DOI: 10.24850/j-tyca-2019-01-01
Articles

Physicochemical water characterization of La Vega Escondida Lake, Tampico, Tamaulipas, México

Caracterización fisicoquímica del agua de la laguna La Vega Escondida, Tampico, Tamaulipas, México

R. P. González-Dávila[1]
R. Ventura-Houle[2]
F. R. De la Garza-Requena[3]
L. Heyer-Rodríguez[4]

[1]Universidad Autónoma de Tamaulipas, México
[2]Universidad Autónoma de Tamaulipas, México, reneventura.houle@gmail.com
[3]Universidad Autónoma de Tamaulipas, México
[4]Universidad Autónoma de Tamaulipas, México

Author for correspondence: Ventura-Houle, R. reneventura.houle@gmail.com

Summary

La Vega Escondida Lagoon is located northwest of the municipality of Tampico, Tamaulipas. It is a protected natural area, in the suburbs area of Tampico, Madero and Altamira. This lagoon is a source of potable water supply for the city of Tampico and provide other ecological benefits. To protect both the ecosystem and human health it is important to know the physicochemical composition of the water in this lagoon. This study assessed the levels of physicochemical parameters of water (pH, electrical conductivity, total solids, temperature, chlorides, hardness, alkalinity, sulphates, chemical oxygen demand and dissolved oxygen) and its spatial distribution in the lagoon. The results

Tecnología y Ciencias del Agua

obtained were compared with the ecological criteria of water quality (CE-CCA-001-SEMARNAT, 1989) and with the Mexican drinking water standards (NOM-127-SSA1-1994). Results showed that the water of the lagoon complies with most quality parameters required to maintain the aquatic life and to human consumption, except for total suspended solids (SST). The patterns of spatial distribution of the physicochemical parameters were heterogeneous and they showed significant differences in the parameter OD at the different depths studied, as well were founded differences at sampling points for the pH and EC, at the level of significance of 5%.

Keywords: Water, physicochemical parameters, spatial distribution, lagoons.

Resumen

La Vega Escondida es una laguna ubicada al Noroeste del municipio de Tampico, Tamaulipas, dentro del área natural protegida colindante con la zona conurbada constituida por las poblaciones de Tampico, Madero y Altamira. Además del beneficio ecológico que representa, es una fuente de abastecimiento de agua potable. Por ello es importante conocer su composición fisicoquímica con el fin de proteger tanto al ecosistema como a la salud humana. Este estudio evaluó la concentración de los parámetros fisicoquímicos del agua (pH, conductividad eléctrica, sólidos totales, temperatura, cloruros, dureza, alcalinidad, sulfatos, demanda química de oxígeno y oxígeno disuelto) así como su distribución espacial dentro de la laguna. Los resultados obtenidos se compararon con los criterios ecológicos de la calidad del agua (CE-CCA-001-SEMARNAT, 1989) y con la Norma Oficial Mexicana (SALUD, 1994). De acuerdo a los parámetros analizados el agua cumple con la calidad requerida para consumo humano y mantener la vida acuática, excepto en el parámetro de sólidos suspendidos totales (SST). Se observó además que los patrones de distribución espacial de los parámetros fisicoquímicos son heterogéneos y que hay diferencias significativas en el parámetro OD (profundidades), así como en el pH y la CE (puntos de muestreo), al nivel de significancia del 5 %.

Palabras clave: agua, parámetros fisicoquímicos, distribución espacial, lagunas.

Recived: 21/05/2015

Accepted: 04/07/2018

Introduction

Lakes and lagoons belong to the category of quiescent waters or lentic (Roldan and Ramirez, 2008), are bodies of freshwater or saltwater, which occupy 13% of the coastal zones (Kjerve, 1994; Mahapatro *et al.,* 2013) as well as other extensive areas around the world. They are of great ecological, limnological and economic importance, due to their high productivity rates (aquaculture), intense human activity (recreation and transport) and as water receiving bodies (Spaulding, 1994). Despite its importance, coastal lagoons are often contaminated because of their geographical position and human activity within them and in their environment (Ahmed *et al.,* 2010; Gikas *et al.,* 2006; Pereira *et al.,* 2009; Specchiulli *et al.,* 2010).

The main pollutants derived from anthropogenic activity that impair water quality are: untreated municipal wastewater, industrial waste chemicals, as well as agrochemicals used in agriculture. They exert pressure on natural systems (Monforte and Cantu, 2009), because they cause acidification, eutrophication and toxicity (Camargo and Alonso, 2007). The sources of natural contamination have a significant influence on the ionic composition of the water, because they provide a great quantity of elements and compounds from the meteorization of the rocks and degradation of organic materials of plant and animal origin, so the water physicochemical parameters concentrations vary over time (from the Lance and Gomez, 1999).

These types of pollution affect all the hydrological basins of the world, especially in those with high population density, such as the river systems: Salween and Yangtze (southeast and central Asia), of La Plata (South America), Bravo (North America), Nile (North Africa) among others.

These systems are among the most polluted in the world, in which aquatic ecosystems present variations in the physical, chemical and biological properties in shorts time periods (Montoya-M, 2008). Studies carried out by Coutinho and Mello (2010) in the water of a subtropical coastal lagoon, determined that the concentration of the physicochemical parameters have been maintained at the same level that previous years (1996 and 1998), which implies that the distribution spatial and temporal water ions are directly related to anthropogenic activities (Batres, 2012).

The physicochemical parameters provide ample information on the nature of the chemical species of the water as well as their physical properties (Orozco *et al*., 2005) and its analysis allows a rapid assessment of the quality of the aquatic resource (Samboni, *et al.,* 2007). Because these parameters are subject to significant fluctuations occurring at spatial and temporal scales (Mambiela *et al.,* 1991; Martínez-Ansemil and Mambiela, 1992; Elosegui and Well, 1994), it is very important to determine their spatial distribution to know the dynamics they have within the water mass (Allan, 1995).

In the lower part of the Guayalejo – Tamesí river basin in the Mexican Republic, there is a lagoon system that has great hydrological, ecological and social importance for the region (Vera, 2004). This system comprises an approximate area of 40.000 ha, depending on the time of year and is made up of eight lagoons belonging to the state of Veracruz and ten lakes belonging to the state of Tamaulipas (NOM-033-CFSP-2003, Hurtado and Mora, 2007, INEGI, 2011). Of the latter, the La Vega Escondida lagoon, is a protected natural area, where at least 24 animal species and 4 plant species are in special protection status as threatened or endangered species, and the lagoon is a vital scale of migratory birds in the north-south corridor of the American continent (official newspaper of the state of Tamaulipas, 2003), besides it passes the water that is captured for the purification and subsequent human consumption in the city of Tampico.

The objective of this work is to determine the concentration and spatial distribution of some water physicochemical parameters indicative of the water quality of the La Vega Escondida lagoon, since there is no recent information about it. Also, we seek to approach the hydrodynamic behavior and its relationship with physicochemical quality of the water of this important body water from the Southern Tamaulipas lagoon system.

Materials and methods

Study Area

The study was carried out in the Laguna La Vega Escondida, which is part of the lagoon system of the river Guayalejo – Tamesí, also known as Champayán (hydrological region RH26 Río Pánuco) located in the municipality of Tampico, at the southeast of the state of Tamaulipas, Mexico (Sánchez and Propin, 2005), Figure 1. In the zone predominates the warm subhumid climate with rains in summer, with average humidity of 75%, temperatures of 22 to 26 ºC and 900 to 1100 mm per year of precipitation. The geology of the watershed that influences the lagoon is composed of sedimentary rocks, in the lower part can be found shale-sandstone, from the geological periods of Quaternary and Paleogene (INEGI, 2009) and in the middle and upper part there are metamorphic rock from the Precambrian Tertiary period, mostly limestone and shales and to a lesser extent gneises, which are occasionally covered by alluvial deposits of the Quaternary (Duma, 2010).

