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Lagoon trophic state determination. Case of study Tecocomulco's lagoon, Hidalgo, Mexico

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Abstract

Because of anthropogenic impacts on the trophic state of Tecocomulco's lagoon in Hidalgo, Mexico, the quantities of nitrogen, phosphorus, and other biologically useful nutrients are being increased in spite of they are the primary determinants of a body of water's trophic state index. Nutrients such as nitrogen and phosphorus tend to be limiting resources in standing water bodies, so increased concentrations tend to result in increased plant growth, followed by corollary increases in subsequent trophic levels. Consequently, a body of water's trophic index may sometimes be used to make a rough estimate of its biological condition. Actually, in order to protect the environment, a new level of planning and execution of development projects have been originated by life cycle assessment, environmental impact researches and evaluating economic financial researches due to the understanding that, environment will be irreversible damaged by any kind of project.

Keywords: trophic index; anthropogenic impact; chlorophyll- α ; biodegradability; eutrophication.

Determinación del estado trófico de un lago. Caso de estudio Lago de Tecocomulco, Hidalgo, México

Resumen

Debido a los impactos antropogénicos en el estado trófico de la laguna de Tecocomulco en Hidalgo, México, las cantidades de nitrógeno, fósforo y otros nutrientes biológicamente útiles se están incrementando a pesar de que son los principales determinantes del índice de estado trófico de un cuerpo de agua. Los nutrientes como el nitrógeno y el fósforo tienden a limitar los recursos en los cuerpos de agua estancados, por lo que el aumento de las concentraciones tiende a dar como resultado un mayor crecimiento de las plantas, seguido de un corolario que aumenta en los niveles tróficos posteriores. En consecuencia, el índice trófico de un cuerpo de agua a veces puede usarse para hacer una estimación aproximada de su condición biológica. En realidad, para proteger el medioambiente, un nuevo nivel de planificación y ejecución de proyectos de desarrollo ha sido originado por la evaluación del ciclo de vida, las investigaciones de impacto ambiental y la evaluación de investigaciones económicas, debido al entendimiento de que el medio ambiente será dañado irreversiblemente por cualquier tipo de proyecto.


Palabras clave: índice trófico; impacto antropogénico; clorofila- α ; biodegradabilidad; eutrofización.

1. Introduction

The huge enrichment of nutrients such as nitrogen and phosphates or the eutrophication of water bodies like lagoons

have grown quickly as a result of human being activities. The effects of eutrophication that appear through the massive growing of phytoplankton, algae and macrophyte biomass, proliferation of toxic algae, the increment in water turbidity;

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the pronounced growth of organic waste matter originated by dead vegetation, the development of hypoxic and anoxic conditions, the decreased diversity of species, the variation of dominant biota and the increased sedimentation level helps the process of blockage and then reduces the longevity of lagoons [1, 2].

Low concentrations of nutrients will determine oligotrophic environments known as “water of good quality”. Its main characteristic is that these waters are of low productivity and high transparency. On the other hand, high amount of nutrients give room to eutrophics environments named “water of low quality” in which the high productivity generates a reduced transparency of the water [3,4].

In a lagoon, water quality monitoring and management are essential as to determine its usage [4]. Among the main factors to consider are the concentration of phosphorus, nitrogen, dissolved oxygen and chlorophyll-a, as well as turbidity, the chemistry and biochemistry demand of oxygen, all of them indicative of eutrophic level of a water body.

Hydrologically, Tecocomulco’s lagoon, it is located in the region called Pánuco River corresponding to the Gulf of Mexico, the basin is considered one of the most important in Mexico, ranking fourth in the national level due to its surface

and fifth due to the volume of its runoff. The objective of this work has been to evaluate the trophic status of the Tecocomulco’s lagoon, Hidalgo, Mexico.

2. Materials and methods

2.1. Study area in research

Tecocomulco’s lagoon in Hidalgo Mexico (Fig.1) is located in the oriental site of the volcanic Trans-Mexican belt. It belongs to the Tecocomulco sub-basin, located in the northeast part of the Mexico valley basin. It is delimited by the geographic coordinates 19° 42’ 13.7” and 19° 59’ 30” north latitude, and 98° 11’ 46.2” and 98° 27’ 30” west longitude; the sea level is 2514 (MSL) average altitude, and depending on the seasonal precipitation its average is 500 to 600 mm. From April to October the period of maximum rains is recorded and between November and March the driest periods. The lagoon has a lengthen shape oriented from northeast to southeast. The average tidal is from 70 cm deep to reach 2 meters depth [5]. The weather in the region is warm climate sub-humid with an average temperature between 8°C to 13°C [6].

