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Abbreviations: HAB: Harmful Algal Blooms; ANP: Protected Natural Area; TSI: Trophic State Index; SD: Standard Deviation; ACP: Analysis of Components Main

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Research Article

Evolution Over Time of the Water Chemistry in the Channels of the National Canal Tourist Corridor and Adjacent Lake Area of Xochimilco, Mexico

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Abstract

In Mexico there is a clear deterioration of urban lakes, so to generate conservation measures and ecosystem services, the monitoring of physical and chemical parameters in these water bodies has a key role. In this study, 16 physical-chemical variables from 10 sites were considered, with the aim of analysing the changes in the physical-chemical quality of the water over nine years of sampling. The statistical analysis showed that despite the fact that the system is hypereutrophic, there are variations in the behaviour of the area over time, and the areas close to places with agricultural and cattle activities and wastewater inputs are separated from the rest due to their differences in the concentrations of organic matter, nitrogen and phosphorus.

Introduction

Wetlands are ecosystems where water resources are the main component. A wide range of habitats can be distinguished in them, among the most characteristic are coastal, marine and epicontinental habitats that host a high wealth of species and provide various ecosystem services [1,2]. The Xochimilco basin with Its tributaries forms an epicontinental ecological system of great environmental and social importance, within which is the Protected Natural Area "Ejidos de Xochimilco and San Gregorio Atlapulco", recognized as a Cultural and Natural Heritage of Humanity by UNESCO [3]. Despite the above, this ecosystem is experiencing marked deterioration due to deforestation and soil erosion, as well as water pollution and excessive extraction, which has caused many public health problems, loss of biodiversity and impacts on cultural and economic activities [3]. The increasing drying up of the canals due to the depletion of natural springs generated the need to pump treated wastewater to maintain the water level, which led to a decrease in its chemical and bacteriological quality; This has had a negative effect on chinampa vegetable crops, which are being replaced by flower production [3,4].

One way to assess water quality is through the analysis of the physical and chemical parameters that They are those components or particular attributes of water bodies that affect the characteristics of the ecosystem such as, for example: suspended solids that influence the color and transparency of the water, the density that depends on the temperature, the pH, the O_2 levels, and the amount of organic and inorganic nutrients present in the environment [5]. Due to the historical, ecological, social and economic relevance of the Xochimilco wetland system, it is necessary to have control and continuous monitoring of the levels of chemical and biological contamination of the ecosystem, since its preservation would help maintain the quality and dynamics of the aquifer, as well as the conservation soil, and sustain the ecological balance at a regional level [6]. Therefore, in this research work, the physical, chemical and trophic level changes of the water in the canals were evaluated during nine years of sampling at ten sites located in the Canal Nacional tourist corridor and the adjacent lake area.

Physical and Chemical Parameters

The measurement of physical and chemical parameters is one of the simplest ways to identify variations in nutritional composition, sediment salinization and changes in temperature and pH, both on spatial and temporal scales, resulting from changes in the lithology, relief, vegetation and climate of the region. It also provides resources that allow evaluations of geochemical processes in different ecosystems [7]. Currently, the quality of surface or groundwater depends on both natural factors and the impact caused by the change in land use of the areas surrounding these bodies of water; It has been reported that the most polluted ecosystems are found in places close to human settlements, since they are more susceptible to changes in their landscape and natural water supply systems, affecting their resilience when there is a disturbance [8]. All parameters Environmental factors influence each other directly or indirectly; the importance of each lies in how they intervene in the quantity and richness of species and in the quality of water used for human consumption or for recreational purposes [9]. The chemical composition of water and its physical properties provide information on contamination processes and allow the evaluation of the levels of environmental impact, both of anthropogenic (mainly) and natural origin [10]. Because water behaves as a solvent of organic and inorganic compounds, different types of substances that modify its properties can be found in it [5,11,12].

