Efficiency of wastewater treatment by a pilot lagoon system with screens and camber curves

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Abstract
Stabilization lagoons are built for municipal, agricultural and industrial wastewater treatment. In this work presents a complementary treatment by lagoon system to real level pilot with screens and banked curves from municipal wastewater coming from a pre-treatment by a subsurface wetland with horizontal flow. Objective is to increase treatment capacity and avoid short circuits and dead zones. Hydrodynamic and total suspended solids transport of water in each lagoon channel it was modeled using software considering physicochemical parameters and operating condition in order to evaluate the performance of this lagoon system and so obtain an effluent quality, according to the Official Mexican Standard NOM 003- SEMARNAT-1997

Keywords
Lagoon, screens, hydrodynamics, dead zones

INTRODUCTION

Water is a finite and limited natural resource of high economic, environmental and social value, essential for life and human activities in the context of their environment. Biological treatments such as stabilization lagoon and constructed wetlands represent an alternative in the treatment of wastewater due to operating costs and maintenance are low, do not require permanent job in the installation facilitate recycling and reusing water (Mara , 2004). Stabilization lagoons are aimed at reducing the content of organic matter, nutrients and pathogens (Barrera, 2008) and are a simple solution for the treatment of municipal and agro industrial, mainly wastewater. They have been widely used in tropical and subtropical countries, but have also been used successfully in temperate countries (Hosetti and Frost, 1998; Lloyd et al., 2003; Kayombo et al., 2005).

Each country regulates the quality parameters for different uses, standards and criteria. In Mexico, according to NOM-003-SEMARNAT-1997 the applicable parameters indicate that for the effluent treatment lagoons of water fecal coliforms below 1000 CFU / 100 mL, solids below 100 mg / L, which no smell and color not observable input receiving system. Stabilization lagoons can be classified according to different criteria: a) Aerobic Lagoons: They are between 1 and 1.5 m. deep to light to penetrate completely and there aerobic conditions in the whole volume of water, b) facultative lagoons: Its interior is divided into an aerobic in the top area and one anaerobically at the bottom, c) Anaerobic lagoons: They have great depth between 3 m and 7 m, with anaerobic conditions throughout the volume of water and d) maturation ponds. Maturation lagoons are aimed at reducing the concentration of pathogenic bacteria and are usually the last step of treatment before making the discharge of treated water in final recipients (Barceló et al., 2002).

The study of the treatment of municipal wastewater is presented in Mexico City, Mexico, through a maturation lagoon pilot to be implemented in rural communities. The most common way to treat wastewater sequence consists of an anaerobic lagoon followed by facultative pond and lagoon finally ripening (Garcia M. et al., 2015). There is however other variants such as the present study prior to the lagoon system where there is a constructed wetland horizontal subsurface flow. Somme of functions of maturation lagoon is: Disinfecting of lagoon system, nitrification of ammonia nitrogen, nutrient removal, clarification of the effluent.

METHODOLOGY

The lagoon has a length of 12.15 m and 8 m wide, divided into 6 channels each 1.14 m wide by 12.15 m long (Figure 1). mainly because in literature (Rosas de Alva, 2010) reports that in stabilization lagoons as there larger number of screens, better treatment is effected, than those without the screens (Rosas et al, 2010, Rosas et al, 2007) . Furthermore the hydraulic characteristics of the lagoons are improved, the stratified flow break and increases the hydraulic retention time.

Banked curves with radii of 2.67 m were designed, considering a minimum camber of 6%, with a slope of 1% and a minimum speed of 0.5 m / min, in order to avoid dead zones in the places where the direction the flow from one channel to another, and reduce short circuits. These curves were constructed from porous blocks as made (Rosa de Alba, 2010) because it was observed that the bacterial film adhered better comparison of a conventional membrane (Figure 2).

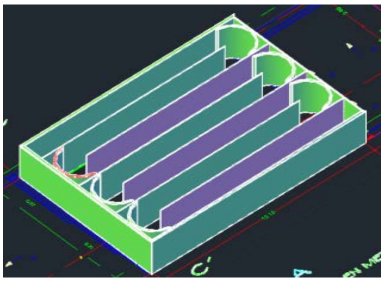


Figure 1: a) Isometric view of the maturation lagoon **Figure 2:** View of the maturation lagoon

In the present study, the results of physicochemical tests in situ and ex situ analysis and modeling of the lagoon system using the IBER software are analyzed.