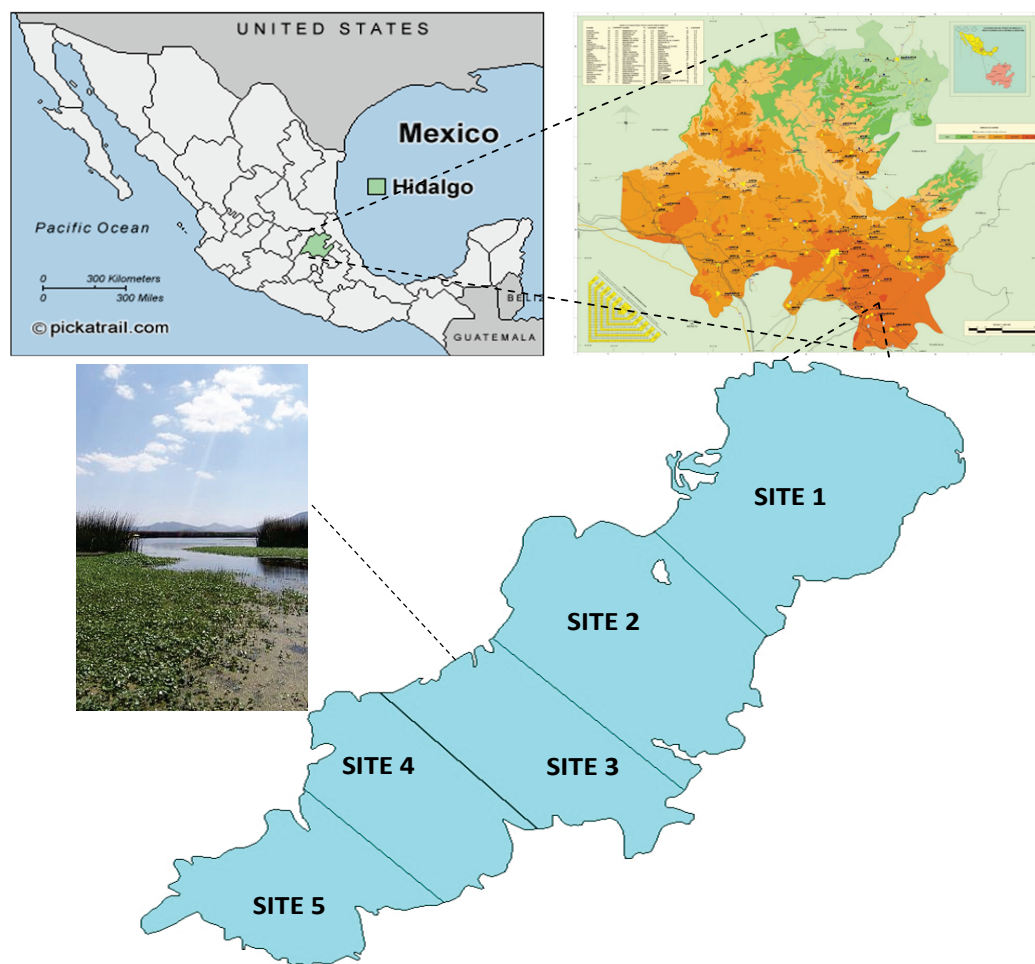


Figure 1. Location of Tecocomulco Lagoon and the sampling sites.
Source: The Authors.

2.2. Sampling

Five sample places were distributed based on accessibility in those areas (Table 1 and Fig. 1). The samples were taken in four seasons of the year: March, June, September and December 2009, with the goal of knowing the physic biochemistry variations of water between dry season and rainy season.

The conservation and handling of the samples were based on Mexican regulation NMX-AA-014-1980 [7]. The samples were preserved at low temperatures, between $4^{\circ}\pm 2^{\circ}\text{C}$. According to Table 2 it can be observed the main criteria taken in order to select the container, minimum collecting volume (by aliquot), preservation and maximum storage time of the water samples.

The physic-chemistry parameters were determined based on Mexican regulations: NMX-AA-007-SCFI-2000 (determination of temperatures); NMX-AA-093-SCFI-2000 (determination of Electric Conductivity); NMX-AA-012-SCFI-2001 (determining of dissolved oxygen); NMX-AA-008-SCFI-2000 (determination of pH); NMX-AA-079-SCFI-2001 (determination of nitrate); NMX-AA-099-SCFI-2006 (determination of nitrite); NMX-AA-026-SCFI-2001 (determination of total nitrogen); NMX-AA-036-SCFI-2001 (determination of total alkalinity); NMX-AA-034-SCFI-2001 (determination of dissolved solids); NMX-AA-030-SCFI-2001 (determination of chemistry request of oxygen); NMX-AA-028-SCFI-2001 (determination of biochemical request of oxygen); and NMX-AA-029-SCFI-2001 (determination of total phosphorus) [7-19].

2.3. Water quality analysis

Table 1.
Geographical coordinates in the sampling stations.

| Sampling sites | Geographical coordinates | | | | | |
|----------------|---------------------------|-----------------|-----------------|-----------|---------------------------------------|------------|
| | Degrees, minutes, seconds | | Decimal degrees | | Universal Transverse Mercator (WGS84) | |
| | Latitude | Longitude | Latitude | Longitude | X | Y |
| Site 1 | 19°52'54.06'' N | 98°22'20.17'' W | 19.88168 | -98.37226 | 565713.88 | 2198510.86 |
| Site 2 | 19°52'18.61'' N | 98°23'11.46'' W | 19.87183 | -98.38651 | 564226.26 | 2197415.66 |
| Site 3 | 19°51'26.30'' N | 98°23'07.75'' W | 19.85730 | -98.38548 | 564339.95 | 2195808.01 |
| Site 4 | 19°51'14.67'' N | 98°24'22.53'' W | 19.85407 | -98.40625 | 562166.41 | 2195442.89 |
| Site 5 | 19°50'34.57'' N | 98°25'03.93'' W | 19.84293 | -98.41775 | 560966.45 | 2194205.80 |

Source: The Authors.