Among the chemical characteristics, one of the most important is the level of dissolved oxygen, since it directly influences the metabolism of organisms and its distribution in the water column according to their oxygen needs. Habitat fragmentation is another factor that creates “artificial” gradients in the water column, since in those places where organic waste is generally dumped, the concentration of dissolved oxygen is lower due to the biological demand for oxygen for the degradation of organic matter, which causes there to be areas with a higher concentration of O2 than in others [13]. Some other compounds are dumped into the epicontinental basins by runoff or by the arrival of wastewater, among them are heavy metals (arsenic, cadmium, copper, lead, iron), fluorides, nitrates and phosphates. In addition to all this, there is also a risk to human health from toxic microbial agents that may be present [14], therefore, it is necessary to constantly monitor these bodies of water so that they can be used sustainably, as well as for their importance for public health and the economy of the places where they are located [15,16]. An example is the entry of a large amount of fertilizers into the bodies of water by runoff or filtration that favors Harmful Algal Blooms (HAB), these microalgae produce toxic compounds, which when ingested cause vomiting, cramps, nausea, headaches, seizures, fever and long-term death. This undoubtedly has a negative effect on the region since more resources must be allocated to mitigating diseases instead of preventing them [17,18].

Another importance of constant monitoring of the chemical evolution of natural water bodies is that it allows monitoring changes in the trophic state or level of contamination of a water body. In the case of rivers and lakes, there are four parameters that serve as main indicators to determine their trophic state: total P and N, chlorophyll a and transparency [19]. If water quality is not adequate, the socioeconomic impact is very large because it compromises the quality of life of people who depend economically and for food on this resource. In summary, the eutrophication process implies a deterioration in water quality because it generates negative ecological, economic and health impacts, a decrease in biodiversity, reduced light penetration, fish mortality, and an increase in the concentration of pathogenic microorganisms and disease vectors [20].

Materials and Methods

Location

Lake Xochimilco is located south of Mexico City in the Xochimilco Municipality, at the foot of the Chichinautzin Mountains at an average altitude of 2240 meters above sea level, at coordinates 19º15’11” and 19º15’19” North Latitude and 98º58” and 99º10” West Longitude. It is part of an ancient remnant of the Lake that covered a large portion of the Basin of Mexico [21]. Ten sites were sampled, located in the tourist corridor area of the National Canal and the adjacent lake area within the Protected Natural Area (ANP) “Ejidos de Xochimilco and San Gregorio Atlapulco” (Figure 1). Data on the physical and chemical parameters of the water column (surface water and groundwater) background) correspond to nine years of sampling in the study area (Figure 1 and Table 1), in two seasons (dry and rains).

Figure 1: Area of study and location of the 10 stations of sampling. Preparation own with [22].

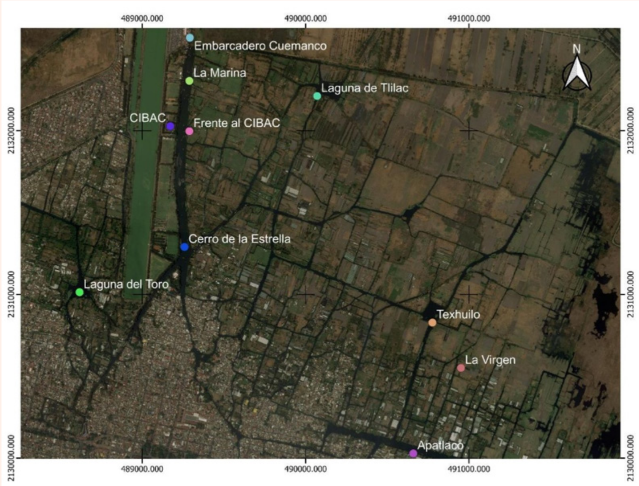


Table 1: Location geographic of the sites of sampling.

Season	Coordinates
Apatlaco	19°15’50”N / 99°05’20”O
Cerro of the Star	19°16’31”N / 99°06’08”O
CIBAC	19°16’55”N / 99°06’11”O
Embarcadero Cuemanco	19°17’12”N / 99°06’06”O
Front go CIBAC	19°16’54”N / 99°06’07” OH
The Marina	19°17’04”N / 99°06’07” Oh
Day Virgin	19°16’07”N / 99°05’10” Oh
Laguna of Tlilac	19°17’01”N /99°05´40.2”E
Laguna go Toro	19°16’22”N / 99°06’30” Oh
Texhuilo Lagoon	19°16’16”N / 99°05’20”E

The data was sorted in the database in such a way that most of the stations and years had he profile physical and chemical complete (depth, transparency, oxygen dissolved, pH, Hey, salinity, conductivity, temperature, suspended materials (SBM), NH_4^+ concentration , NO_2^-, NO_3^-, PO_4^{3-}, OCD, N and P total) for can carry out studies multivariate without information wrong, with base in the recommendation of Garmendia (2018), with aid of the program computer scientist Microsoft Office Excel 2013. Table 2 shows the years and seasons of sampling studied.