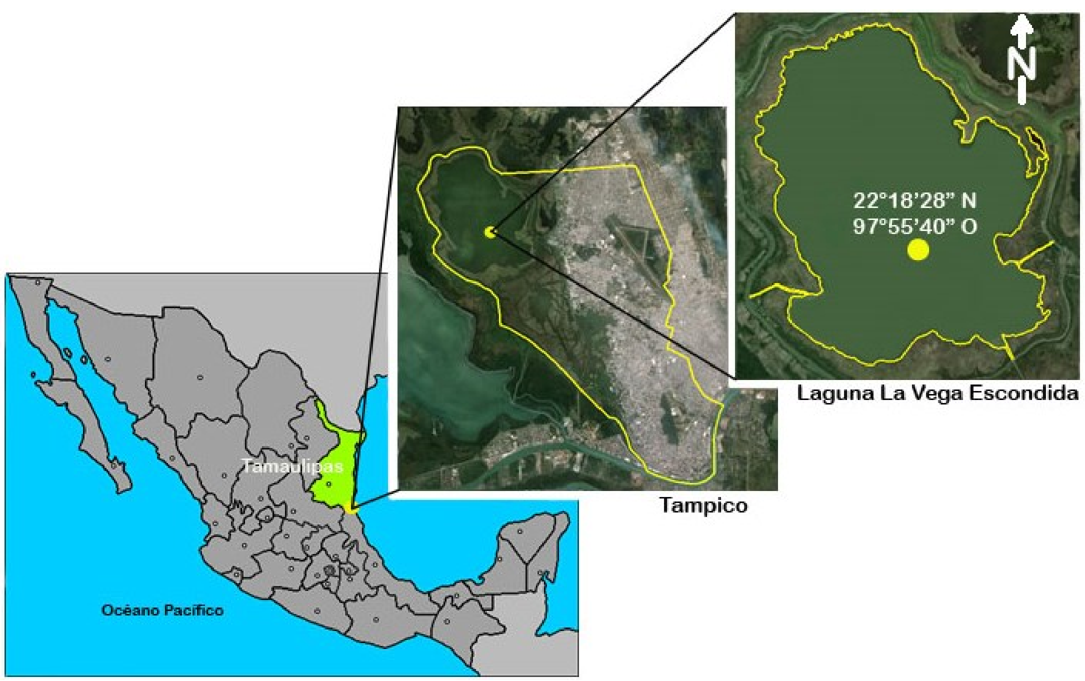
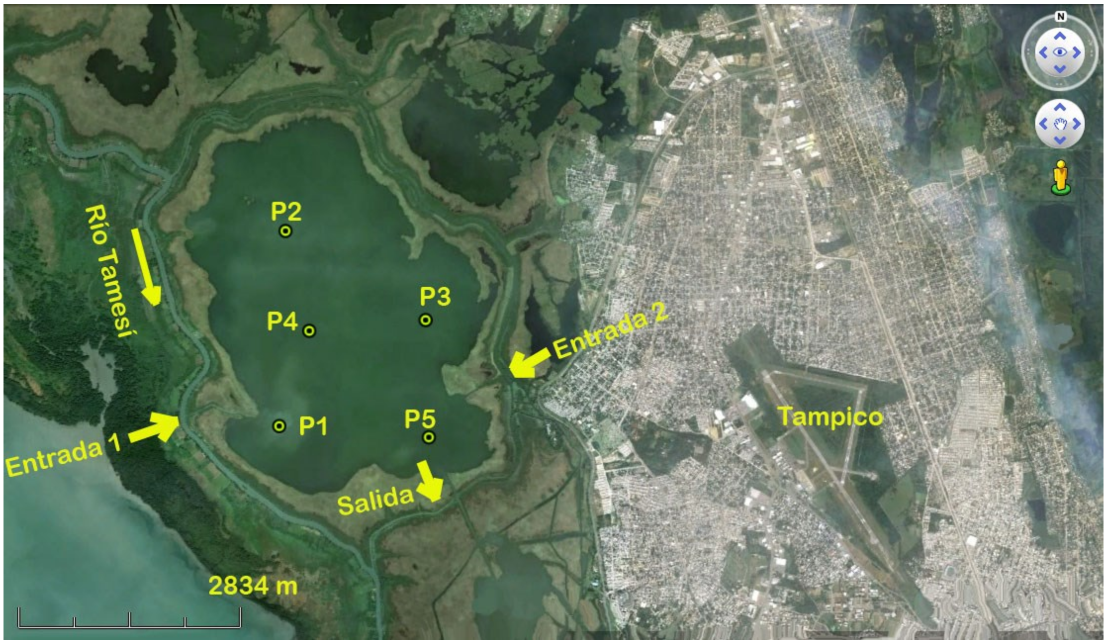


Figure 1. Geographic location of La Vega Escondida lagoon in Tampico, Tamaulipas, México.

Water sampling

Five points were established for water sampling (P1 = 22 ° 17 ' 40.9 "N – 97 ° 56 ' 5.62 O; P2 = 22 ° 19 ' 2.7 "N-97 ° 56 ' 5.9 O; P3 = 22 ° 18 ' 26.8 "N-97 ° 55 ' 1.1 O; P4 = 22 ° 18 ' 21.0 "N-97 ° 55 ' 53.6 O; P5 = 22 ° 17 ' 37.9 "N-97 ° 54 ' 58.0 O), Figure 2. These points covered the water inlet, outlet, and slowdown zones of the system. A grab sample was collected at each point from three depths (0.30; 0.70 and 1.2 m respectively) with an Alpha or Van Dorf bottle, following the methodology of the Mexican standard for sampling water bodies receptors NMX-AA-014-SCFI1980 (SCFI, 1980). Each sample consisted of 2 liters of water, which were placed in plastic bottles and stored in ice-coolers at 4 °C for preservation. The transport to the laboratory was carried out following the methodology stipulated at the APHA Standard Methods for the Examination of Water and Waste Water (Clesceri *et al*., 1998).



Fuente: Google earth 2015.

Figure 2. Location of sampling points at Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Analytical methods

The concentration of the physicochemical parameters of the lagoon water was determined by direct measurement in the field and in the laboratory according to the Mexican norms stipulated for the analysis of each parameter. (Table 1). These parameters are part of the water quality ecological criteria (CE-CCA -001/89), which indicates the main components to establish water quality for potential uses as: source of drinking water supply, recreational use, agricultural irrigation and the livelihood of biological systems. These parameters were chosen for functioning as indicators of the general state of water quality and for technical and economic limitations for the development of this study.

Table 1. Mexican standard methodology for the analysis of water physicochemical parameters.

Parameter	Mexican standard methodology
Ph	NMX-AA-008-SCFI-2011 *
Electrical conductivity (CE)	NMX-AA-093-SCFI-2000 *
dissolved oxygen (OD)	NMX-AA-012-SCFI-2001 *
Temperature	NMX-AA-007-SCFI-2013 *
Total suspended solids (SST)	NMX-AA-034-SCFI-2001 * *
Alkalinity	NMX-AA-036-SCFI-2001 * *
Hardness	NMX-AA-072-SCFI-2001 * *
Chlorides	NMX-AA-073-SCFI-2001 * *
Chemical oxygen demand (COD)	NMX-AA-030-SCFI-2001 * *
NitratesNo_3^-)	NMX-AA-079-SCFI-2001 * *
SulfatesSO_4^{2-})	NMX-AA-074-SCFI-2001 * *

* Field Measurement * * Laboratory analysis

Spatial distribution of compounds

It was carried out by applying the Geostatistical method of Kriging in the program ARC Gis 10.2, for which an exploratory analysis of the data was carried out to evaluate data normality and determination of tendencies and anisotropy. A Semivariogram was constructed for the determination of ranks, plateau and the value of the Pepita effect. Followed by adjustment of theoretical models to the variogram for analysis of the Pepita effect and evaluation of clusters and cross-validation.

Results and Discussion

Analysis of variance

The average pH value was 7.79 $\pm$ 0.09, therefore, the water of the Laguna La Vega Escondida is classified as weakly basic (MayoClinic.com, 2013), similar pH values have been reported for the El Chairel lagoon (SEMARNAT, 2010), which is an adjacent water body. The average electrical conductivity in the La Vega Escondida lagoon was 872.7 $\pm$ 40.6 MS cm^{-1}, this value differs with the average reported for an earlier monitoring period of 16 years of the Pánuco River water (1122.75 µS cm^{-1}) realized by SEMARNAT (2010) but is similar to the reported for the Chairel lagoon (650 µS cm^{-1}) by Pérez-Arreaga (2012).

The comparison of the averages values of temperature, COD and nitrates (NO^{-3}) at La Vega Escondida Lagoon with those reported for a 15 years period from the water of the Chairel lagoon and the Pánuco River, showed that the temperature and the COD of these were higher (temperature = 27.0 and 27.2 °C; COD = 6.9 and 12.7 mg L^{-1} respectively) than the water of La Vega Escondida lagoon. In the case of nitrates, the water of La Vega Escondida lagoon, has an average of 0.26 mg L^{-1}, this concentration is less than the reported for the El Chairel lagoon and the Pánuco river, where the content of NO^{-3} was 0.75 and 0.5 mg L^{-1} respectively (SEMARNAT, 2010).

