Wastewater treatment plant suitable for a dwelling

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Abstract
The goal of this study was to evaluate an inexpensive plant (construction, operation and maintenance) for the treatment of the wastewater produced in dwellings inhabited by five though 10 people per house. The target population are communities where there is no water supply or sewage system. The whole system consists in a biofilter, a floating wetland system and a chlorination system that was evaluated for 121 days. The results of the whole system evaluation demonstrated good removal efficiencies of pollutants, obtaining more than 50% removal efficiencies of TSS and organic matter as Chemical Oxygen Demand (COD) and low efficiencies for the removal of nutrients (P and N). During the operation time, it was observed that it was necessary to keep improving the system to reach an effluent that produces the water quality that permits its reutilization for irrigation of landscaping or any other activity that requires high water quality.

Keywords
Decentralized wastewater treatment; small scale water system; floating wetlands.

Introduction

There are approximately 26 millions of people living in rural communities in Mexico. Only about the 70% of population of communities have swage systems (CONAGUA, 2013), so that's an important reason to create decentralized wastewater treatment systems. Specifying, in the Guanajuato state, 98% of the municipalities that have potable water supply systems also have sewage system, but from this total number only the 53% of them give treatment to, at least, some part of their wastewaters (CONAGUA, 2013), leaving out of the stats the amount of water that decentralized systems contribute.

The decentralized wastewater treatment systems represent an opportunity for the treatment and reutilization of the water resources in rural communities. Thus, the evaluation of the pollutant removal capacity of a low cost (construction, operation and maintenance), individual and decentralized wastewater treatment plant is a fair proceeding to do for the people in these communities and also for the environment.

Nowadays, there are centralized systems in the market that produced effluents with high water quality, however, to some segments of society, like the rural areas, these technologies are still economically unaffordable. The combination between biofilters and wetlands have been studied and accepted as a great alternative for treating domestic wastewater because the benefits that offers: the removal of organic matter and nutrients being a low cost system but also because of its low maintenance and low electrical supply (Maheesan et al., 2011). That is the reason why the objective of the study was to evaluate the capacity of a system (biofilter-floating wetland-chlorination tank) to treat domestic wastewater with the aim of obtaining an effluent that matches the national official standards of reuse of treated wastewater.

Material and Methods

A wastewater treatment system was boot and stabilized to give treatment to the wastewater produced by a 5 people house, which its potable water supply is executed by water pipe trucks. The house is located near the community of Cuevas, in Cañada de Bustos, Guanajuato, Mexico, in the southern part of the city where the vast majority of dwellings had no sewage system. The raw domestic wastewater characteristics of the dwell are shown in the Table 1.

Table 1. Raw domestic wastewater characteristics of the dwell.

Parameter	Average	Standard Deviation
OD (mg/L)	0.04	0.063
pH	8.15	0.100
Turbidez (NTU)	106.91	22.962
DQOT (mg/L)	493.61	73.315
SST (mg/L)	55.23	25.24

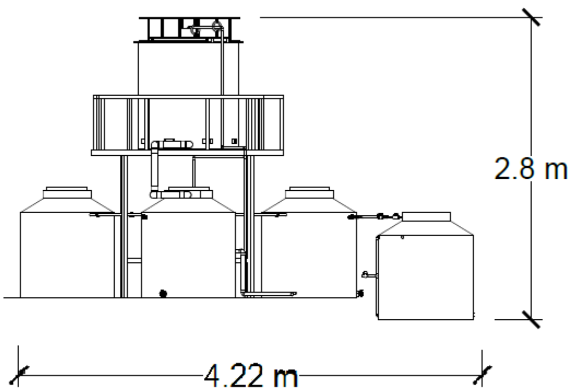

Figure 1. General measurements of the system.

The whole plant consists in a biofilter, a floating wetland system and a chlorination system, preceded by a septic tank that worked only as a container for the wastewater. The water flow follows this arrangement: 1) the water was pumped from the septic tank to the biofilter; 2) the water went by gravity from the biofilter to the floating wetlands; 3) the water flow went from the floating wetlands to the chlorinator by gravity; and 4) the water flow went from the chlorinator to the usage. In the Figure 1 it can be seen the parts previously referred, some general measurements and in Figure 2 their final set up in the dwelling.