He states trophic of the water of surface and background in the different sampled sites It was calculated with the Trophic State Index (TSI), which provides values ranging from 0 to 100 (from oligotrophy to hypereutrophy), and considers the Transparency calculated with Secchi disk, in addition to other parameters as the Clα and he phosphorus total [23], the indices were averaged according to the recommendations of [24] (Figure 2). The values of reference of the index by each indicator HE shows in the Table 3.

Figure 2: Formulas to calculate the Index of State Trophic (TSI) of Carlson modified by Aizaki [24].

$$IET_{Sec} = 10 * \left(2{,}46 + \frac{3{,}76 - 1{,}57 * ln(Ds)}{ln(2{,}5)}\right) IET_{PT} = 10 * \left(2{,}46 + \frac{6{,}68 + 1{,}15 * ln(PT)}{ln(2{,}5)}\right)$$

PT: Phosphorus total in mg/L; Ds: Transparency in meters

Table 2: Arrangement of the stations by year.

Season / Year	Jun-09	Feb-10	May-11	Oct-12	May-13	Oct-14	Oct-15	Oct-18	Oct-19
Apatlaco			X	X					
Hill of The Star		X		X	X	X	X		X
CIBAC						X			X
Pier Cuemanco					X	X	X	X	X
Front at CIBAC					X		X	X	
The Marina					X	X			X
The Virgo			X		X		X	X	X
Lagoon of Tliac		X	X	X	X		X	X	X
Lagoon of the Bull	X	X		X					
Texhuilo	X		X	X		X			

Table 3: Reference scale of TSI values taking as indicators the depth and he phosphorus total (Orquera and Cabrera, 2020).

TSI	Disk of Secchi (m)	Total P (mg/L)
0	64	0.00075
10	32	0.0015
20	16	0.003
30	8	0.006
40	4	0.012
50	2	0.024
60	1	0.048
70	0.5	0.096
80	0.25	0.192
90	0.12	0.384
100	0.062	0.768

Results and Discussion

The temperature varied depending on the time of year (between 16 and 22°C): in 2011, during the season of dry, they presented he worth further high of 22°C and in 2019, during the season of rains, he worth further low with 16ºC, these values are those expected for this area [25, 26]. The values obtained for conductivity during the dry season were similar to those reported by these authors (Table 4). The high values of conductivity found in the years belonging to the season of the rains could have been due to the low temperatures recorded in those years, since that the solubility of the ions inorganic and salts present in water are greater when the temperature decreases [11], and the increase in ions inorganic carried in season of rains by runoff [27]. This could also, explain the older concentrations of oxygen dissolved that HE presented in those years, already that the dissolution of the oxygen increases as the temperature drops [28], all this combined with that in this area, there is a continuous passage of boats and trajineras for tourist activities that constantly stir the water column allowing the homogeneous mixing of the surface water layer and the bottom layer, which explains why there are no found significant differences between O_2 values in surface and bottom water as also reported by [27].

The salinization of some areas has also been increasing as reported by [29], due to the runoff that carries the salts from from the surrounding agricultural areas (Table 4). According to [30] the values obtained from pH (6.8 to 8.4) are inside of the boundaries permissible in the norm, that also are reported values in bodies of water nearly settlements urban [31]. Table 5 shows the great variability that existed between the values of suspended materials and inorganic and organic nutrients in the nine years of sampling according to the time of year in which the sampling was carried out of agreement with the [30], the values boundaries permissible of compounds of nitrogen in bodies of water are: NO_3^- (10 mg/L), NO_2^- (0.05 mg/L) and NH_4^+ (0.5 mg/L). In the study area the values in the concentrations of NO_3^- were much lower than the permissible limits indicated by the NOM, this could be explained by: 1) because many areas are under conditions of low oxygenation (3.3 mg/L of O_2) that can prevent the processes of nitrate regeneration *in situ*; 2) the nitrification process may be inhibited by the presence of heavy metals or by excess ammonium [32], verified that nitrifying autotrophic bacteria are sensitive to metals such as Cr, Cu, CN, Pb, Mg, Ni, Zn, SO_4 since microorganisms when exposed to a toxic environment carry out a process of bioaccumulation of these metals in their tissues; 3) Likewise, due to the hypereutrophic state of the water, primary producers use excess ammonium for their photosynthesis process.