The SST showed significant statistical differences, both between depths and between sites (table 2). When making a comparison between the average SST (321.0 mg L^{-1}) of the Laguna La Vega Escondida, with those determined in the Tamesí river (50.0 mg L^{-1}) by Batres (2012) during a period of five years (2000 to 2005), it was observed that the average concentration of SST at La Vega Escondida was greater than in

Tamesis river, with a difference of 290.0 mg L^{-1}. So the water from La Vega Escondida lagoon in relation to SST is classified as contaminated water (Nava, 2010).

The average alkalinity found in this study (168 mg L^{-1}) differs with the average (70 mg L^{-1}) reported for the Tamesis river, so the study water has a good buffer capacity that can resist changes of pH (Riberos *et al*., 2008).

The evaluation of analysis of variance of the results determined that the average values of temperature, SST, alkalinity, hardness, chlorides chemical oxygen demand, NO^{-3} and SO_4^{2-}, had significant differences between the depths of each point, as well as between the different sampling points (Table 2), which could be due mainly to the hydrodynamics of the water within the lagoon that generates a complex mixture of the recent water with the already stored, involving processes of water residency (Calvo and Mora, 2007; Pérez-Castillo & Rodríguez, 2008; Rendon-Dircio *et al*., 2012). The average values of the physicochemical parameters analyzed (pH, Temperature, Cl^-, hardness, alkalinity, SO_4^{2-}, SST and OD) in La Vega Escondida lagoon, did not exceed the permissible maximum limits suggested in the ecological criteria of water quality (CE-CCA -001/89) except for SST, which exceeds the level of reference.

Table 2. Analysis of variance at 0.05 of significance, between depths (vertical) and sites (horizontal) of water sampling at La Vega Escondida lagoon, Tampico, Tamaulipas, Mexico.

Parameter	$\bar{x} \pm S$	Analysis of variance	
		Vertical	Horizontal
		P-Value	P-Value
pH	7.79 ± 0.09	0.22 ns	0.03 *
CE (□S cm^{-1})	872.7 ± 40.8	0.79 ns	0.01 *
OD (mg O_2 L^{-1})	7.16 ± 1.17	0.01 *	0.71 ns
Temperature	24.5 ± 0.36	0.12 ns	0.22 ns
SST (mg L^{-1})	321.0 ± 49.0	0.90 ns	0.60 ns
Alkalinity (mg L^{-1} of $CaCO_3$)	168.35 ± 8.35	0.75 ns	0.50 ns

Hardness (mg L^{-1})	278.3 ± 6.88	0.31 ns	0.30 ns
Chlorides (mg L^{-1})	45.6 ± 0.75	0.76 ns	0.63 ns
Cod (mg L^{-1})	3.85 ± 4.90	0.07 ns	0.80 ns
Nitrates (mg L^{-1})	0.26 ± 0.21	0.26 ns	0.55 ns
Sulphates (mg L^{-1})	15.06 ± 1.25	0.57 ns	0.06 ns

* Significant $p \leq 0.05$, (ns) non-significant

Spatial distribution

For the analysis of the spatial distribution of the physicochemical parameters of the study water, were established three concentration ranges (low, medium and high), which were distributed in each parameter between the lowest value and the highest value of all measurements.

The potential for hydrogen (PH)

Under the conditions of the present study, it was determined that the high concentration of pH was in the superficial and intermediate layers of inlet 2 and the outflow of water. The medium concentration was in the superficial and intermediate layer of the slowing zone and at Inlet 1, as well as in the deep layer of inlet 2 and the water outlet. The low pH concentration was in the three water layers of the slowing zone (Figure 3). The high concentration of pH at Inlet 2 is because it comes from a low-flow secondary channel, which may have potential sources of contamination in its route before reaching the lagoon, which also influences the area surrounding the exit of water since it is very close. The medium concentration is due to hydrodynamic properties, which allow a permanent mixture of water within the lagoon, making that the pH distribute evenly between the different depths. The low

2019, Instituto Mexicano de Tecnología del Agua

concentration of pH zones is formed because these receive water directly from the river Tamesí, which provides a high flow and provides damping to pH changes because there is a correlation between flow and pH (Calvo and Mora, 2007).

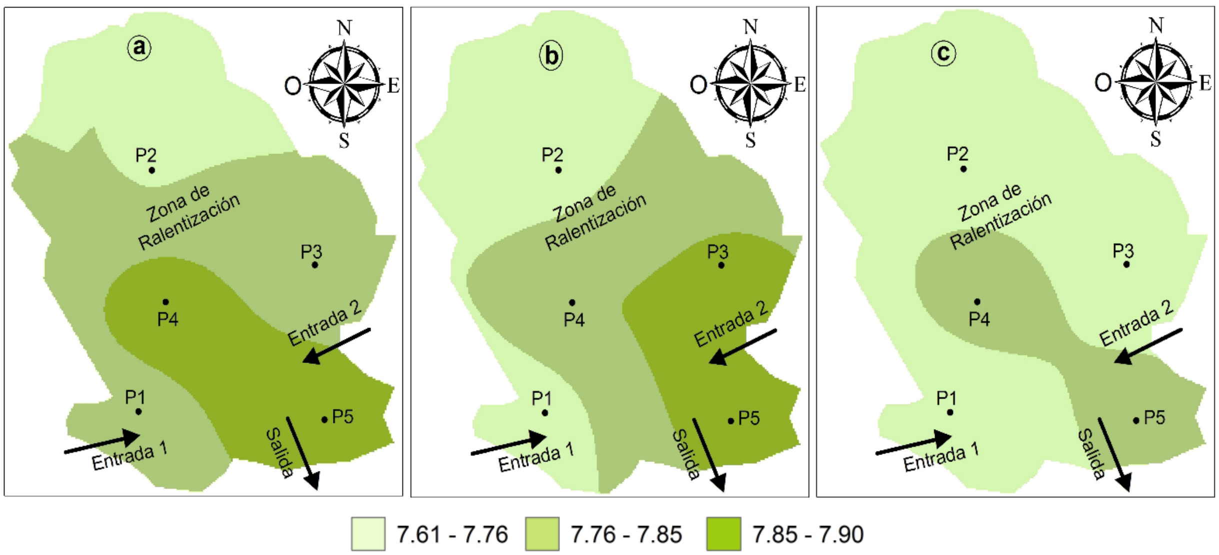


Figure 3. Spatial distribution of pH in the superficial (a), intermediate (b) and deep (c) layers of water at La Vega Escondida lagoon, Tampico, Tamaulipas, México.

Electrical conductivity (EC)

The spatial distribution of EC shows higher values in the intermediate and deep layers of inlet 2, the outflow of water and in the deep layer at the northeast of the slowing zone. The intermediate values of EC were in the central part from the north to the south of the intermediate and deep layers of the lagoon and in the same areas of the superficial layer the inlet 2. Finally, it was determined that the lowest values of EC are in the three water layers of inlet 1 of the lagoon (Figure 4). The heterogeneous behavior of the EC in space and time is conditioned by the fresh water mixture (Rendon-Dircio et al., 2012) of the Tamesí

River, which brings with it carbonates from the limestone rocks that make up the basin (Pérez-Arriaga, 2012).

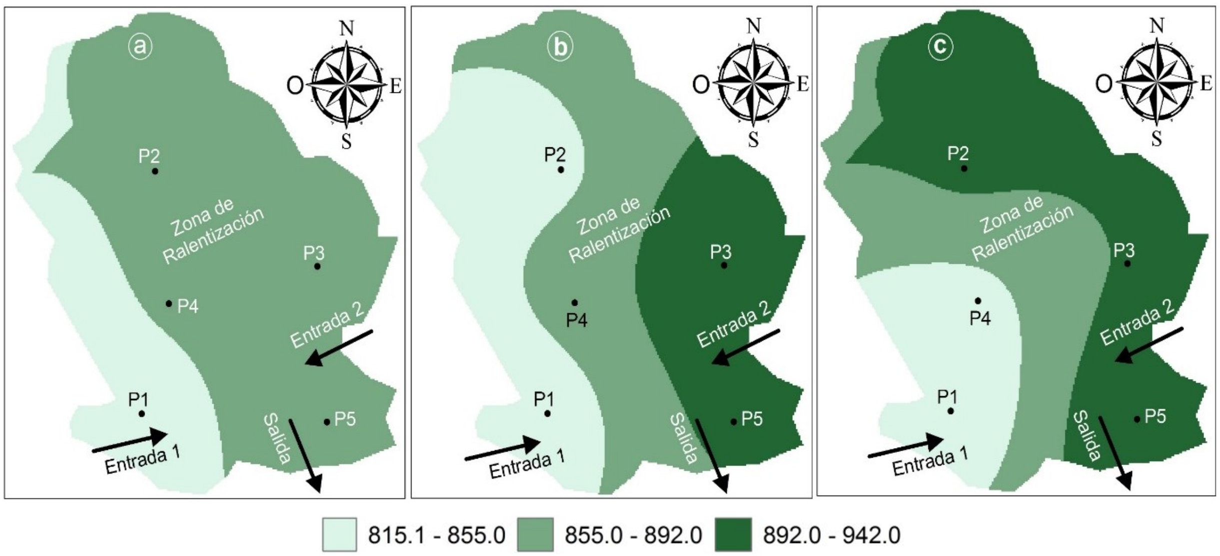


Figure 4. Spatial distribution of electrical conductivity (EC) expressed □S cm^{-1}, In the superficial (a), intermediate (b) and deep (c) water layers of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Total suspended solids (SST)

It was determined that the highest concentration of SST was in the superficial layer of the Northeast area, in the intermediate layer of the entrances 1, 2 and the water outlet, as well as in the central part of the lagoon with relation: East-West (Figure 5). The intermediate concentration was in the three study layers of the slowing zone, in the area of influence of the inlet 2 and the outflow of water in the superficial and deep layers. The lowest concentration of SST was in the superficial layer of inlet 1 and in the intermediate layer of the northeastern area of the lagoon. The above is produced by the hydrodynamic characteristics of the lagoon, which allow the water to mix constantly.