Table 2.
Criteria for sampling to know physic-chemistry parameters of water.

| Parameters | Container | Minimum sample volume, mL | Preservation | Maximum storage time |
|--|---------------------------------|---------------------------|---|----------------------|
| Water temperature | - | - | I ^c | 0 |
| Electrical conductivity (EC) | - | - | I ^c | 0 |
| Dissolved oxygen (DO) | G ^a , BOD bottle | 300 | I ^c | 30 minutes |
| pH | - | - | I ^c | 0 |
| Nitrate-nitrogen (NO ₃ ⁻ -N) | P ^b , G ^a | 500 | C ^d | 48 hours |
| Nitrite-nitrogen (NO ₂ ⁻ -N) | P ^b , G ^a | 200 | C ^d | 24 hours |
| Ammonia-nitrogen (NH ₄ ⁺ -N) | P ^b | 1000 | C ^d and H ₂ SO ₄ at pH < 2 | 7 days |
| Total Kjeldahl Nitrogen (TKN) | P ^b | 1000 | C ^d and H ₂ SO ₄ at pH < 2 | 7 days |
| Dissolved solids (DS) | P ^b | 500 | C ^d | 7 days |
| Turbidity | P ^b , G ^a | 100 | C ^d | 24 hours |
| Chemical oxygen demand (COD) | P ^b , G ^a | 100 | C ^d and H ₂ SO ₄ at pH < 2 | 28 days |
| Biochemical oxygen demand (BOD) | P ^b , G ^a | 1000 | C ^d | 24 hours |
| Total Alkalinity | P ^b , G ^a | 500 | C ^d | 24 hours |
| Total phosphorus (TP) | P ^b | 500 | C ^d | 28 days |
| Chlorophyll- <i>a</i> | P ^b | 1000 | C ^d | 24 hours |

a: G, glass; b: P, polyethylene; c: I, *in situ*; d: C, cooling

Source: As recommended by [7]

2.4. Determination of soluble reactive phosphorus

In order to determine the solubility of reactive phosphorus in 20 ml sample of filtered water, 2ml of reactive 1 (see below) was added, and 0.4 ml of reactive 2 (see below), followed by a moderate shaking. Then, the sample was placed in darkness for 45 minutes; after this time color intensity was measured using a spectrophotometer UV/Vis to 880 nm [20].

Reactive 1: solution A. Dissolve 0.2 g of tartrate of potassium and antimony in 500ml deionized water. Add 1 ml of sulfuric acid, then weight 11.2 g of ammonium molybdate of ammonium tetra-hydrated and dilute in solution A. Shake continuously to facilitate the complete dissolution of molybdate. Gauge the solution to 1L.

Reactive 2: dissolve 27 g of ascorbic acid in 500mL of deionized water. Solution mother of phosphate 1000 mg/L de PO_4P : weight 4.390 g of di-acid phosphate of potassium and add deionized water up to 1L.

2.5. Determination of photosynthetic pigments

In order to determine Chlorophyll-a, a sample of 500mL of water was filtered through a glass filter Whatman GF/C of 25 mm diameter. The chlorophyll was extracted with 50 mL of acetone 90% during 48 hours in the darkness. From the measurement of absorbency checking with different wave longitudes, the concentration of chlorophyll-a was calculated by using the following formula:

$$\text{Chlorophyll } a \left(\frac{\mu\text{g}}{\text{L}} \right) = \frac{[(26.7)(E_{664\text{nm}} - E_{750\text{nm}})(V_{\text{acetone}})]}{V_{\text{filtered}}} \quad (1)$$

2.6. Eutrophic state evaluation

The evaluation of TSI was determined by the concentration of TP ($\mu\text{g/L}$) and chlorophyll-a ($\mu\text{g/L}$). The calculation was made through the following equations:

$$TSI = (14.42 \ln TP) + 4.14 \quad (2)$$

$$TSI = (9.81 \ln \text{Chlor. } a) + 30.6 \quad (3)$$

This type of index will reduce the trophic state of any lagoon or lake (in a scale from 0 to 100) by trying to avoid the inherent subjectivity to the terms oligotrophic, mesotrophic and eutrophic. The Table 3 summarizes the scale of values in a trophic state of a water body [21].

2.7 The OCDE (Organización para la Cooperación y el Desarrollo Económico), Organization for Economic Cooperation and Development

In order to achieve the determination of the trophic state by means of trophic category sequences recommended by OCDE, the TP and chlorophyll-a concentration were measured (Table 4).

Table 3.
Scales of values in a trophic state of a water body.

| Estate Eutrophic | TSI | TP ($\mu\text{g/L}$) | Chlorophyll-a ($\mu\text{g/L}$) |
|--------------------------------|-----|------------------------|-----------------------------------|
| | 0 | 0.75 | 0.04 |
| Oligotrophic (TSI<30) | 10 | 1.5 | 0.12 |
| | 20 | 3 | 0.34 |
| | 30 | 6 | 0.94 |
| | 40 | 12 | 2.6 |
| Mesotrophic (30<TSI<60) | 50 | 24 | 6.4 |
| | 60 | 48 | 20 |
| | 70 | 96 | 56 |
| Eutrophic (60<TSI<90) | 80 | 192 | 154 |
| | 90 | 384 | 427 |
| Hipereutrophic (90<TSI<100) | 100 | 768 | 1183 |

Source: [21]

Table 4.
Scale of values in eutrophic state recommended by OCDE.