The high NH_4^+ values in 2015, 2018 and 2019 (Table 5) are due to the runoff of these rainy seasons and cyclones, from the surrounding agricultural areas into the adjacent canals and to a high concentration of organic carbon that, due to degradation processes, could have been ammonifying the system. The high concentrations of NO_2^- observed in 2010, which was a dry season, with reduced bottom water (55.13 mV SD 9.99 mV) indicate that during sampling the sediment was resuspended and the ammonium produced in the surface sediment was rapidly oxidized to nitrites upon passing into the water column (Table 5) which was at an oxygen concentration of 7.56 mg / L (SD 3.79 mg / L). According to the trophic index, the concentration of total phosphorus exceeds the concentration limit for waters contaminated (0.77 mg/L). These high values could be associated with the constant dredging carried out in the canals to facilitate tourist activities, and the heavy rainfall that caused runoff from the surrounding crop areas into the canals. Another cause could be the discharge of wastewater from the Cerro de la Estrella Treatment Plant that is used to maintain a good water level in the area, as has been pointed out by Alonso-Duré (2013) for a similar ecosystem.

It has been reported by [4,27], that these waters present large fluctuations in their N and P load over time. On the contrary, the years 2010, 2018 and 2019 (cold front and little rain, isolated showers) showed a similar profile between them, with average pH values of 7.7 (SD 0.59), temperature of 17.1°C (SD 1.56) and NH_4^+ of 1.75 mg / L (SD 1.17), the grouping of these years is represented in red in (Figure 3). Finally, the years 2009, 2011, 2012, 2014 and 2015 make up another group with a similar physical-chemical profile with higher average values of oxygen, pH, temperature and Ptot to the group previous (Tables 4 and 5); in Figure 3 this group is represented by the dotted lines. Most of the years studied belong to the rainy season (June 2009, October 2012, 2014, 2015, 2018); only the years 2010 (February), 2011 and 2013 (May) belong to the dry season. Despite this, in the analysis by seasons there are no very large differences in the grouping due to that he processes of pollution in the system is constant [27], except for 2013, which was an atypical year since a tropical depression occurred in May, causing very strong rains and winds with temperatures of 21°C [33]. Likewise, the year 2018 also behaved differently as it was a warm year with a temperature 1.24°C above normal (average of 19°C) which was classified as the wettest October [34].

In the other years studied, weigh of that changes were manifested between them, these were minimal and were not a significant increase or decrease in the values of inorganic compounds was observed nitrogen and phosphorus, neither in the values of O2, temperature and pH, by it that he system HE remained relatively homogeneous. Through Cluster analysis, it was observed the training of two big groups to a distance Euclidean of 2.33. He first cluster gathers to the years 2009, 2011, 2012, 2014 and 2015, this cluster this shaped by two subgroups: he first subgroup contains to the years 2012 and 2015 represented in color green, due to their values averages of O2 (8.71mg/L with SD 0.69), pH (7.93 with SD 0.28) and temperature (18.87°C with SD 1.47), and the second subgroup made up of the years 2009, 2011 and 2014 represented by a line dotted, these are unite due to their values averages of O2 (10.58 mg/L with SD 2.98), pH (7.62 with SD 0.72), conductivity (901.68 µS/cm^2 with SD 111.28), temperature (20.31°C with SD 1.45), PO 4 3- (11.21 mg/L with SD 2.42) and phosphorus total (9.81 mg/L with SD 0.94) (Figure 3).