After a comparison between SST and water COD of the study pond, was determined that the origin of SST was mineral and non-organic, because COD representing organic solids is at low levels, so the presence of SST is due to soil erosion occurring throughout the year in the middle and high portion of the basin from the river Guayalejo – Tamesí. Thus, when comparing the SST averages of this study with the ecological criteria of water quality, the vital fluid is within the range of contaminated water (Nava, 2010).

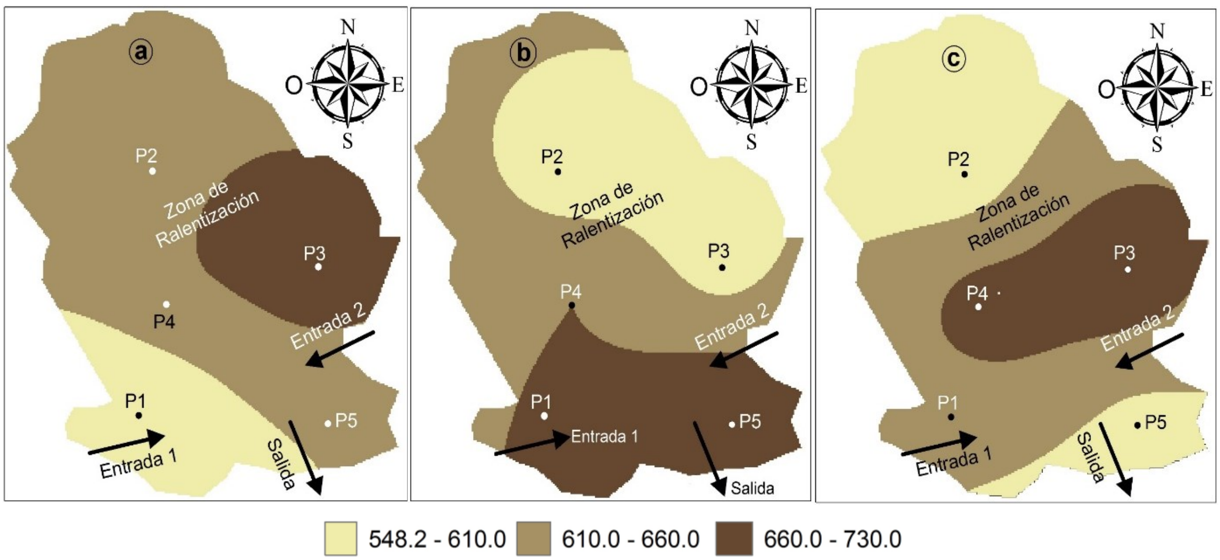


Figure 5. Spatial distribution of total suspended solids (SST) expressed in mg L^{-1}, in the superficial (a), intermediate (b) and deep (c) water layers of Laguna La Vega Escondida, Tampico, Tamaulipas – México.

Temperature (T)

The warmest temperatures (24.5-25.5 º C) were in the superficial and intermediate layers of inlet 2, the water outlet, in the central part and northeast of the lagoon. The intermediate temperature (24.3-24.5 º C), it is in the superficial and intermediate layers of the slowing zone, the Inlet 1 and in the deep layer of inlet 2 and its area of influence. The lower temperature range (24.0-24.3 º C) was found in the entire water column (three layers of study) of inlet 1 from where it is distributed towards the slowing zone and the water outlet through the deep layer (Figure 6). The behavior of the high temperature range of (24.5-25.5 º C) is because the water of inlet 2, comes from a small secondary channel, where it has more time of residence and there is a positive correlation between the air temperature with the thermocline (Zadereev *et al.* 2014), this has the tendency to be warmer, so it is maintained and always moves by the superficial layer of the lagoon.

The tendencies of the intermediate water temperature (24.3 – 24.5 °C) are due to that this is a mixture of the warm water from the inlet 2 with the cold water of the inlet 1, product of the hydrodynamics and the water body size. The behavior of the low temperature range (24.0-24.3 º C) is because at entry 1, the water comes from the main channel (Tamesí River), which has a large flow that remains in constant movement (Batres, 2012), this allows the water to maintain a stratified thermal pattern (Montoya-M, 2008), with lower temperature and density in relation to the water that is inside the lagoon, so when the cold water enters the lagoon, it is located and spreads through the bottom of the lagoon (Figure 6).

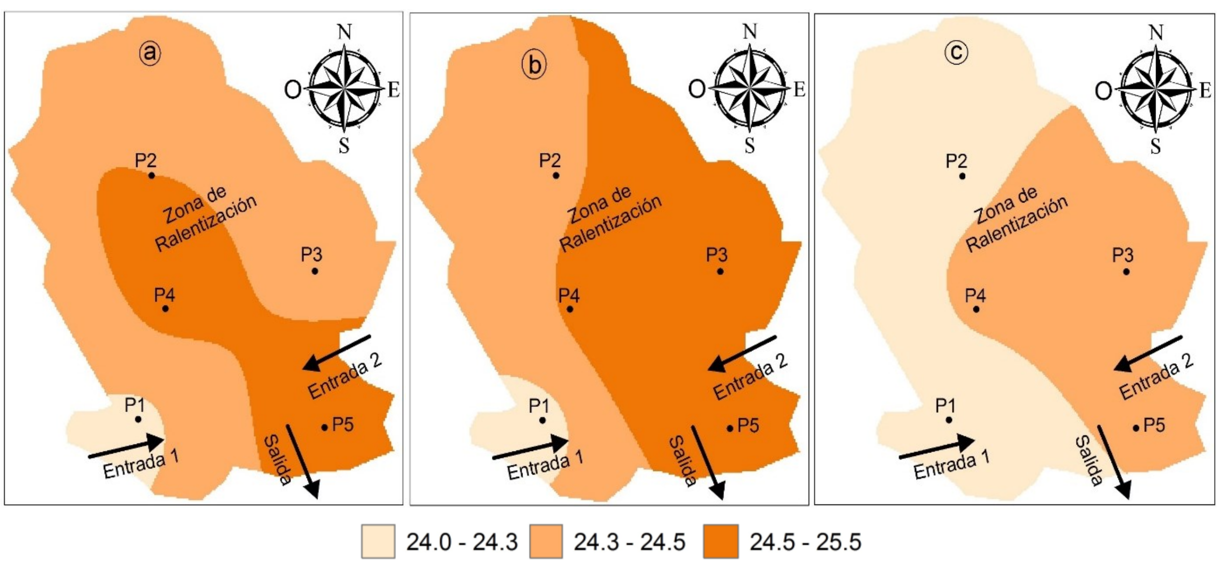


Figure 6. Spatial distribution of temperature (T) expressed in º C in the superficial (a), intermediate (b) and deep (c) layers of the water of the Laguna La Vega Escondida. Tampico, Tamaulipas, México.

Chlorides (Cl^-)

The higher concentrations (45.4-46.4 mg L^{-1}) of Cl^- was in the superficial and deep layers of the area of inlet 2 and in the intermediate layer of the area of inlet 1 and the slowdown zone. Intermediate concentration (44.7-45.4 mg L^{-1}), were in the superficial layer of the central part (from the north to the south) of the lagoon, in the intermediate layer of the inlet 2, exit of water, the deep layer of the inlet 1 and the slowing zone. The lowest concentration of Cl^-, was located at inlet 1 of the lagoon (Figure 7). This distribution is due to the hydrodynamic conditions of the water (Wetzel, 2001), which are influenced by the area and the average depth of the lagoon (Cardoso *et al*., 2003), as well by the orientation of the water inlets. These conditions allow the water body to have horizontal and vertical homogeneity (Branco *et al*., 2000; Briand *et al.,* 2002; Figueredo and Giani, 2009; Nogueira and Ramírez, 1998; Coutinho and Mello, 2011), because there is a constant and homogeneous mixture of water that enters with the one located inside the lagoon.