| Parameters | Eutrophic State | | | | |
|-----------------------------------|-------------------|--------------|-------------|-----------|----------------|
| | Ultraoligotrophic | Oligotrophic | Mesotrophic | Eutrophic | Hipereutrophic |
| TP ($\mu\text{g/L}$) | <4.0 | 4.0-10 | 10-35 | 35-100 | >100 |
| Chlorophyll-a ($\mu\text{g/L}$) | <2.5 | 2.5-8.0 | 8.0-25 | 25-75 | >75 |

Source: [21]

Table 5.
Index scale of trophic state TRIX and water quality.

| Scale TRIX | Estate of water quality | Characteristics of water |
|------------|-------------------------|--|
| 2-4 | high | Poorly productive low trophic level. |
| 4-5 | Good | Moderately productive, medium trophic level |
| 5-6 | bad | Between moderate and high productivity. |
| 6-10 | poor | Highly productive, it has the highest trophic level. |

Source: [22]

2.8 Trophic state *TRIX*

To determine the trophic state *TRIX*, the concentration of chlorophyll-a, percentage of dissolves oxygen saturation, the concentration of NO_3^- -N, NO_2^- -N, NH_4^+ -N and soluble reactive phosphorus have already been determined [22]. The estimations were made by the following mathematic expression:

$$TRIX = \frac{\text{Log}_{10} [(Clora)(\%Od)](NID)(PRS) + K}{m} \quad (4)$$

Where each one of the four components represent a variable trophic state: Productivity factor

Chlor α = chlorophyll- α concentration - α ($\mu\text{g/L}$)

$|\%Od|$ = absolute value about percentage deviation of saturation dissolved oxygen, it means $|100 \text{ } Od|$

And nutritional factor

NID = Dissolved inorganic nitrogen, calculated as:

$$\text{NO}_3^- \text{-N} + \text{NO}_2^- \text{-N} + \text{NH}_4^+ \text{-N} (\mu\text{g/L}) \quad (5)$$

The constant $K=1.5$ y $m=12/10=1.2$ are values of scale and were introduced to adjust the lower limit value of the index and the spreading of the trophic scale already related, from 0 to 10 units *TRIX* (Table 5).

Table 6
Criteria for sampling physic-chemistry parameters of water.

| Parameter | Sampling station | SAMPLING PERIOD 2009 (Results with 95% of CI) | | | | |
|--|------------------|---|---------------------|---------------------|---------------------|--------------|
| | | March | June | September | December | Average site |
| pH | Site 1 | 6.88 \pm 0.022 | 6.92 \pm 0.041 | 7.16 \pm 0.063 | 7.28 \pm 0.023 | 7.06 |
| | Site 2 | 6.78 \pm 0.049 | 6.16 \pm 0.064 | 7.25 \pm 0.028 | 6.89 \pm 0.009 | 6.77 |
| | Site 3 | 7.25 \pm 0.093 | 6.24 \pm 0.151 | 7.77 \pm 0.047 | 7.46 \pm 0.004 | 7.43 |
| | Site 4 | 6.52 \pm 0.094 | 6.50 \pm 0.232 | 7.52 \pm 0.013 | 7.63 \pm 0.003 | 7.04 |
| | Site 5 | 6.75 \pm 0.057 | 6.69 \pm 0.055 | 7.30 \pm 0.045 | 7.80 \pm 0.001 | 7.19 |
| Total Alkalinity (mg CaCO_3/L) | Site 1 | 187.577 \pm 0.354 | 190.300 \pm 0.239 | 157.979 \pm 0.931 | 150.234 \pm 0.127 | 171.522 |
| | Site 2 | 131.672 \pm 0.578 | 130.603 \pm 0.059 | 117.346 \pm 0.176 | 110.983 \pm 0.276 | 122.651 |
| | Site 3 | 125.525 \pm 0.701 | 138.672 \pm 0.195 | 92.605 \pm 0.315 | 110.542 \pm 0.254 | 116.836 |
| | Site 4 | 168.345 \pm 0.536 | 171.493 \pm 0.247 | 149.953 \pm 0.097 | 120.998 \pm 0.136 | 152.697 |
| | Site 5 | 175.438 \pm 0.157 | 177.577 \pm 0.189 | 152.166 \pm 0.055 | 140.937 \pm 0.203 | 161.529 |
| NO_3^- -N (mg/L) | Site 1 | 4.919 \pm 0.022 | 4.281 \pm 0.012 | 5.344 \pm 0.012 | 4.906 \pm 0.023 | 4.862 |
| | Site 2 | 4.859 \pm 0.015 | 4.129 \pm 0.024 | 4.902 \pm 0.038 | 5.124 \pm 0.011 | 4.753 |
| | Site 3 | 4.962 \pm 0.017 | 4.233 \pm 0.025 | 6.174 \pm 0.023 | 4.808 \pm 0.010 | 5.794 |
| | Site 4 | 4.745 \pm 0.037 | 4.080 \pm 0.019 | 4.460 \pm 0.009 | 5.326 \pm 0.034 | 4.652 |
| | Site 5 | 4.455 \pm 0.012 | 4.003 \pm 0.012 | 4.944 \pm 0.022 | 5.436 \pm 0.020 | 4.709 |
| NO_2^- -N (mg/L) | Site 1 | 0.021 \pm 0.002 | 0.012 \pm 0.001 | 0.019 \pm 0.001 | 0.017 \pm 0.001 | 0.017 |
| | Site 2 | 0.022 \pm 0.001 | 0.023 \pm 0.001 | 0.023 \pm 0.002 | 0.021 \pm 0.001 | 0.022 |
| | Site 3 | 0.012 \pm 0.001 | 0.021 \pm 0.002 | 0.027 \pm 0.001 | 0.023 \pm 0.001 | 0.020 |
| | Site 4 | 0.031 \pm 0.003 | 0.012 \pm 0.001 | 0.019 \pm 0.001 | 0.017 \pm 0.003 | 0.019 |
| | Site 5 | 0.010 \pm 0.001 | 0.032 \pm 0.001 | 0.020 \pm 0.003 | 0.015 \pm 0.001 | 0.019 |
| NH_4^+ -N (mg/L) | Site 1 | 0.412 \pm 0.001 | 0.535 \pm 0.002 | 0.310 \pm 0.009 | 0.381 \pm 0.023 | 0.409 |
| | Site 2 | 0.406 \pm 0.002 | 0.581 \pm 0.004 | 0.368 \pm 0.002 | 0.343 \pm 0.045 | 0.424 |
| | Site 3 | 0.472 \pm 0.004 | 0.603 \pm 0.001 | 0.336 \pm 0.008 | 0.280 \pm 0.025 | 0.423 |
| | Site 4 | 0.411 \pm 0.003 | 0.557 \pm 0.001 | 0.412 \pm 0.003 | 0.347 \pm 0.058 | 0.432 |
| | Site 5 | 0.377 \pm 0.001 | 0.483 \pm 0.003 | 0.528 \pm 0.023 | 0.488 \pm 0.034 | 0.469 |