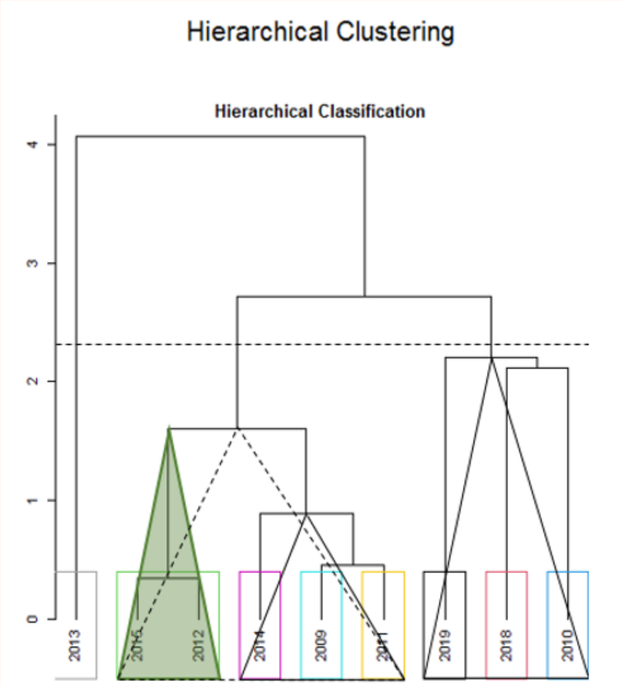
Table 4: Average and Standard Deviation (SD) of the values of the physical and chemical parameters of surface and bottom water during the nine years of sampling.

Year	Depth(cm)	Transparency (cm)	OD (mg/L)	pH	Eh (mV)	Salinity (ppm)	Conductivity (µS / cm^2)	Temp (°C)
2009 (SD)	77.5 46.0	30 0	11.1 2.3	8.0 0.7	74.4 12.6	0.42 0.12	1028.3 285.6	19.3 1.4
2010 (SD)	108 62.4	28.67 3.40	7.6 3.8	8.4 0.8	55.1 10	0.43 0.05	1139.2 218.4	16.6 1.7
2011 (SD)	115 26.5	27.5 17.7	13.3 8.1	8.1 0.9	158.8 93.4	0.87 0.29	819.5 38.2	22.0 1.2
2012 (SD)	100 64.7	ND	9.2 4.2	8.1 0.6	76 83.5	0.49 0.12	982 231.8	19.9 0.5
2013 (SD)	110 54.8	45.83 12.81	ND	7.4 1.3	290.6 297.9	0.33 0.02	688 34.1	21.6 0.8
2014 (SD)	ND	ND	7.4 1.6	6.8 0.1	ND	ND	857.3 226.2	19.7 2.2
2015 (SD)	85.8 59.7	33.42 14.84	8.2 2.3	7.7 0.8	ND	1.58 0.67	ND	17.8 0.9
2018 (SD)	56.1 31.0	29.62 4.5	3.3 0.8	7.6 0.2	ND	ND	1318.3 264.3	18.9 0.6
2019 (SD)	77.2 42.6	12.67 13.47	ND	7.2 0.4	121.9 89.4	3.67 1.69	ND	15.9 2.0

Table 5: Mean and Standard Deviation (SD) of nutrient values for water of surface and background during the nine years of sampling (mg/L).

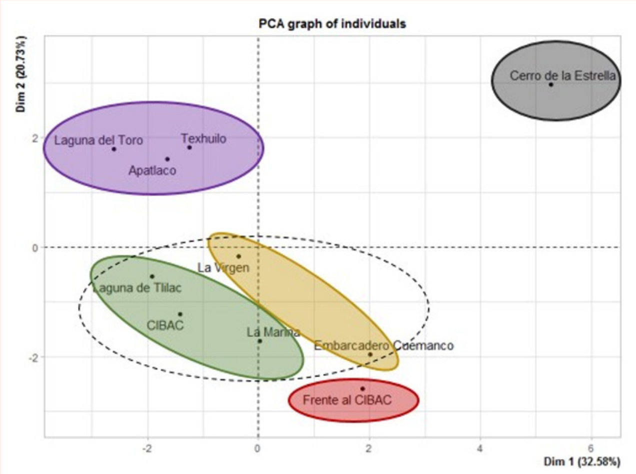
Year	Month	NH_4^+	NO_2^{-1}	NO_3^{-1}	PO_4^{2-}	TOC	P Total
2009 (SD)	0.13 0.001	0.03 0.03	0.03 0.003	0.97 0.57	13.66 0.32	ND	9.77 2.3
2010 (SD)	0.04 0.03	0.65 0.66	8.16 8.68	1.98 2.09	9.78 1.83	ND	11.6 0.89
2011 (SD)	74.7 46.9	0.01 0.004	0.23 0.21	0.75 0.06	11.16 2.09	ND	8.89 6.53
2012 (SD)	229.7 2 24.5	0.31 0.29	0.29 0.34	0.64 0.69	9.54 1.97	20.1 11.9	9.26 3.14
2013 (SD)	ND	0.51 0.21	0.01 0.007	2.82 1.98	8.04 1.36	76.58 92.65	12.92 10.76
2014 (SD)	0.02 0.03	0.01 0.005	0.04 0.008	0.16 0.03	8.82 2.1	33.37 39.35	10.78 1.2
2015 (SD)	187.0 254.9	2.05 1.05	ND	ND	ND	15.62 5.71	5.73 2.13
2018 (SD)	0.045 0.01	2.98 1.69	0.03 0.005	0.55 0.13	8.71 1.35	34.54 13.67	7.90 3.15
2019 (SD)	66.5 51.2	1.60 0.3	4.10 1.75	0.93 0.69	ND	40.17 17.6	7.95 4.33