Modeling using the software IBER

For the hydrodynamic study the IBER lagoon system software (CEDEX, 2010), which is a numerical simulation model of free surface flow in non-steady state was used, and environmental processes in river hydraulics (Barceló et al., 2002).The scope IBER covers breakage of river dams hydrodynamics simulation, evaluation of flood zones, calculating the transport of suspended material and water flow. The two-dimensional hydrodynamic module, where the mass conservation equations for this study and the time resolved was used.

$$\frac{\partial h}{\partial t}+\frac{\partial hU_x}{\partial x}+\frac{\partial hU_y}{\partial y}=Ms \qquad (1)$$

$$\frac{\partial hU_x}{\partial t}+\frac{\partial hU_x^2}{\partial x}+\frac{\partial hU_xU_y}{\partial y}=-gh\frac{\partial Z_s}{\partial x}+\frac{\tau_{s,x}}{\rho}-\frac{\tau_{b,x}}{\rho}-\frac{g}{\rho}\frac{h^2}{2}\frac{\partial \rho}{\partial x}+2\Omega sin\lambda U_y+\frac{\partial h\tau_{xx}^{e}}{\partial x}+\frac{\partial h\tau_{xy}^{e}}{\partial y}+Mx \qquad (2)$$

$$\frac{\partial hU_y}{\partial t} + \frac{\partial hU_xU_y}{\partial x} + \frac{\partial hU_y^2}{\partial y} = -gh\frac{\partial Z_s}{\partial y} + \frac{\tau_{s,y}}{\rho} - \frac{\tau_{b,y}}{\rho} - \frac{g}{\rho}\frac{h^2}{2}\frac{\partial \rho}{\partial y} - 2\Omega sin\lambda U_x + \frac{\partial h\tau_{xy}^e}{\partial x} + \frac{\partial h\tau_{yy}^e}{\partial y} + My \qquad (3)$$

Where:

h= depth.
Ux y, Uy= horizontal velocities averaged depth.
G= acceleration of gravity.
Zs= elevation of the free surface.
τs= friction free surface due to friction caused by the wind.
ρ= density of water.
Ω= angular velocity of rotation of the earth.
Λ= latitude of the point considered.
τexx, τexy, τeyy= horizontal shear stresses are effective.
Ms, Mx, My= are respectively the terms source / sink mass and moment, by which the modeling is done.

Sampling of water in the lagoon system

Water sampling was conducted at 21 sites maturation pond (Figure 3) in triplicate, where the L1 site is located at the entrance of it. The water comes from a subsurface constructed wetland horizontal flow, which is fed with municipal wastewater and site 21 is located at the exit of the lagoon system.

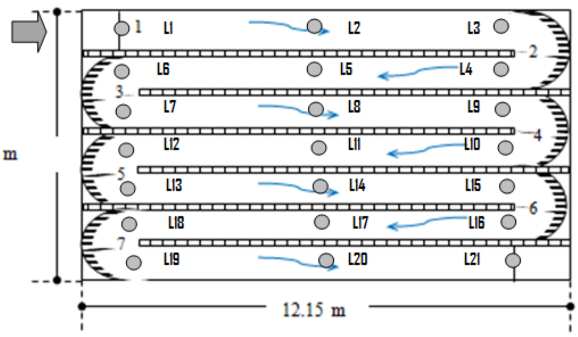


Figure 3: Sampling sites maturation lagoon

The sites mentioned in order to determine the behavior of lagoon system based on the parameters were established: temperature, pH, conductivity, redox potential (OPR), dissolved O2, total solids (TS) and COD, which is important to determine the behavior in cambered sections and channel changes. The system was monitored for 2 periods in the winter and spring of 2016. Water samples from each site were taken at a depth of 25 cm using a Bailers type sampler, samples were placed in containers Nalgen and maintained under cooling at 4 ° C. With these parameters the efficiency of treatment of this lagoon system was determined.

In situ measurements

Were measured at each site, the parameters: pH, temperature, conductivity, dissolved oxygen (DO) and redox potential (OPR), were measured using a Vernier LabQuest with HI 98150 sensor interface HI 1618 Hanna.