Figure 2. Final set up in the dwelling

The biofilter was made of glass fiber due the specific characteristics of endurance and durability

that provides this material. It was made with a cylindrical shape with 1m of height and a diameter of 0.91m. Its volume was 202L, of which 65% was filled with supporting media. This media was formed by volcanic and highly porous rock called tezontle, native of the region.
The floating wetlands consisted in three tanks with an effective volume of 400L approximately. The hydraulic retention time (HRT) of this wetland system was 5.1 days and its total volume was 1275L. In the upper part of each tank a pot made of glass fiber was placed. The pots had openings of 6 cm of diameter with a separation of 6 cm between every one of them. Their insides were filled with the same media as the biofilter and also three different species of plants were planted: *Chlorophytum comosum*, *Pelargonium x citrosum* and *Zantedeschia aethiopica.*
The chlorination system consisted in a tank with a pool chlorinator in the upper part, that had in its interior pills of calcium hypochlorite that got in touch with the wastewater as they were the first thing that touched the water.
The following parameters were monitored: total chemical oxygen demand (COD_T), total suspended solids (TSS), total nitrogen (N_T), total phosphorous (P_T), pH, and dissolved oxygen (DO), they were taken at the output of every system. The TSS value was obtain using the gravimetric method described in Standard Methods (APHA, 2005). The analysis to determine the quantity of organic matter as COD, N_T and P_T were done using the HATCH methods. For values of pH, a portable multiparametric Orion 4-star equipment was used. And finally the DO was obtain using an oximeter HACH model 2100P.
The system was evaluated during 121 days. The system was fed for one period of time in a day: from 20:00 to 22:00 hours, with the purpose of supplying the right amount of water generated by the dwellers. The volumetric flow (Q) that was supply to the whole system corresponds with the wastewater discharge of the house, that was approximately 250 L/day. The hydraulic retention time of the whole system was 6.8 days and the organic loads for the biofilter and the floating wetland system were: 0.87 kg COD_T/m^3 for the biofilter and 0.09 kg COD/m^3 for the wetlands.

Results and Discussion

After the period of evaluation, the results obtained though the analysis can be seen in the Table 2, were the average concentration of the most important parameters are shown.

Table 2. Parameters taken at the exit of every part of the operations and processes

	Septic Tank	Biofilter	Floating wetlands	Chlorinator
DO (mg/L)	0.01	0.44	1.68	4.39
pH	8.19	8.44	8.43	7.62
COD_T (mg/L)	521.33	484.33	280.67	275
N_T (mg/L)	160	151.67	150	132.67
P_T (mg/L)	49.47	49	46.6	46.27
TSS (mg/L)	70	73.33	43.3	31.67

It is appreciable the amounts of pollutants removed in the system, specially in the floating wetlands and in the chlorinator. Consequently, in these parts of the treatment parameters like COD_T, N_T, P_T and TSS are vastly removed from the water. But also the pH and the DO improved; in the case of the pH, it got close to the neutrality, and in the case of DO it grew to aerobic conditions.
Moreover, the nitrogen and phosphorous concentration decayed due to the different processes caused by the presence of the plants. They subtract, in the form of dissolved chemical components, their requirements of nutrients from the wastewater, metabolizing, and due a matter of pH, the

nitrogen in the form of NH_4^+ and NO_3^- and the phosphorus of its form PO_4^{3-}.
In the Figure 2, it can be seen the percentage of COD_T that was removed in every part of the treatment process. About 8% of the organic matter was removed from the water in the Biofilter, serving also as a way to aerate the waste and as a consequence, transform some of the organic and inorganic compounds. Clearly, the majority of this pollutant is removed in the floating wetland system were almost a 47% of it was taken away by the microorganisms and plants, in the form of dissolved organic matter which they utilized for their vital cycle, turning it to a more oxidised state.