Source: The Authors.

Table 6
Criteria of sampling for physic-chemistry parameters of water. (Continuation).

| Parameter | Sampling station | SAMPLING PERIOD 2009 (Results with 95% of CI) | | | | |
|-------------------------|------------------|--|-----------------|-----------------|-----------------|--------------|
| | | March | June | September | December | Average site |
| TKN (mg/L) | Site 1 | 32.145 ± 0.002 | 33.082 ± 0.021 | 34.312 ± 0.023 | 33.362 ± 0.009 | 33.225 |
| | Site 2 | 30.325 ± 0.003 | 32.304 ± 0.025 | 31.808 ± 0.045 | 35.925 ± 0.024 | 32.591 |
| | Site 3 | 31.182 ± 0.002 | 30.136 ± 0.013 | 35.208 ± 0.032 | 34.067 ± 0.058 | 32.648 |
| | Site 4 | 28.298 ± 0.004 | 29.024 ± 0.045 | 30.979 ± 0.088 | 32.645 ± 0.012 | 30.237 |
| | Site 5 | 30.229 ± 0.001 | 32.081 ± 0.021 | 30.752 ± 0.013 | 30.271 ± 0.004 | 30.833 |
| DO (mg/L) | Site 1 | 4.684 ± 0.329 | 2.397 ± 0.055 | 7.407 ± 0.134 | 7.702 ± 0.101 | 5.547 |
| | Site 2 | 1.921 ± 0.008 | 1.120 ± 0.060 | 6.690 ± 0.018 | 7.294 ± 0.009 | 4.256 |
| | Site 3 | 6.133 ± 0.098 | 2.552 ± 0.034 | 7.760 ± 0.060 | 8.308 ± 0.127 | 6.188 |
| | Site 4 | 8.294 ± 0.066 | 7.670 ± 0.052 | 7.287 ± 0.018 | 9.321 ± 0.076 | 8.143 |
| | Site 5 | 12.520 ± 0.113 | 8.758 ± 0.025 | 9.235 ± 0.107 | 10.536 ± 0.088 | 10.262 |
| COD (mg/L) | Site 1 | 78.822 ± 0.153 | 134.423 ± 0.237 | 113.635 ± 0.241 | 78.025 ± 0.021 | 101.226 |
| | Site 2 | 103.809 ± 0.642 | 112.842 ± 0.367 | 106.823 ± 0.301 | 100.431 ± 0.421 | 105.976 |
| | Site 3 | 87.683 ± 0.432 | 128.881 ± 0.349 | 120.478 ± 0.444 | 98.801 ± 0.213 | 108.960 |
| | Site 4 | 99.084 ± 0.598 | 116.032 ± 0.512 | 120.843 ± 0.298 | 96.880 ± 0.182 | 108.209 |
| | Site 5 | 99.927 ± 0.286 | 124.073 ± 0.223 | 114.822 ± 0.132 | 100.427 ± 0.477 | 109.812 |
| BOD ₅ (mg/L) | Site 1 | 6.636 ± 0.025 | 6.864 ± 0.009 | 4.506 ± 0.051 | 2.219 ± 0.012 | 5.056 |
| | Site 2 | 6.256 ± 0.014 | 8.409 ± 0.017 | 8.167 ± 0.103 | 7.543 ± 0.015 | 7.593 |
| | Site 3 | 6.636 ± 0.021 | 7.497 ± 0.008 | 6.006 ± 0.012 | 2.425 ± 0.012 | 5.641 |
| | Site 4 | 5.952 ± 0.037 | 6.408 ± 0.008 | 1.845 ± 0.023 | 1.044 ± 0.025 | 3.812 |
| | Site 5 | 8.029 ± 0.009 | 9.635 ± 0.011 | 11.456 ± 0.215 | 7.694 ± 0.043 | 9.203 |
| TP (mg/L) | Site 1 | 0.083 ± 0.001 | 0.084 ± 0.002 | 0.073 ± 0.001 | 0.050 ± 0.001 | 0.073 |
| | Site 2 | 0.041 ± 0.001 | 0.124 ± 0.001 | 0.090 ± 0.003 | 0.064 ± 0.001 | 0.080 |
| | Site 3 | 0.033 ± 0.002 | 0.101 ± 0.001 | 0.074 ± 0.002 | 0.070 ± 0.003 | 0.069 |
| | Site 4 | 0.067 ± 0.001 | 0.075 ± 0.002 | 0.055 ± 0.001 | 0.052 ± 0.002 | 0.062 |
| | Site 5 | 0.048 ± 0.003 | 0.092 ± 0.002 | 0.067 ± 0.002 | 0.054 ± 0.001 | 0.065 |

Source: The Authors.