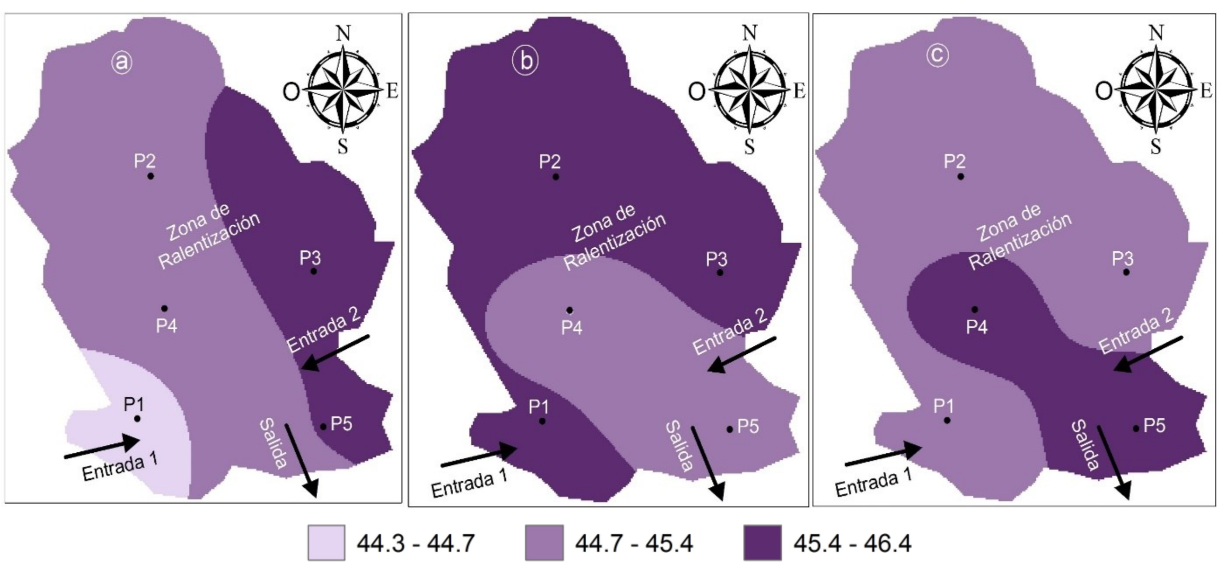


Figure 7. Spatial distribution of chlorides (Cl^-) expressed in mg L^{-1}, in the superficial (a), intermediate (b) and Deep (c) water layers of the Laguna La Vega Escondida, Tampico, Tamaulipas – México.

Hardness

The spatial distribution of the study water, determined that the highest concentration of hardness (282.0-290.0 mg L^{-1}), was in the intermediate layer of inlet 1 and 2 and in the water outlet and in the deep layer north of inlet 2. Intermediate concentration (276.5-282.0 mg L^{-1}) of hardness, covered approximately 90% of the surface layer and the intermediate layer of the central zone (East-west relation). Low concentration (267.0-276.5 mg L^{-1}), was in the surface layer of inlet 2, in the intermediate and deep layer of the slowing zone as well as in the deep layer of the water outlet (Figure 8). The variation in the concentration of hardness in the water column is mainly due to the hydrodynamics of the water, which keeps in constant mixture and movement the carbonate that comes from the meteorization of the limestone rocks that are forming the Sierra Madre Oriental of Mexico, through which flows the water that is in the system lagoon of the river Guayalejo-Tamesí and thus within the lagoon of study (Vera, 2004).

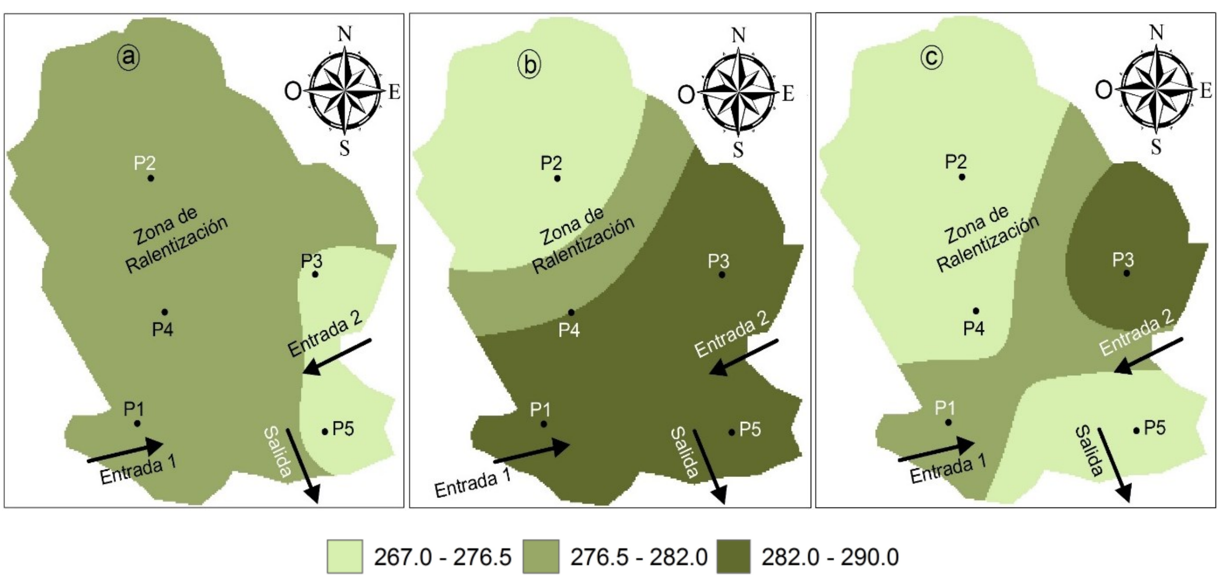


Figure 8. Spatial distribution of the hardness expressed in mg L^{-1}, in the superficial (a), intermediate (b) and deep (c) water layer of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Alkalinity

The spatial distribution (Figure 9), determined that the high range (168.0-176.0 mg L^{-1}) of alkalinity is in the three layers of input 2, in the deep layer of inlet 1 and the intermediate layer of the slow zone. This behavior is because the channel of Inlet 2 has a higher concentration of carbonates ($CaCO_3$), the same that comes from the weathering of limestone rocks that conform the geology of the basin (Vera, 2004) and possibly also by discharges of contaminants that may be in the path of the Tamesí river that passes very close to the city of Tampico. The middle range (162.0-168.0 mg L^{-1}), was found in the superficial and deep layers of the slowing zone and in the intermediate layer of the central part (North-South relation) of the lagoon, which is due to the mixture of water coming from Inlet 2 and the inlet 1 where the low range of alkalinity (15 6.0-162.0 mg L^{-1}) is located. There is a positive relationship between alkalinity with pH, the alkalinity is in greater concentration where there are higher pH values. According to the average of alkalinity found, it can be said that the water has good capacity to maintain the adequate pH for the development of aquatic life.

Tecnología y Ciencias del Agua

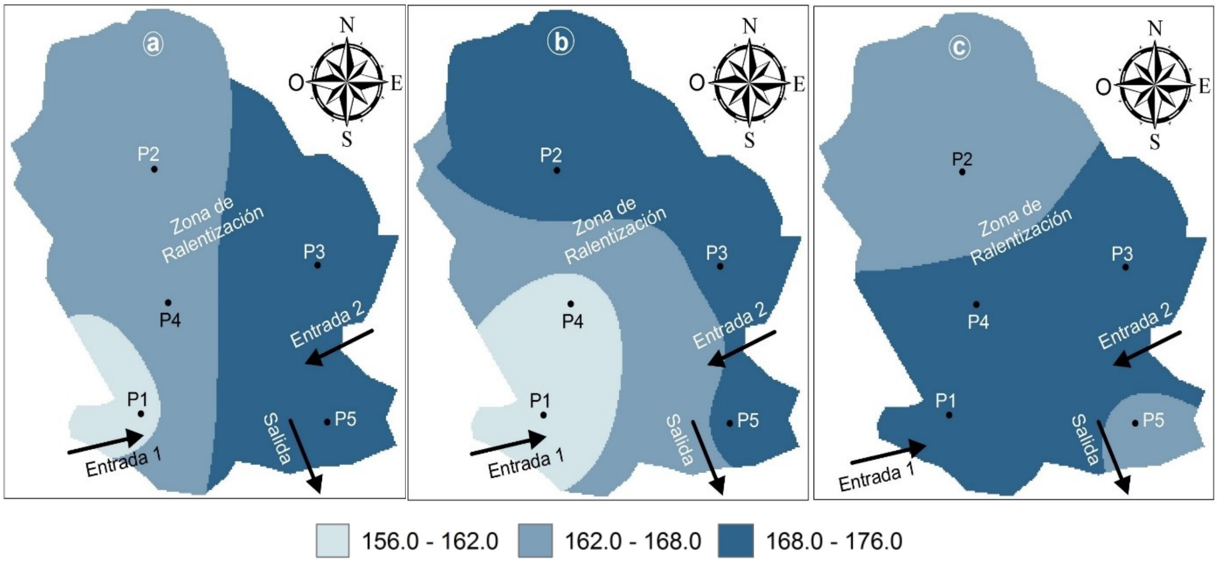


Figure 9. Spatial distribution of alkalinity in the surface layer expressed in mg $CaCO_3$ L^{-1} in the superficial (a), intermediate (b) and deep (c), water layers of Laguna La Vega Escondida, Tampico, Tamaulipas – México.