Figure 3: Cluster Analysis shows the association of the different years and sampling periods according to the similarities of the values of physical variables and Chemicals that they share.



The second group is made up of the years 2010, 2018 and 2019, and like In the PCA analysis the variables that allowed their grouping were pH (7.7, SD 0.59), temperature (17.1°C, SD 1.56) and NH4+ (1.75 mg/L, SD 1.17). He year 2013 stands out from the rest by presenting an electropositive Eh (290.6 mV, SD 297.88), high carbon values organic total (7.58 mg/L with SD 92.65), transparency (45.83 cm with SD 12.81), NO_3^- (2.82 mg/L with SD 1.98) and Total P (12.92 mg/L with SD 10.76) (Figure 4).

Figure 4: He Analysis of Components Main (ACP) sample the association of sampling sites based on the similarity of variable values physical and chemicals.



From CP analysis based on physical and chemical profile of the water (Figure 4), HE noticed that the seasons Hill of the Star (in color grey) and Forehead to the CIBAC (in color red) presented the older differences with with respect to the rest of the sites studied. Hill of the Star was he place further deep (196.3 cm, SD 22.41 cm), with the greatest transparency (51.3 cm SD 16.53) and with the higher concentrations of NO_2^- (4.9 mg/L, SD 7.77), NO_3^- (2.96 mg/L, SD 2.56) and OCD (68 mg/L, SD 95.86); and he second place (Forehead to the CIBAC) presented he worth further high of NH_4^+ (2.5 mg/L , SD 2.92). The separation of These two sites of Sampling showed correspondence with the areas where they are located, since the high concentrations of nitrogen and carbon compounds are related to the discharge of wastewater from the Cerro de la Sierra treatment plant the Star and the inhabited areas that border them. These compounds are displaced by the water currents that are produced by the passage of trajineras and boats, which also remove the sediment and make the particles organic matter to be resuspended in the water column; these particles form microhabitats where mineralization processes take place bacteria aerobic that HE finds attached to the surface of the same [35], which consume oxygen and acidify the environment.

The sites located in Laguna del Toro, Apatlaco and Texhuilo, make up a group separated from the others, represented in Figure 5 by the violet color, due to Their similarities in average transparency values of 33.9 cm with SD 5.68, high concentrations of O2 (11.6 mg/L with SD 1.45), basic pH (8.1 with SD 0.57), salinity (0.53 ppm with SD 0.04), high concentrations of PO43- (10.7 mg/L with SD 0.91) and P total (9.4 mg/L with SD 0.89). These are areas of agricultural activities, with wastewater drains that are dumped directly into the canals and a lot of sediment removal by the constant passage of trajineras. last, the sites The Marine, Lagoon of Tlilac, CIBAC, The Virgin and Pier Cuemanco, represented by lines dotted, make up other cluster joined by the lowest values of transparency (25.3 cm with SD 2.45), pH of 7.6 (SD 0.2), show signs of the beginning of salinization (1.5 ppm with SD 0.22) and an average temperature of 18.8°C (SD 0.01). On the other hand, although the system presents conditions with a hypereutrophic category, variations in the TSI values were presented throughout the nine years studied (Table 6). And again, in this analysis, the year 2013 presented the highest value (121.2) and 2015 the minor (113.3), when the TSI was calculated by the concentration of P total (Table 6), standing out from the other sampling years.