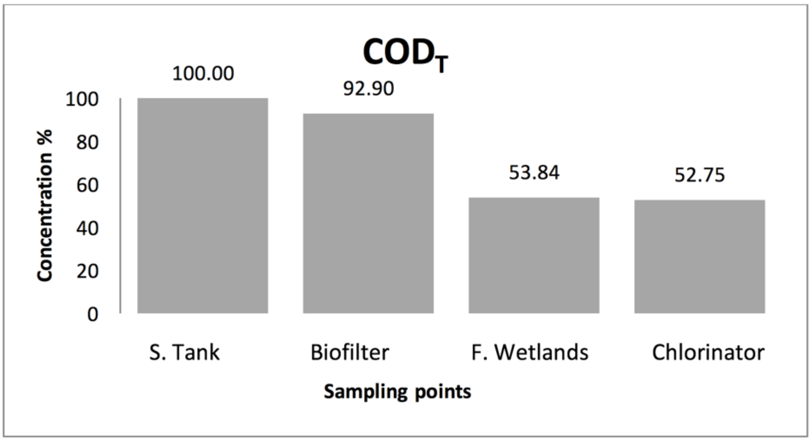

Figure 2. Percentage of COD_T removed in each part of the system

In Figure 3, it can be seen the removed percentage of TSS in each of the parts of the system. It is evident that the amount of solids at the exit of the biofilter was even greater than the raw water, this due the loosening of the biofilm attached to the media in its inside. In the floating wetlands, the organic matter and the biomass presented in the form of TSS, due the high HRT (5.1 days) and the filter provided by the roots of the plants, a great amount of this pollutant, about 40%, was sedimented and therefore removed from the wastewater.

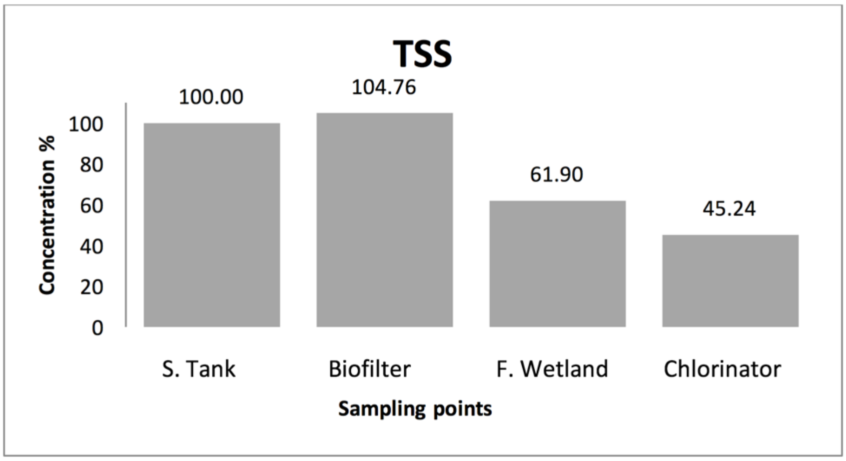

Figure 3. Percentage of TSS removed in each part of the system

If we compare this wastewater treatment system with the ones in the national market like CBR (COCOA, 2015), Aclara (Aclara-IESSUS, 2015) or WGS (WGS, 2015), it becomes clear that some economic and energetic advantages were reached using our system:
(i) while the wastewater treatment plants that are available in the market used expensive materials such as stainless steel or reinforced concrete, the developed plant was made using fiber glass, which conferred durability, and commonly used cisterns adapted to the usage,

(ii) while the commercial plants used several pumps due their extensive modular nature, the developed technology made use of 1 pump and gravity as the forces to made the water flew through the whole system.
In terms of normativity, the plant matched the regulation standards to be used to watered soil for agriculture (SEMARNAT, 1996).

Conclusions

The plant showed advantages compared to those available in the market, in the matter of used materials and energy usage while matching the national discharge standards. Because of being compact and inexpensive the wastewater treatment plant fitted the necessities of the people that lives in the house. Although the obtained removal efficiencies of pollutants were good, the used technology require optimizations to reach a water quality to be reuse directly without risks for the users.

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