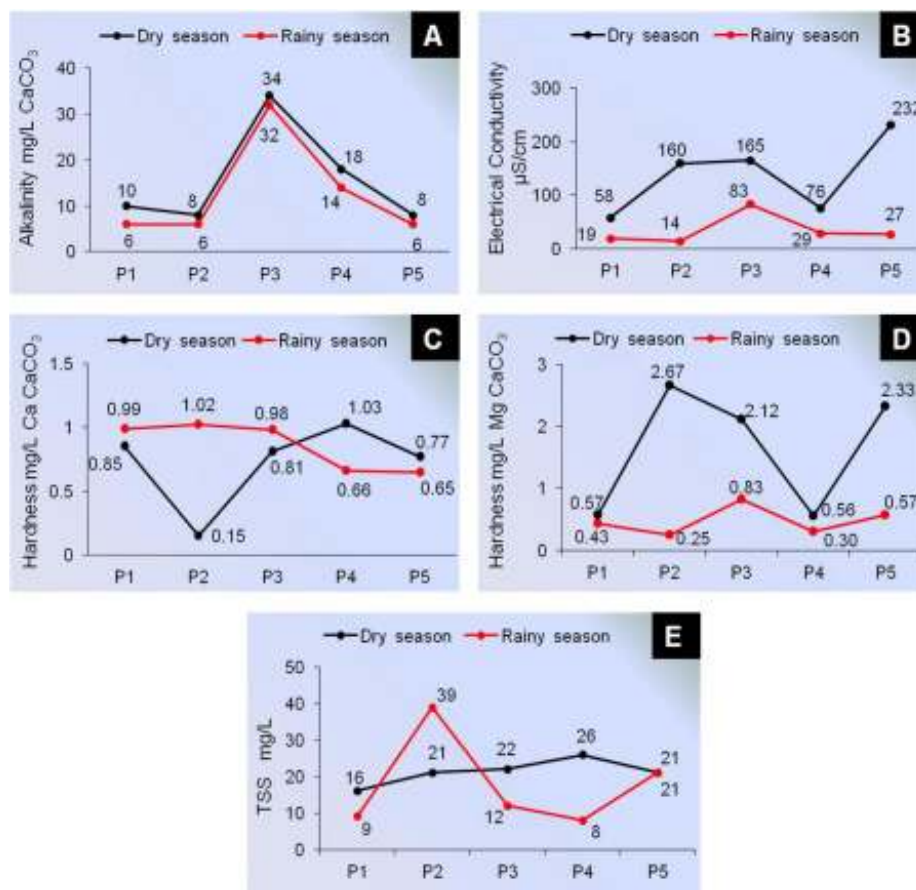


Figure 3. Results of the parameters that showed disagreement with CONAMA n°357/2005 resolution. Data relating to: pH (A); DO (B); Fe (C); Mn (D); Colour (E). The collection points are represented by P1, P2, P3, P4 and P5.

3.3 Parameters in accordance with the CONAMA n°357/2005 resolution

The values of the parameters BOD, dissolved aluminum, ammonia nitrogen, TDS, nitrate, chloride and Turbidity shown in Figure 4 are all in accordance with CONAMA n°357/2005 resolution. The BOD parameter showed value (4.53 mg/L) close to the reference value only in point 4 in the dry season. The BOD represents the potential of biodegradable organic matter in aquatic environments, and corresponds to the amount of dissolved oxygen removed from the water by respiration of microorganisms, the higher the amount of biodegradable organic matter oxidizable (which may be increased by dumping of wastes) greater demand for oxygen [22]. The value close of the reference value can be related to create buffalo cattle in sites or nearby farms this collection point.

The value of aluminum parameter (0.091 mg/L) in point 3 dry season showed approach with the reference value. The existence of dissolved aluminum in the soil can be extremely harmful to vegetation, especially in the rainy season when the metal can react

with acids coming of the rains, can also be adduced to water bodies [30]. The existence of several residences nearby of point 3 (see Figure 1), as a source of waste disposal may be related with the value presented.

The parameter ammonia nitrogen ($\text{NH}_3\text{-N}$) and the nitrate parameter showed low values (highest value equal to 0.69 mg/L for $\text{NH}_3\text{-N}$ and 2.5 mg/L for $\text{NO}_3^-\text{-N}$) at all points both in the dry and in the rainy period. Organic nitrogen is converted to ammonia by ammonification, ammonia is converted into nitrite by nitrification, which is converted into 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 [14, 31]. Nitrate is the end product of the mineralization of nitrogenous organic matter. Trace amounts of nitrate are present in natural waters and its increase may occur as a consequence of waste disposal or use of fertilizers in agricultural activities near rivers and lakes [32]. The low values of $\text{NH}_3\text{-N}$ determined may indicate two possibilities, or there are low levels of waste of animal and vegetable origin, or ammonia would have already been converted to nitrate (with higher values).