With respect to the different sites studied within the system, the average highest TSI presented it La Virgen station (104.8) and the minor station Hill of the Star (95.4) (Table 7). The little the depth of the water column allows organic matter of plant and animal origin to accumulate at the bottom of the canals, causing an exhaustion of the oxygen due to the high biochemical oxygen demand by heterotrophic aerobic microorganisms. The depletion of oxygen at the bottom prevents rapid mineralization of the organic matter deposited at the bottom, allowing the proliferation of anaerobic microorganisms and thus a slow process of mineralization of the organic matter. In summary, this state Hypereutrophic of the sampling area has caused that there exists in the beginning, a high proliferation of organisms, mostly of the producers primary, as he lily water, that to the die causes a decrease in the concentration of oxygen dissolved by the great activity of the organisms heterotrophs herbivores that it consume, causing smells unpleasant, change in the coloration of the water, decrease in the transparency and in the concentration of other pollutants, that They propitiate the appearance of diseases in the nearby towns in addition to the training of algal blooms with the consequent production of phycotoxins [36].

TSI: Values of the Index of State Trophic; SD: Deviation Standard

Table 6: Average values and categories of the trophic status index obtained by years of sampling.

Year	Transparency (m)	TSI for Transparency	Total P (mg/L)	TSI by P Total	Averages	SD	Category
2009	0.3	82.8	9.8	120	101.4	26.3	Hypereutrophic
2010	0.2867	83.6	11.6	122.2	102.9	27.3	Hypereutrophic
2011	0.275	84.3	8.9	118.8	101.6	24.4	Hypereutrophic
2012	ND	ND	9.3	119.3	119.3	ND	Hypereutrophic
2013	0.4583	75.6	12.9	123.5	99.5	33.9	Hypereutrophic
2014	ND	ND	10.8	121.2	121.2	ND	Hypereutrophic
2015	0.3342	81	5.7	113.3	97.1	22.9	Hypereutrophic
2018	0.2962	83.1	7.9	117.3	100.2	24.3	Hypereutrophic
2019	0.1267	98	8	117.4	107.5	14	Hypereutrophic

TSI: Values of the Index of State Trophic; SD: Deviation Standard

Table 7: Average values and categories of the trophic status index obtained by sampling sites.

Site	Transparency (m)	Water	P Total (mg/L)	Water	Averages	SD	Category
Lagoon of the Bull	0.29	83.6	8.4	118	100.8	24.4	Hypereutrophic
The Navy	0.25	85.8	8.4	118.1	101.96	22.8	Hypereutrophic
Hill of the Star	0.51	73.7	7.74	117.1	95.4	30.7	Hypereutrophic
Lagoon of Tlilac	0.25	86.3	11.2	121.7	104	25	Hypereutrophic
Texhuilo	0.33	81.2	10.1	120.4	100.8	27.7	Hypereutrophic
Apatlaco	0.4	77.9	9.7	119.9	98.9	29.7	Hypereutrophic
The Virgin	0.25	86.1	12.9	123.5	104.8	26.4	Hypereutrophic
Pier Cuemanco	0.29	83.3	8.7	118.6	100.9	25	Hypereutrophic
Forehead to the CIBAC	0.32	82	5	111.5	96.7	20.8	Hypereutrophic
CIBAC	0.21	88.9	9.9	120.2	104.6	22.1	Hypereutrophic

Conclusions

The associations between the different sampling areas indicate that although the system is generally in a hypereutrophic state, its physical and chemical profile presents some differences according to the degree and type of anthropogenic impact present. The hypertrophic state indicated by the TSI indices is due to the impact caused by urban areas and agricultural activities, due to the discharge of waters loaded with phosphates, nitrogen and organic matter that reach this basin directly; the high concentration of inorganic nutrients has allowed the existence of areas with outcrops of floating primary producers on the surface of the water column and an insufficient rate of mineralization of this organic matter by aerobic heterotrophic microorganisms found in the bottom water and in suboxic sediments. Since all the sampled sites are in a hypertrophic state as a consequence of the loss of the natural balance of nutrients, a significant change in the composition and structure of the different levels of biological organization of the system may occur. Lake Xochimilco is a lentic system and is naturally sensitive to eutrophication due to the low exchange of atmospheric oxygen from other aquatic ecosystems. For the above reasons, constant monitoring of the evolution of the chemistry and trophic state of the water in the ecosystem is necessary in order to guide the implementation of better management practices for this. natural resource, as well as establishing permissible limits of N and P in the wastewater that comes from of the different economic activities of the site.

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