3. Results and discussion

3.1. Water Quality Analysis

Table 6 summarizes the results obtained to determine the physic- chemistry parameters of the water of Tecocomulco's lagoon. The average temperature of the water body indicates a spatial-temporary distribution with maximum values registered during June and minimums on winter (Fig. 2). The temperature varies between 13.1 to 21.2°C. The characteristic of the course (low deep, approximately 70 cm) suggests that most of the year the lagoon presents thermic homogeneity in depth.

The average conductivity values in the months of March, June, September and December were of 253.111, 327.159, 196.755 and 211.148 $\mu\text{S}/\text{cm}$ respectively. It is related to the concentration of dissolved solids (193.678, 261.853, 186.022 y 189.648 mg/L, in sites 1, 2, 3, 4 and 5, respectively), the

temperature and the evaporation. The highest conductivity and dissolved solids values were obtained during the month of June, when the temperature was higher (Figs. 3, 4 and 5).

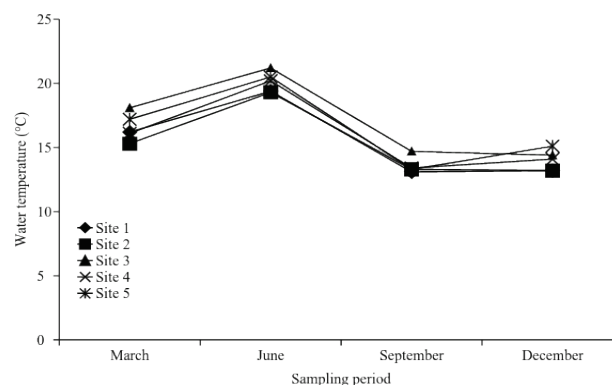


Figure 2. Spatial - temporary distribution of water temperature.
Source: The Authors.

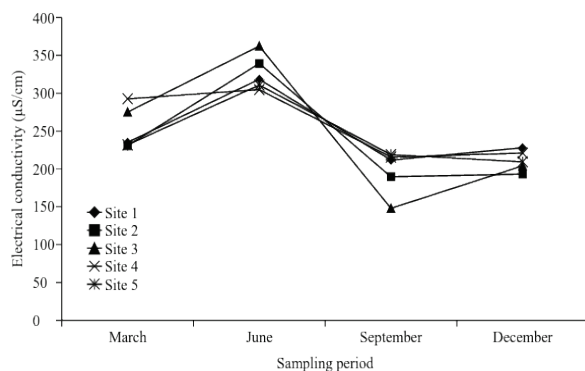


Figure 3. Spatial-temporary distribution of water electric conductivity. Source: The Authors.

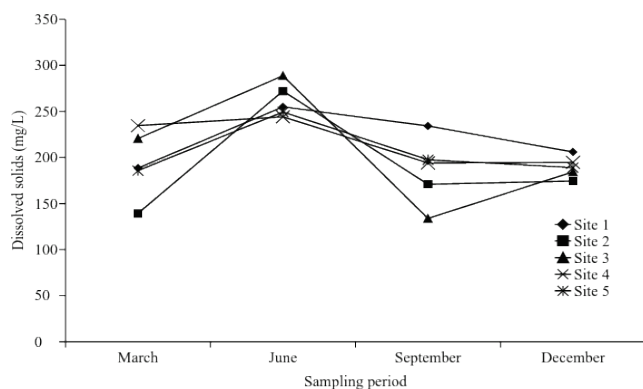


Figure 4. Spatial-temporary distribution of water dissolved solid concentration. Source: The Authors.

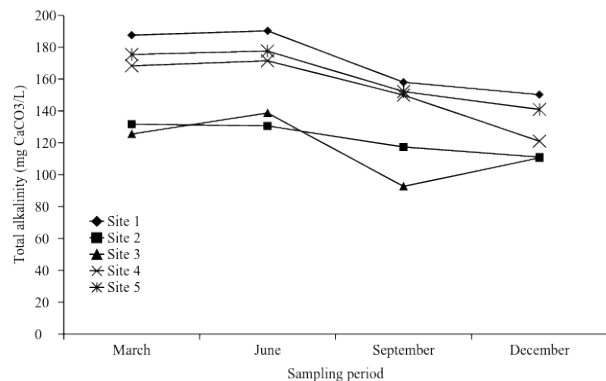


Figure 5. Spatial-temporary distribution of total alkalinity (low productivity < 75; medium productivity 75-150; high productivity > 150). Source: The Authors.

The determination of pH in the water body is a parameter to consider when it is necessary to analyze the chemistry speciation and solubility of organic and inorganic substances. Abiotic factors regulate half-full of the biologic processes by enzyme (photosynthesis, respiration); the availability of essential nutrients that limit the growth of the organisms (PO_4^{3-} , NO_3^-) and the mobility of heavy metals. Therefore, to understand the physic- chemistry behavior of the body water

in lagoons this parameter seems very important.