Determinations of TDS showed low levels both in the dry season (higher value of 0.110 mg/L) as in the rainy season (highest value equal to 0.041). The inorganic salts are the main constituents of dissolved solids, but they may also contain dissolved gases and small amounts of organic matters [10]. Low values for TDS were also determined in research with the waters of the Rio Araguari-Amapá-Brazil [25].

The chloride parameter showed low values compared with the reference value (maximum of 62.98 mg/L in the dry season and maximum of 59.98 mg/L in the rainy season). In natural waters Cl^- ions may have originated in soil lixiviation and rocks composed of chlorine salts, their values can be increased by the influence of the dump of residences, industries and agricultural activities [29]. The low values determined can be attributed to the absence of naturally rocky terrain near the Lagoon of the Indians, and also by the absence of agricultural activities of the nearby collection points.

The turbidity showed a higher value in point 2 in the rainy season (30 NTU). The turbidity is related to the presence organic and inorganic matter finely divided microscopic organisms, and silica and clay in water. Its increase may be caused by naturally soil lixiviation and anthropogenic influence from the dumping of waste [10]. The low turbidity values show that this parameter shows good results for Lagoon of the Indians. The increase of turbidity in point 2 in relation to other points may be related with the presence of nearby residences this collection point (see Figure 1), which can result in dump of organic and mineral origin.

3.4 Differences during the dry and rainy

The data shown previously in Figures 2, 3 and 4 related to physicochemical parameters studied show a trend of these parameters, which in general, their values are higher in the dry season and lower in the rainy season. 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 rainy season. 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].

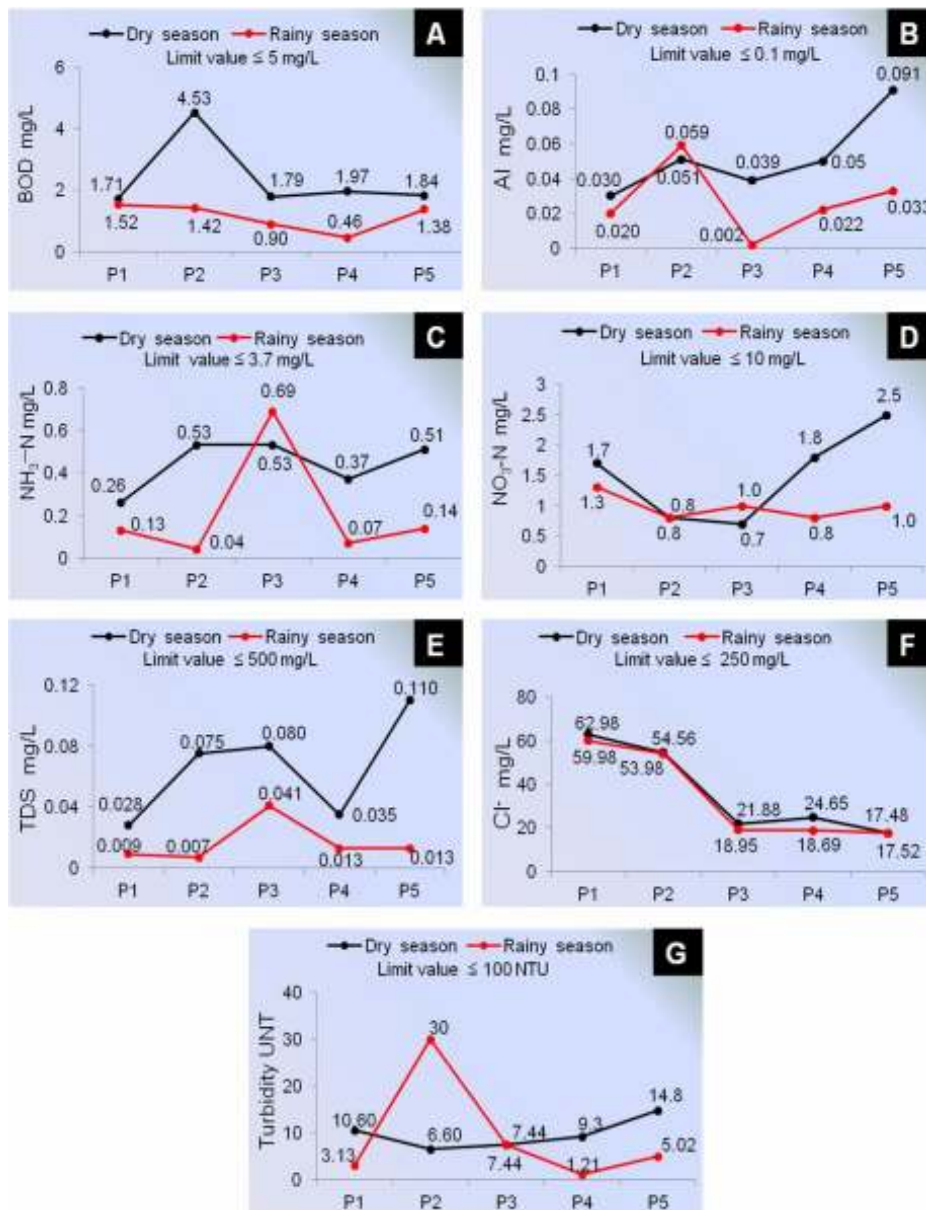


Figure 4. Results of the parameter that showed accordance with CONAMA n°357/2005 resolution. Data relating to: BOD (A); Al (B); $\text{NH}_3\text{-N}$ (C); $\text{NO}_3\text{-N}$ (D); TDS (E); Cl^- (F); Turbidity (G). The collection points are represented by P1, P2, P3, P4 and P5.