Ex situ measures

They were measured in laboratory total COD, solids and hardness, COD test uses the equivalent oxygen to organic matter (biodegradable and non biodegradable) in wastewater that can be chemically oxidized using potassium dichromate in an acidic medium. Vials were used the aforementioned content of the reagents, with a time of two hours of digestion at a temperature of 150C. Also, the COD was determined using a visible light spectrophotometer Hach, the reactor for COD was brand model Hanna For the test of total solids was made from a homogenized sample volume of 20 mL. The procedure and calculations for Ts and hardness were performed as stipulated in the Standard Methods.

Modeling software by IBER

By modeling with software IBER, displacement flow was determined in banked curves proposals and variation of flow rate of water, both channel changes as the input and output of the system was observed. Data were entered as the value of outstanding, roughness, dimensions and radius 6 banked curves. Then the boundary conditions, in which the value of the roughness was introduced, with Manning coefficient n = 0.10 for the firm and n = 0.15 for building lightweight notebook screens were granted. Similarly a constant for the design flow Q = 1.7L / s was assigned. Once established variables, a triangular mesh was generated with a point spacing of 1 cm, and preceded to the analysis.

RESULTS AND INTERPRETATION

It can be seen in graph of figure 4, temperature average values in each sampling site during first and second work period. Optimum temperature for bacterial activity development was found in an interval between 20 and 35°C, with average of 22 °C and variation between 18 °C and 25 °C, Sampling was carried out from 11:00 to 14.00 hours in two periods and it tried that hours of temperature measurement in both cases were same. The pH variations in each sampling sites (Figure 5); where each fieldwork period indicated; were observed in both periods a pH lowering; in L5 site in February there was tendency of pH at remain constant; in case of April the decline was not as sharp, but dropped slightly in continuous, probably it influenced start of rainy season.

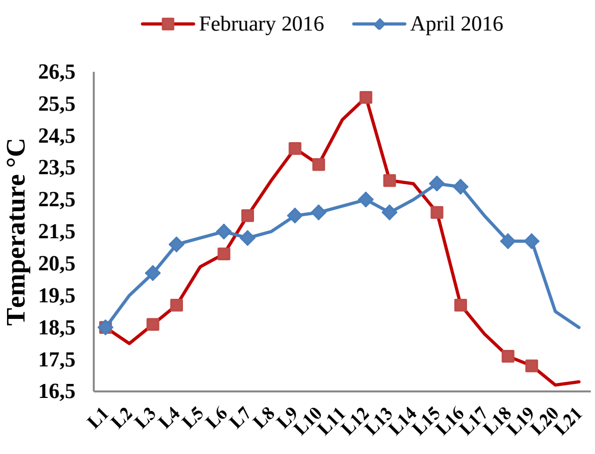


Figure 4: Temperature variation

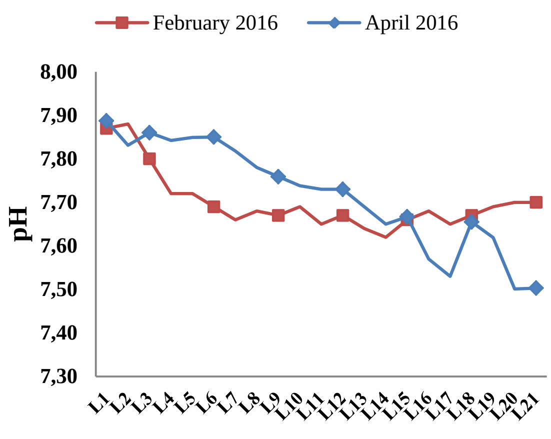


Figure 5. pH variation

In Figure 6, results of total solids concentration in mg/L are displayed in each sampling period, generally exist a clear downward trend in solids concentration, until to be scarce in output of lagoon system; is important in graphics observe a slight increase in TS in each channel change, this is due to cant and slope of each curve; it was not observed in these changes any stagnation, which means that curves inhibit the short circuits generation.