Table 6 shows that during the first two periods of sampling, the water had a slightly acid pH values; this phenomenon was emphasized during the month of June because of the presence of CO_2 produced by anaerobic bacterial respiration, the photosynthetic activity of submerged algae and aquatic macrophyte, and due to the decomposition of organic matter.

The variation of pH between periods and sampling sites could be explained by the diverse intrinsic and extrinsic factors such as:

- 1) Intrinsic factors:
 - a) Buffer capacity of the alkalinity carbonate and bicarbonate system.
 - b) Evaporation.
 - c) Intensity of biological processes such as photosynthesis, respiration and activities of organic matter decomposition.
- 2) Extrinsic factors:
 - a) Soil composition adjacent to the lagoon.
 - b) Pollution source: residual water spilled, influence of septic tank.
 - c) Temperature.

The pH is an important parameter; it is determined to identify the ionic species that contribute to water alkalinity. Alkalinity represents the main buffer system of water environments, and it plays an important role in the growth and development of algae and aquatic plants. It works as a reserve source to photosynthesis. Therefore, it could be used as an indicator of body water lagoons productivity, where high levels of alkalinity indicate high productivity.

The variability of values can be attributed to diverse factors such as: the wearing away, rock and minerals dissolution, aerobic and anaerobic respiration processes and photosynthetic process, among others. Due to the values found in alkalinity (Table 6), it could be concluded that Tecocomilco's lagoon has a high productivity (Fig.6), which can be confirmed through the ranking of eutrophication.

The parameter that shows wide-ranging in spatial and temporary differences is was DO. The level of DO is an indicator of the pollution rank and its capacity to support the vegetal and animal life. Commonly, a higher level of DO indicates better water quality; on the contrary, too low levels of DO mean that some biological species could not survive.

The sampling station with the lowest concentration of DO was site number 2, a place with high amount of *Scirpus lacustris* (common name tule), where hypoxia conditions are present (< 2.7 mg/L) during the first two periods of sampling, as a result of low water circulation, high temperatures, contribution of high organic matter content, and the consumption of oxygen during its composition.

The site number 5 had maximum values of DO (Table 6), showing submerged vegetation and high transparency, very important characteristic due to free oxygen during the process of submerged aquatic plants photosynthesis, a factor that contributes to increase the DO concentration.

A closely related parameter to DO is BOD, measured as the of amount of oxygen required to degrade organic matter in the water by microorganisms. The process of waste

decomposition will take place when the aquatic environments is polluted by organic matter like dead plants, residual water, organic waste from animals, and even food. When it happens, a lot of DO available is consumed by aerobic microorganisms, originating the reduction of big amounts of oxygen that can be used by other microorganisms. In this case, if DO is high, the level of BOD will be high too. Whereas organic waste is consumed the levels of BOD will get down. The water temperature can contribute to high levels of BOD. Once temperature increases, the speed of photosynthesis produced by algae and macrophytes usually increases as well in the water. When it happens the hydrophytes grow up and die quicker, making them to fall in depths where bacteria that usually require oxygen decompose them. So, the water with high temperature will accelerate the decomposition of bacteria and then will provoke high levels of BOD.

According to what was quoting before, it is possible to deduce that the sampling period with high levels of BOD₅ is June. This information could be confirmed by the experimental determination of this parameter. During this month, the highest temperatures are present, as well as the lower levels of DO; it suggests that the microbial activity was high, and for this reason so was the BOD₅. On the contrary, on December DO rises and the BOD₅ was lower, due to lower temperatures.

The determination of COD and the calculus of biodegradability level (%) of organic waste ($\%BD = [BOD_5/COD] * 100$) showed low values in all sites and sampling periods; these values are related and correspond to the rate BOD₅/COD and it is an indication of a low percentage of biodegradability matter (Table 6). It means that a high proportion of dead material is refractory and tends to form humus compounds that attach to the sediments and it is going to represent another factor that can favor the obstruction of body water (Fig. 6 and Fig. 7).

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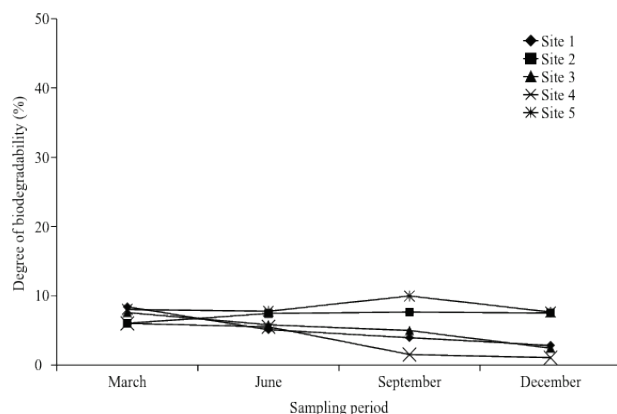


Figure 6. Spatial-temporary distribution of Percentage and rank of organic matter biodegradability.
Source: The Authors.