3.5 Heterogeneity of Lagoon of the Indians

The data disposed in Table 2 shows the values of mean and standard deviation (SD) in relation to collection points into dry season and rainy season. Standard deviation values represent the variability of the parameters in relation to mean. Note that the temperature parameters (dry and rainy season), DO (dry and rainy season), BOD (dry season), hardness/Mg CaCO₃ (dry season), iron (dry season) and nitrate (dry season) show low variability (standard deviation values close to 1). Nevertheless of the 18 parameters analyzed only six show low variability, being most these parameters only in a characteristic season demonstrating that the Lagoon of the Indians has a high level of heterogeneity. The extent of the lagoon and the different types of vegetation communities and existing animals and levels of human occupation in their environment can be the causes for the large variations of the standard deviation for most of parameters.

Table 2. Mean and standard deviation for data from the dry and rainy season.

Parameter	Season	Mean	Standard deviation
Temperature (°C)	Dry	27.55	1.2018*
	Rainy	26.858	0.9135*
pH	Dry	5.5458	0.5124
	Rainy	5.8296	0.3626
Alkalinity (mg/L CaCO ₃)	Dry	15.6	11.0815
	Rainy	12.8	11.2783
Electrical conductivity (µS/cm)	Dry	138.2	71.2264
	Rainy	34.4	27.8352
DO (mg/L)	Dry	2.13	1.2217*
	Rainy	2.03	1.3087*
BOD (mg/L)	Dry	2.388	1.2569*
	Rainy	1.136	0.4473
Hardness mg/L Mg CaCO ₃	Dry	1.63	0.9938
	Rainy	0.476	0.2336
Hardness mg/L Ca CaCO ₃	Dry	0.742	0.3443
	Rainy	0.86	0.1877
Iron dissolved (mg/L Fe)	Dry	4.056	1.1638*
	Rainy	1.57	0.6455
Aluminium dissolved (mg/L Al ³⁺)	Dry	0.0522	0.0233
	Rainy	0.0272	0.021
Manganese dissolved (mg/L Mn)	Dry	0.1098	0.0645
	Rainy	0.0546	0.0156
Ammonia nitrogen (mg/L NH ₃ -N)	Dry	0.44	0.1208
	Rainy	0.214	0.2693
Colour (mg/L PtCo)	Dry	218.6	86.6389
	Rainy	114.8	32.9955
Total Suspended Solids (mg/L)	Dry	21.2	3.5637
	Rainy	17.8	12.9112
Total Dissolved Solids (mg/L)	Dry	0.0656	0.034
	Rainy	0.0166	0.0139
Nitrate (NO ₃ ⁻ - N)	Dry	1.5	0.7517*
	Rainy	0.98	0.2049
Chloride (mg/L Cl ⁻)	Dry	36.31	20.8752
	Rainy	33.464	21.6089
Turbidity (NTU)	Dry	9.748	3.2282
	Rainy	9.296	11.78

* Represent low variability

4. CONCLUSION

The analyzes performed showed that five parameters (pH, DO, Fe, Mn and Colour) have values outside of the established standards. The case of the pH parameter has peculiarity, once that, Amazon waters show a tendency to acidity and even with values below permitted by CONAMA nº357/2005 resolution can be considered normal. The data relating to DO, to the metals iron and manganese and Colour show that these parameters are in the initial state of change in Lagoon of the Indians. The dumping of waste generated by residences and establishments engaged in commercial activity around of the lagoon can be the result of alterations.

The results for parameters that do not have CONAMA regulations can be considered normal when compared to other existing results in the literature for Amazonian waters. Regarding the dry and rainy seasons parameter values were lower in the rainy period and higher in the dry season, a fact that can be attributed to decreased concentration physico-chemical constituents due to increase in volume of water from the rains.

The data of mean and standard deviation show that the Lagoon of the Indians has a high level of heterogeneity for most parameters. The large extension area of the lagoon and the different features of fauna and of flora that comprise it, addition to the different anthropogenic influences in the region could be related to heterogeneity of water. Because of the results discussed here are necessary extremely for it to be done one monitoring of Lagoon of the Indians, so that be possible monitor changes caused by anthropic action and for to be steps taken on possible ways to stop these modifications.

CONSENT

Not Applicable

COMPETING INTERESTS

Authors hereby declare that there are no competing interests.

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