Sulfates (SO_4^{2-})

The spatial distribution analysis showed that due to the hydrographic conditions of the body of water under study, the SO_4^{2-}, were in Higher concentration (16.0-19.0 mg L^{-1}) into the surface layer of the inlet 1. Intermediate concentration (14.8-16.0 mg L^{-1}), was in the superficial and deep layers of the slowing zone and in the intermediate layer of inlet 1 and the water outlet (figure 10). This is due to the constant mixing of the sulfate in the Lagoon's water system. The concentrations found of SO_4^{2-} do not represent risk to the development of the life in the water system in study, since these levels, are not toxic for the plants and animals.

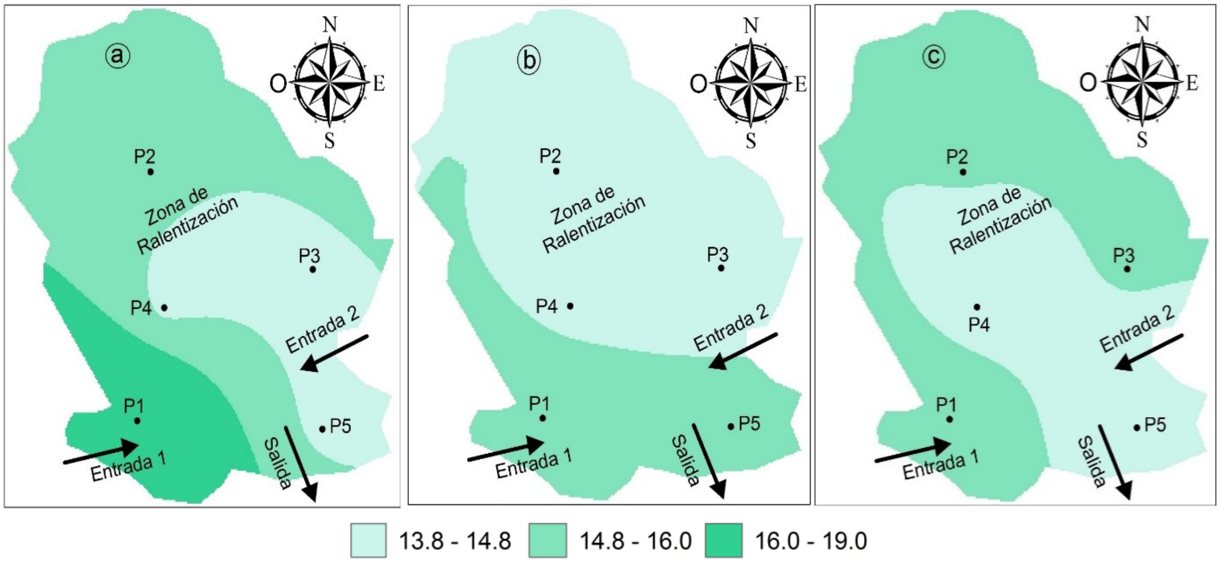


Figure 10. Spatial distribution of sulphates (SO_4^{2-}) expressed in mg L^{-1}, in the superficial (a), intermediate (b) and deep (c) layers of water of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Chemical Oxygen Demand (COD)

The spatial distribution of the COD in the water column of the Laguna La Vega Escondida, showed that most part of study area had low concentration of COD (0.0-3.0 mg L^{-1}) in the three water layers of the laguna. The medium and high concentration was found in the superficial and intermediate layers of the slowing zone, as well as in the deep layer of the inlet 2 and its area of influence and at the outflow of water (figure 11). It should be noted that the levels of COD found would correspond to natural levels of organic matter that come from the biological activity.

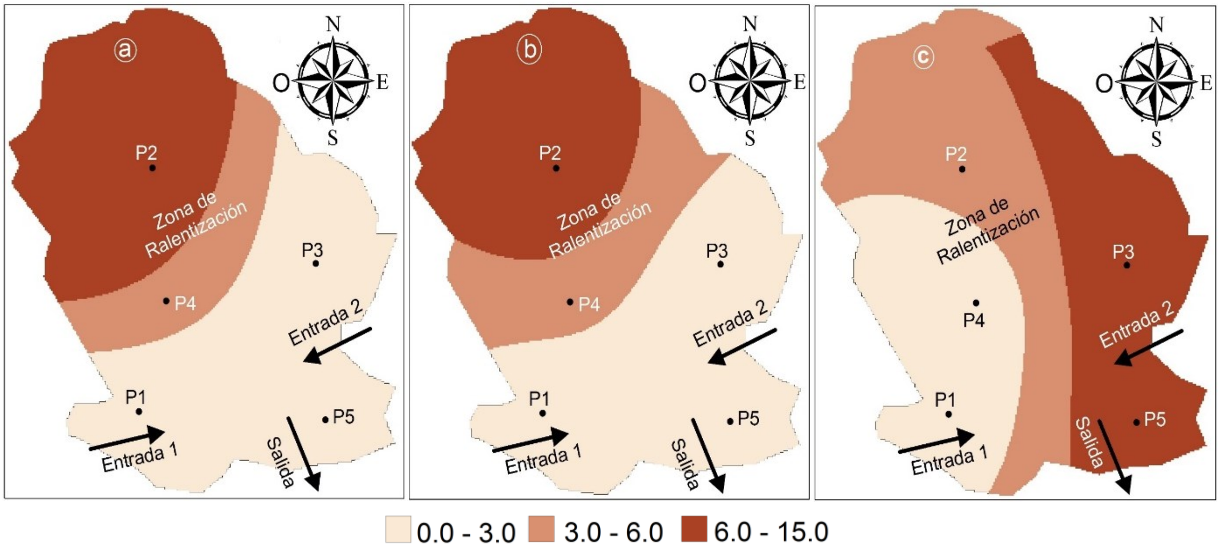


Figure 11. Spatial distribution of the chemical demand for oxygen (COD) expressed in mg L^{-1}, in the superficial (a), intermediate (b) and deep (c) water layers of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Dissolved oxygen (DO)

The spatial distribution determined that the highest DO concentration was in the superficial layer of all sampling points and in the central part (relation: East-west) of the lagoon. The intermediate concentration was in the intermediate layer of the slowing zone and at outflow of water. The lowest concentration was in the deep layer of the entire lagoon (figure 12). The above, it happens because OD has a close relationship with COD, so in the areas of the lagoon where this parameter are at high level, DO decreases, because there is a high consumption of oxygen from the microorganisms that are degrading the organic matter present in the water. The levels found, do not present risk of producing hypoxia in aquatic species of this body of water (Montalvo *ET al.,* 2008).