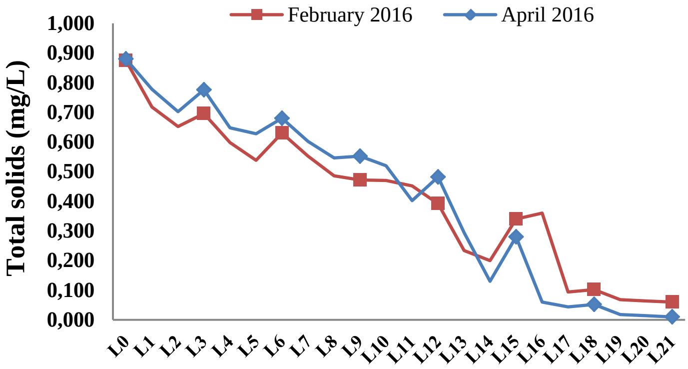


Figure 6: TS variation

In Figure 7a OD of the lagoon is presented, in Figure 7b is presented the OD of the wetland where the water comes. The water is conducted through a tube that distributes to 12 landfills that lead to the first channel of the lagoon, where previously a hydraulic jump of 50 cm is generated, allowing water aeration so entering the first channel with almost 3.80 ± 0.175 mg / L OD in February and 3.48 ± 0.132 in April. In Figure 7a shows OD That Increases flow as it progresses along each channel and there is an improvement in areas of curves L3, L6, L9, L12, L15 and L18, which allow a better aeration of a channel to another. In the month of February it was presented better oxygenation due to the presence of algae. In April the action of strong wind resulted beneficial to generate aeration system and on the other hand was prejudicial due to falling leaves and OM in the first channel. Another important factor influencing the behavior of OD is the rain that intensified in late March caused the death of algae. In spite of the influence of external factors, behavioral profiles were preserved, indicating that the system works properly.

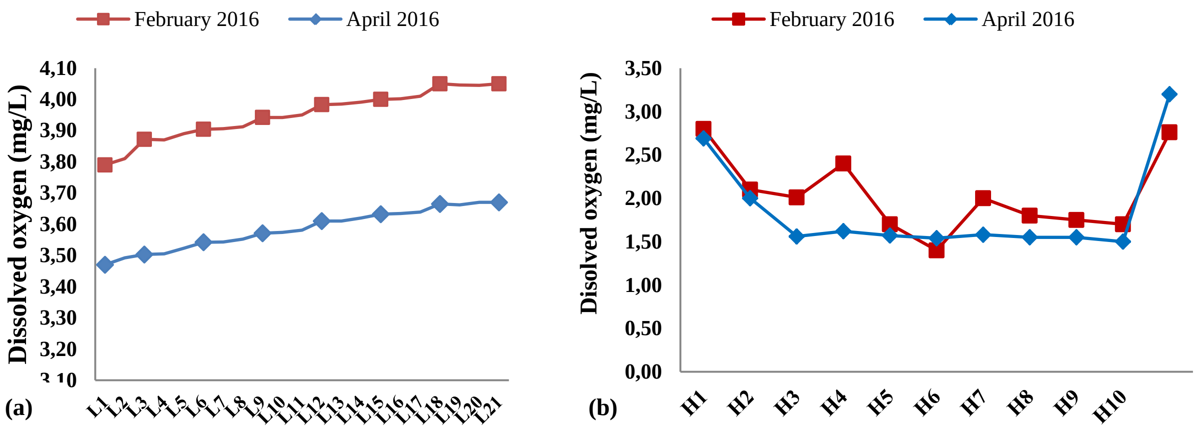
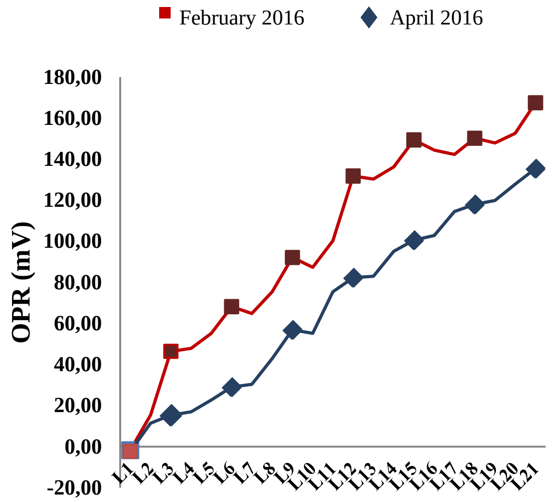


Figure 7: 7a. Lagoon DO variation. 7b. Wetland DO Variation

In Figure 8a OPR of the lagoon is observed with positive values and Figure 8b represents OPR wetland where the values are negative. This means that the OPR is related to the OD. In the two sampling periods, it was observed that the OPR was increasingly positive, coinciding with the increased OD and the OPR measured in February resulted slightly higher than April values. The profile of both curves is similar, where in areas of curves, presented a similar behavior OD.