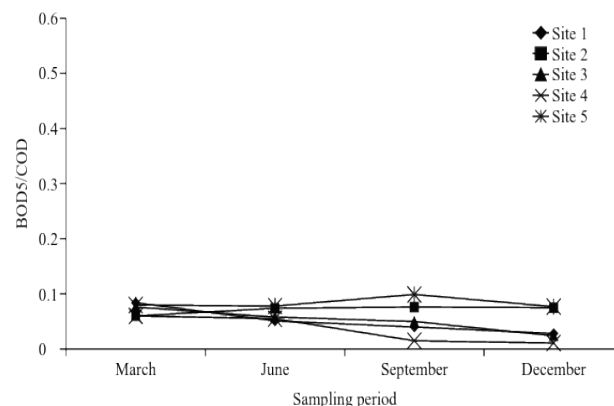


Figure 7. Spatial-temporary distribution related to the rate BOD₅/COD (DBO/DOQ>0.6 very degradable organic matter; BOD/COD<0.2 little degradable organic matter few).
Source: The Authors.

References

- [1] Glibert, P.M., Seitzinger, S., Heil, C.A., Burkholder, J.M., Parrow, M.W., Codispoti, L.A. and Kelly, V., The role of eutrophication in the global proliferation of harmful algal blooms. *Oceanography*, 18(2), pp. 198-209, 2005. DOI: 10.5670/oceanog.2005.54
- [2] Selman, M. and Greenhalgh, S., Eutrophication: policies, actions, and strategies to address nutrient pollution. World Resources Institute. WRI Policy Note. Water Quality: Eutrophication and Hypoxia. 3, pp. 1-16, 2009.
- [3] OECD. Eutrophication of waters. Monitoring, assessment and control. Research of the Organization for Economic Co-operation and Development (OECD). Ed. Soil and Water Conservation Society of Metro Halifax (SWCSMH). [online]. 2006. Available at: <http://lakes.chebucto.org/TPMODELS/OECD/oecd.html>. Accessed 19 February 2011.
- [4] Echaniz, S. and Vignatti, A., Determination of the trophic state and carrying capacity reservoir house. *BioScriba*, [online]. 2(1), pp. 41-51, 2009. Available at: <https://www.researchgate.net/publication/242398337>
- [5] GEH (Gobierno del Estado de Hidalgo). Consejo Estatal de Ecología. Ficha informativa de los humedales de Rammsar. 2003, pp. 1-10.
- [6] CONAGUA (Comisión Nacional del Agua). Subdirección General Técnica. Gerencia de Aguas Subterráneas. Subgerencia de evaluación y modelación hidrogeológica. Determinación de la disponibilidad de agua en el acuífero Tecocomulco, Estado de Hidalgo, México. 2002, pp. 1-25.
- [7] NMX-AA-014-1980. Receiver bodies. Sampling. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-014-1980.pdf>
- [8] NMX-AA-007-SCFI-2000. Analysis of water. Temperature measurement in natural water, sewage and waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/nmx-aa-007-scfi-2013.pdf>
- [9] NMX-AA-093-SCFI-2000. Analysis of water. Determination electrolytic conductivity. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-093-SCFI-2000.pdf>
- [10] NMX-AA-012-SCF2001. Analysis of water. Determination of oxygen dissolved in natural water, sewage and waste treated. Test method. [online]. Available at: <http://www.anic.org.mx/pqta/pdf/NMX-AA-quimicosgpo1.pdf>
- [11] NMX-AA-008-SCFI-2000. Analysis of water. Determination of pH. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-008-SCFI11.pdf>

- [12] NMX-AA-079-SCFI-2001. Analysis of water. Determination of nitrates in natural water, drinking, and waste waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-079-SCFI-2001.pdf>
- [13] NMX-AA-099-SCFI-2006. Analysis of water. Nitrogen determination of nitrite in natural and wastewater. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-099-SCFI-2006.pdf>
- [14] NMX-AA-026-SCFI-2001. Analysis of water. Total Kjeldahl nitrogen measurement in natural water, sewage and waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-026-SCFI-2001.pdf>
- [15] NMX-AA-036-SCFI-2001. Analysis of water. Determination of acid and alkalinity in natural waters, sewage and waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-036-SCFI-2001.pdf>
- [16] NMX-AA-034-SCFI-2001. Analysis of water. Determination of solid and sales dissolved in natural water, sewage and waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-034-SCFI-2001.pdf>
- [17] NMX-AA-030-SCFI-2001. Analysis of water. Determination of demand chemical oxygen in natural water, sewage and treated waste. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-030-SCFI-2001.pdf>
- [18] NMX-AA-028-SCFI-2001. Analysis of water. Determination of biochemical oxygen demand in natural waters, wastewater (BOD₅) and treated wastewater. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-028-SCFI-2001.pdf>
- [19] NMX-AA-029-SCFI-2001. Analysis of water. Determination of total phosphorus in natural water, sewage and waste treated. Test method. [online]. Available at: <http://www.conagua.gob.mx/CONAGUA07/Noticias/NMX-AA-029-SCFI-2001.pdf>
- [20] Elosegí, A. y Sabater, S., Conceptos y técnicas en ecología fluvial. 1^{ra} edition, Ed. Rubes, Spain. 2009. ISBN-978-84-96515-87-1.
- [21] Carlson, R.E. and Simpson, J., A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society. Madison, Wisconsin, 1996.
- [22] Vollenweider, R.E., Giovanardi, F., Montanari, G. and Rinaldi, A., Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic Sea: proposal for a tropic scale, turbidity and generalized water quality index. *Environmetrics*, 9, pp. 329-357, 1998. DOI: 10.1.1.473.7203andrep

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