Tecnología y Ciencias del Agua

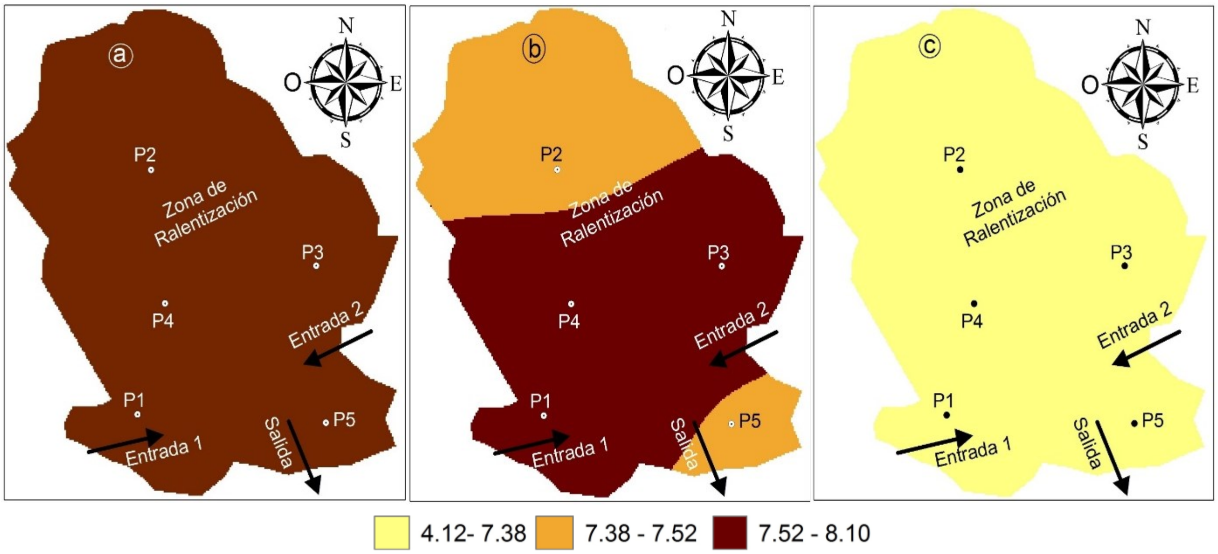


Figure 12. Spatial distribution of dissolved oxygen OD mg O_2 L^{-1}, in the superficial (a), intermediate (b) and deep (c) water layers of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Nitrates NO_3

The spatial distribution determined that NO_3^- were in greater concentration in the superficial layer of the central area of the lagoon and the intermediate and low concentrations were in most of the superficial and intermediate layer of the slowdown zone and at outflow of water (figure 13). It should be indicated that the analysis of NO_3^- did not determine a concentration in the deep layer, so no distribution map is Presented. The levels of nitrates found in this study correspond to natural concentrations, product of the breakdown of organic materials, therefore when the NO_3^- at a low level (0.26 mg L^{-1}), you can tell the study water is not contaminated by this parameter, because it is below the nitrate levels of natural waters which is 0.45 mg L^{-1} (Chapman, 1996).

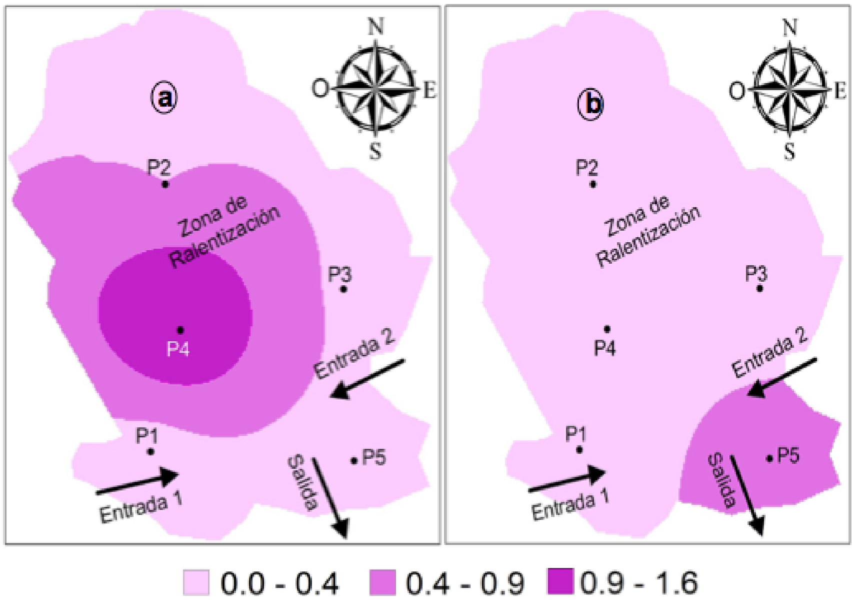


Figure 13. Spatial distribution of nitrates (NO_3^-) expressed in mg L^{-1}, in the superficial (a), intermediate (b) and deep (c) water layers of Laguna La Vega Escondida, Tampico, Tamaulipas, México.

Conclusions

The general behavior of the analyzed components are directly influenced by the 2 points of entry of water to the Laguna La Vega Escondida, the Inlet 1 is connected directly to the Tamesí river, its characteristics depend on the level and the quality of the water of this main tributary, while the characteristics of the water entering by the Inlet 2, depend on the activity in the channel that surrounds the area of the lagoon and discharges its waters in the study area.

The Inlet 1 incorporates water from the trawling of the entire route of the Tamesí River system, which drains an approximate area of 15 735 Km^2 and that allows the dilution of contaminants, so that the water that enters at the Inlet 1, is of better quality than that which enters by the Inlet 2. The water that enters through the Inlet 2, comes from the same hydrologic system, but when entering in the channel the slowdown and urban activities surrounding the Laguna La Vega Escondida, generate a deterioration of the quality of water entering the Lagoon

Inside the lagoon the waters of Inlet 1 and 2 are mixed generating a mixing zone in the southern part of the lagoon, at the north of the mixing zone there is an area where the flow slows, which is reflected in the behavior of the different components analyzed. The chemical parameters evaluated indicate a healthy and stable body of water, with an adequate resilience to the effects of contamination from the various activities of the basin, allowing the development of aquatic life and the subsistence of biological systems. Also, the water from the lagoon can be used as potable water supply, agricultural irrigation and recreational use.

It is important to continue this type of work, for a continuous monitoring of the water quality of the Laguna La Vega Escondida and the entire Champayan lagoon system, to which it belongs. It is important that this information is made available to the public. It must be publicly available, due to the ecology, social and economic importance of this lagoon system, which lacks proper monitoring of its ecological status and water quality.

Acknowledgments

To the National Council of Science and Technology (CONACYT) of Mexico and the Equinoctial Technological University of Ecuador (UTE), for the financial support, by means of scholarship to the principal author to carry out the studies of mastery, from which this investigation derives.

References

Ahmed, B., Seto M., Ishiga, H. K., Fukushima T., H. & Roser, B. P. (2010). Abundances, distribution, and sources of trace metals in Nakaumi–Honjo coastal lagoon sediments, Japan. *Environmental Monitoring and Assessment*, 167, 473-491.

Allan, J. D. (1995). Stream ecology: structure and function of running waters. *Chapman & Hall*, 5 (2), 87-172.

Batres, J. J. (2012). Crecimiento urbano e industrial, consecuencias ambientales en las lagunas urbanas y periurbanas en Tampico-Madero-Altamira del sur de Tamaulipas, México en *Planificación*

Territorial y Desarrollo Regional.(tesis de doctorado). Universidad de Barcelona. España.

Branco, W. C., Esteves, F. A. & Kozlowsky-Suzuki, B. (2000). The zooplankton ona other limnological features of a humic coastal lagoon (Lagoa Comprida, Macaé, R.J.) in Brazil. *Hydrobiologia*, 437, 71–81.

Briand, J. F., Robillot, C., Quiblier-Lloberas, C., Humbert, J. F., Coutè, A. & Bernard, C. (2002). Environmental context of Cylindrospermopsis raciborskii (Cyanobacteria) blooms in a shallow pond in France. *Water Research*, 36, 3183–3192.

Calvo-Brenes, G. & Mora-Molina, J. (2007). Evaluación y clasificación preliminar de la calidad del agua de la cuenca del río Tárcoles y el Reventazón. Parte I: Análisis de la contaminación de cuatro ríos del área metropolitana. *Tecnología en marcha*, 20 (2), 3-9.

Camargo, J. A. & Alonso, A. (2007). Contaminación por nitrógeno inorgánico en los ecosistemas acuáticos: problemas medioambientales, criterios de calidad del agua e implicaciones del cambio climático. *Ecosistemas*, 16 (2), 1697-2473.

Cardoso, L. S., Silveira, A. L. L. & Marques, D. M. L. M. (2003). Aação do vento como gestor da hidrodinámica na lagoa Itapeva (litoral norte do Rio Grande Sul— Brasil). *Revista Brasileira de Recursos Hídricos*, 8(3), 5–15.

Chapman, D. (1996). *Water quality assessments: A guide to the use of Biota, sediments and water in environmental monitoring*.(second edition). Cambridge, Great Britain: University Press.

Coutinho, M. & Mello, M. (2011). Spatial and temporal dynamic of trophic relevant parameters in a subtropical coastal lagoon in Brazil. *Environmental Monitoring and Assessment*, 181, 347–361.

Clesceri, L. S., Greenberg, A. E. & Eaton, A. D. (1998). *Standard methods for the examination of water and wastewater* (20th Edition). Washington DC, United States: American Public Health Association.