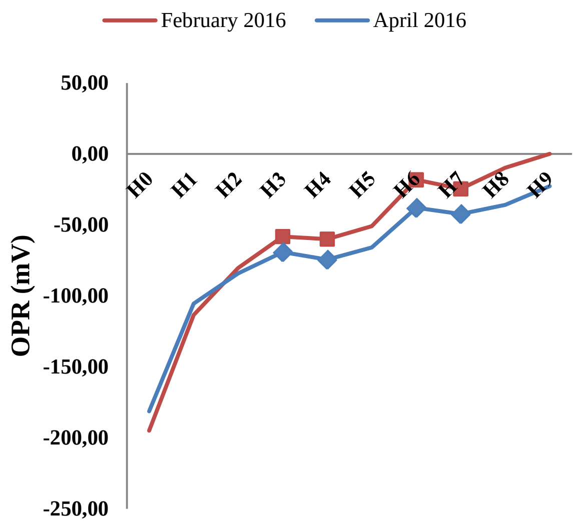


Figure 8: 8a. Lagoon OPR variation. 8b. Wetland OPR variation

In figure 9 conductivity values are presented, there is an increase in these areas of channel changing L3, L6, L9, L12, L15 and L18, the two-stage sampling. At the beginning of each banked curve increased ion concentration decreases as the water is stabilized along each channel is observed. In figure 10 the water hardness is provided in each channel, red areas represent zones of curves where hardness increases at the entrance of each curve.

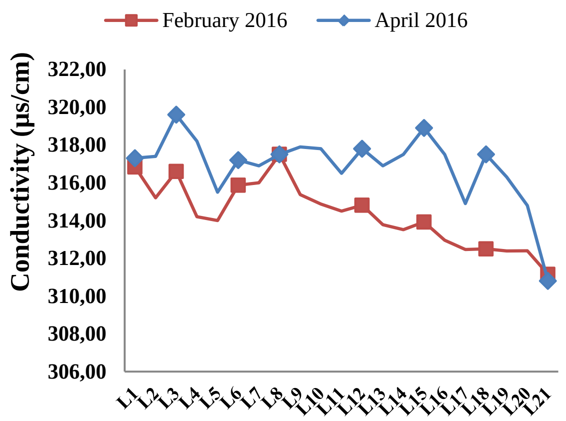


Figure 9: Conductivity variation

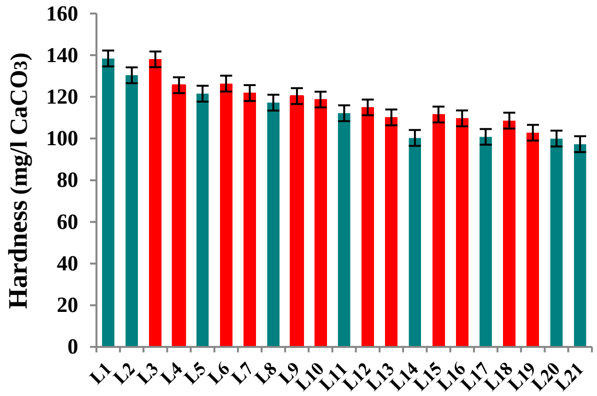


Figure 10. Water hardness variation

In Figure 11, the variation in COD is observed at different sampling sites. In areas where there is a channel change, there is a greater concentration of COD, due to the curvature which allows no dead zones or short circuits. It is observed that from the site L18, exist in both cases a stabilization of the COD to the exit of the lagoon.

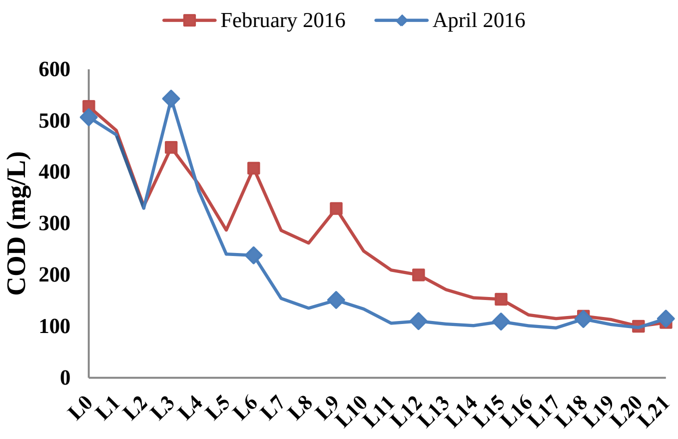


Figure 11: COD variation

MODELING RESULTS WITH SOFTWARE IBER

In Figure 12, modeling indicates one velocity distribution in different sections of lagoon system, identifying water flow variation with different colors: blue light means a uniform flow that changes to dark blue in outer section of curve, where flow decreases its velocity, but in inner section from curve, there is an increase it drives the flow to curve exit, stabilizing this flow along of the channel. Phenomenon is repeated in each curve in intense form to the last channel, where flow acquires a faster velocity along the same until outlet of lagoon with faster velocity, this is indicated with a yellow-green color with somewhat lower in walls porous and more in center, observe the color almost yellow where the flow is virtually free.

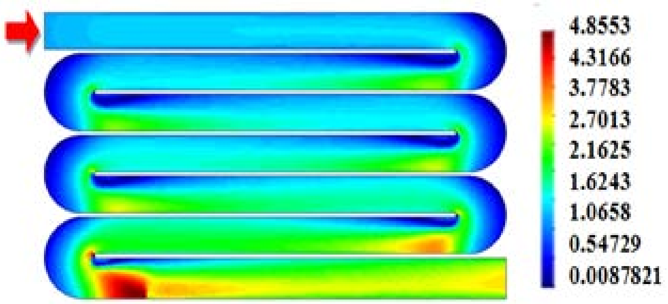


Figura 12: Velocity variation

TRANSPORT OF SUSPENDED SOLIDS

This software was also used to modeling of TS transport in lagoon system (figure 13). The TS concentration in water, corresponding to measured field values, was introduced in the software. Results indicate that highest concentration occurred in the first channel (red color), although it appears that previous to inputs in curves as inside of first curve tend TS to concentrate, which may be due the speed reduction. In the second channel there is a TS drag, concentrating in entrance of second curve and something in third channel, almost before of third curve, decreasing in each channel until finally TS concentration is practically nulled. It is important to note with this model that in the curves zones, blue color is homogeneous, indicating no presence of short circuits, therefore there is no "dead zones" and the hydraulic flow improves significantly.

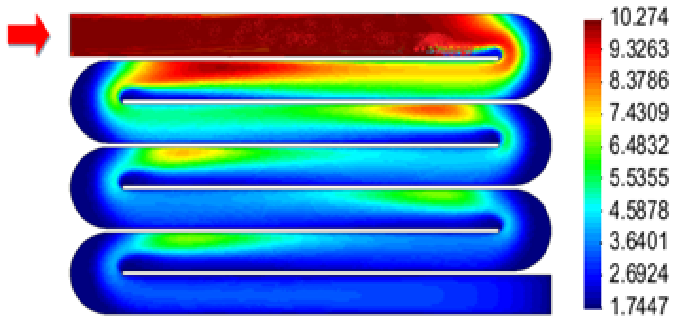


Figure 13: Transport of suspended solids

CONCLUSIONS

The several screens design in lagoon helps bring the total flow of the lagoon to piston flow, which is optimized by banked curves that induce water flow to pass through of channel section where tangential forces are, distributed evenly avoiding dead zones, short circuits and dispersed flows. In addition, this flow is enhanced by design of camber of each curve. One good distribution of hydraulic flow was achieved, that was demonstrated through behavior of OD, OPR, TS, hardness and COD, as is noted in graphs of figures preceding.

With modeling IBER software, it was possible to obtain the velocity distribution in the different sections of the lagoon system, likewise modeling the total solids transport it was possible to know zones susceptible to saturation of TS. This data are useful even for the maintenance of lagoon system.

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