EcuRed.(2013). *Enciclopedia colaborativa cubana*. Cuba: Joven Club de Computación y Electrónica. Recuperado de http://www.ecured.cu/index.php/Clasificaciones_qu%C3%ADmicas_del_agua

Elosegui, A. & Pozo, J. (1994). Variaciones nictemerales de las características físico-químicas de un río Cantábrico. *Limnética,* 10 (2), 15-25.

Figueredo, C. C. & Giani, A. (2009). Phytoplankton community in the tropical lake of Lagoa Santa (Brazil): conditions favoring a persistent bloom of Cylindrospermopsis raciborskii. *Limnologica*, 39(4), 264–272.

Forero-Céspedes, A. M. & Reinoso-Flórez, G. (2013). Evaluación de la calidad del agua del río OPIA (Tolima-Colombia) mediante macroinvertebrados acuáticos y parámetros fisicoquímicos. *Caldasia*, 35(2), 371-387.

Gikas, G. D., Iannakopoulou, T. Y. & Tsihrintzis, V. A. (2006). Water quality trends in a costal lagoon impacted by non-point source pollution after implementation of protective measures. *Hidrobiologia*. 563, 385-406.

Hurtado, S. & Mora, A. (2007). Estudio de Flora y Vegetación Acuática del Humedal Sistema Lagunario del río Tamesí. Hábitat que Sustenta el Ecosistema. Tampico, Tamaulipas.

INEGI (2009). Prontuario de información geográfica municipal de los Estados Unidos Mexicanos. Tampico, Tamaulipas. (material de consulta). Recuperado de http://www3.inegi.org.mx/sistemas/mexicocifras/ datos-geograficos/28/28038.pdf

Kjerve, B. (1994). Coastal lagoons process. *Elsevier Oceanography Series,* (60), 577. Recuperado de http://dx.doi.org/10.1016/S0422-9894(08)70006-0.

Lanza De la, G. & Gómez, S. (1999). Fisicoquímica del agua y Cosecha de Fitoplancton en una Laguna Costera Tropical. *Ciencia Ergo Sum*, 6(2), 147-153.

Li, X., Bianchi, T. S., Yang, Z., Osterman, L. E., Allison, M. A., DiMarco, S. & Yang, F. G. (2011). Historical trends of hipoxia in Changjian River estuary. Applications of chemical biomakers and microfossils. *Journal of Marine Sistems,* 86, 57-68.

Mahapatro, D., Panigrahy, R. C. & Panda, S. (2013). Coastal Lagoon: Present Status and Future Challenges. *International Journal of Marine Science*, 3 (23), 178-186.

Mambiela, P., Montes, C. & Martínez-Ansemil, E. (1991). Características hidroquímicas de los ríos de Galicia (NW Península Ibérica). *Limnética*, (7), 163-174.

Martínez-Ansemil, E. & Mambiela, P. (1992). The low mineralized and fast turnover watercourses of Galicia. *Limnética*, (8), 125 -130.

Monforte, G. & Cantú, P. C. (2009). Escenario del agua en México. *Culcyt//Recursos Hídricos*, (30), 31–40).

Montalvo, J. F., García, LL., Loza, S., Esponda, S. C., César, M. E., González de Zaya, R. & Hernández, L. (2008). Oxígeno disuelto y materia orgánica en cuerpos de aguas interiores del Archipiélago Sabana-Camagüey, Cuba. *Serie Oceanológica*. (4), 71–84.

Montoya-M., Y. (2008). Variaciones nictemerales de algunas variables climáticas, físicas y químicas en una laguna somera en Guatapé, Antioquia, Colombia. *Actualidades Biológicas*, 30 (88), 83-96.

Nava, C. (2010). *Diagnóstico de calidad del agua en zonas costeras*, Conagua, México. Recuperado de http://coin.fao.org/coinstatic/cms/media/6/12859463663950/10.cna-medicion-calidad_24ago10.pdf

Orozco, C., Pérez, A., González, M. N., Rodríguez, F. & Alfayete, J. (2005). *Contaminación ambiental: Una revisión desde la química* (3ª. ed.). España:Thomson Editoriales, Paraninfo S.A.

Pereira, P., Pablo, H., Vale, C., Franco, V. & Nogueira, M. (2009). Spatial and seasonal variation of water quality in an impacted coastal lagoon (Óbidos Lagoon, Portugal). *Environmental Monitoring and Assessment*, 153, 281–292.

Pérez-Arreaga, E., Garza-Flores, R., Canales-Caballero, S. & Guevara-Guerrero, M. (2012). *Análisis de la calidad del agua y del paisaje del sistema lagunario Chairel*. Ciudad Victoria, Tamaulipas: Instituto Tecnológico de Ciudad Victoria.

15-21.http://www.itvictoria.edu.mx/personal/tecnointelecto/TecnoINTELECTO-FINAL-%20Vol%209%20%282%29-2012.pdf

Pérez-Castillo, A. G. & Rodríguez, A. (2008). Índice fisicoquímico de la calidad de agua para el manejo de lagunas tropicales de inundación. *Revista Biología Tropical*, 56 (4), 1905-1918.

Periódico Oficial del Estado de Tamaulipas. (2003). Recuperado de http://www.tampico.gob.mx/gobierno1/areas/obras_pub/ecologia/vega.htm.

PESCA. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. (2003). NOM-033-PESC-2003. *Pesca responsable en el sistema lagunar Champayán y río Tamesí, incluyendo las lagunas*

Chairel y La Escondida, ubicados en el Estado de Tamaulipas. Especificaciones para el aprovechamiento de los recursos pesqueros.

Rendón-Dircio, J. A., Ponce-Palafox, J. T., Rojas-Herrera, A., Arredondo-Figueroa, J. L., Lanza De la, G. & Flores-Verdugo, F. (2012). Morfometría, hidrodinámica y físico-química del agua de la laguna de Chautengo,.*Revista Bíociencias*, 1 (4), 25-37.

Riveros, N. E., Varela, P. & Augusto, M. (2008). Determinación de Bacterias Coliformes y Análisis de Parámetros Fisicoquímicos del Arroyo Agua Negra. San Juan.

Roldán, G. & Ramírez J. J. (2008). *Fundamentos de limnología neotropical*. Colombia : Universidad de Antioquia.

SALUD. Secretaría de Salud. (1994). NOM-127-SSA1-1994. *Salud ambiental, agua para uso y consumo humano-límites permisibles de calidad y tratamientos a que debe someterse el agua para su potabilización.*

Samboni, N. E., Carvajal, Y. E. & Escobar, J. C. (2007). Revisión de parámetros fisicoquímicos como indicadores de calidad y contaminación del agua. Ingeniería e Investigación, 27 (3), 172-181. Recuperado de http://www.scielo.org.co/pdf/iei/v27n3/v27n3a19.pdf

Sánchez, A. & Propin, E. (2005). Potencial regional del turismo en la zona metropolitana de Tampico, México. Cuadernos Geográficos, (37), 153-182. Recuperado de http://www.ugr.es/~cuadgeo/docs/articulos/037/037-007.pdf

Seduma. (2010). *Programa municipal de ordenamiento territorial y desarrollo urbano de Tamaulipas*. Recuperado de http://seduma.tamaulipas.gob.mx/wpcontent/uploads/2011/11/Programa_municipal_Altamira.pdf.

Semarnat. (2010). *Compendio de estadísticas ambientales.* Recuperado de http://aplicaciones.semarnat.gob.mx/estadisticas/compendio2010/10.100.13.5_8080/ibi_apps/WFServletad33.html

Spaulding, M. L. (1994). Modeling of circulation and dispersion. in coastal lagoons. In B. Kjerfve (ed.). *Coastal lagoon processes* (pp.103–132). Amsterdam: Elsevier.

Specchiulli, A., Renzi, M., Scirocco, T., Cilenti, L., Florio, M., Breber, P., Focardi, S. & Bastianoni, S. (2010). Comparative study based on sediment characteristics and macrobenthic communities in two

Italian lagoons. *Environmental Monitoring and Assessment*, 160, 237–256.

Vera V., R. (2004). Calidad del agua. *La cuenca del río Guayalejo-Tamesí, situación actual, políticas públicas y perspectivas*. México: El colegio de Tamaulipas, 75–88.

Wetzel, R. G. (2001). *Limnology: Lake and river ecosystems* (3rd ed.). San Diego, United States of America: Academic Press.

Zadereev, E., Tolomeev, A. & Drobotov, A. (2014). Spatial and seasonal dynamics of dissolved and suspended nutrients in the water column of meromictic lake Shira. *Acta Geológica Sinica*, 88 (1), 173-174. DOI: 10.1111/1755-6724.12267_18