Performance of a biofilter system with agave fiber filter media for municipal wastewater treatment

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ABSTRACT

Agave plants grow in semi-arid regions and are used for mescal production. However, agave fiber by-products are considered waste materials. Thus, we tested agave fiber as a filter media and biofilm material carrier for removing pollutants from municipal wastewater. Three laboratory-scale biofiltration reactors were used in two trials with five hydraulic loading rates (HLRs = 0.27, 0.54, 0.80, 1.07 and 1.34 m^3 m^{-2} d^{-1}). One series was conducted using mechanical aeration (0.62 m^3 m^{-2} h^{-1}). To prevent compaction, decreasing pressure and clogging of the filter media, 4, 8 and 12 internal divisions were evaluated in the biofilter column. After 17 months of continuous operation at an HLR of 0.80 m^3 m^{-2} d^{-1}, the removal efficiencies of the aerated biofilters were 92.0% biochemical oxygen demand, 79.7% chemical oxygen demand, 98.0% helminth eggs, 99.9% fecal coliforms and 91.9% total suspended solids. Statistical analysis showed that the chosen operational parameters significantly influenced the removal efficiencies of the biofilters. The effluent quality obtained under these conditions complied with the Mexican and US EPA standards for agricultural irrigation and green spaces, except for coliforms, which is why the effluents must be disinfected. Thus, agave fiber is a favorable choice for use as a packing material in biofiltration processes.

Key words | biofiltration, decentralized wastewater treatment, organic filter media, sanitary quality

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INTRODUCTION

Wastewaters cause serious environmental problems, including eutrophication and toxic effects, when they are discharged into natural aquatic ecosystems (Cohen 2001). Because conventional treatment systems are expensive and/or difficult to install and operate in developing countries, wastewaters are commonly discharged into aquatic ecosystems in rural and marginal peri-urban communities and in micro industries. Therefore, innovation and appropriate technological developments, including wastewater treatment plants (WWTPs) that are easy to operate, require low investment and maintenance, and have low operating costs, are needed. Biofiltration systems that use organic packing media are a good option for decentralized wastewater treatment systems (Talbot *et al.* 1996; Garzón-Zúñiga *et al.* 2008; Garzón-Zúñiga & Buelna 2011). A biofilm is a bacterial mass that grows on the surface of bedding material (Cohen 2001). In a biofilter, wastewater is fed to the top of the biofilters and is allowed to infiltrate downwards through the media. This process is similar to that of a trickling filter (Wik 2003). Biofilters that are packed with organic material are characterized by a filtration-flow rate of less than 0.5 m^3 wastewater m^{-2} d^{-1}, which favors the retention of organic matter and pollutants by filtration, adsorption, absorption and ion exchange mechanisms (Lens *et al.* 1994; Buelna *et al.* 2011). Pollutants are hydrolyzed and degraded by the microorganism community that grows in the filter media.

In the past two decades, biofiltration processes that use organic materials have been studied and applied at both laboratory and full scale for drinking water treatment (Wahman *et al.* 2011) and in domestic (Lens *et al.* 1994; Talbot *et al.* 1996), municipal (Buelna & Bélanger 1990; Garzón-Zúñiga *et al.* 2008) sanitary and agro-industrial wastewaters (Garzón-Zúñiga & Buelna 2011). The following pollutant removal efficiencies were previously reported for

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domestic wastewaters: biochemical oxygen demand (BOD_5) $\geq$96%, chemical oxygen demand (COD) between 63 and 87%, total suspended solids (TSS) between 72 and 98%, fecal coliforms (FC) $\leq$99% (4 log units) and helminth eggs (HE) $\leq$97% (Buelna & Bélanger 1990; Hu & Gagnon 2006; Garzón-Zúñiga & Buelna 2011).

The organic media used in these systems included peat, granular activated carbon, pine and tropical tree bark and woodchips, and sugar cane and date palm fibers. The advantages of the organic packing material include a high void fraction, low bulk density, high microbial population density and low cost (Nicolai & Janni 2001). Although several biofiltration studies were previously conducted with various organic support materials, these materials were insufficient. Thus, the use of readily available, inexpensive and autochthonous organic materials (mainly those considered as waste) to obtain a sustainable system has not been fully explored. To the best of our knowledge, no reports are available regarding the use of organic materials that are common to arid and semi-arid zones where water scarcity occurs and the reuse of properly treated wastewater is necessary. Agave (*Agave durangensis*) is an autochthonous plant that grows in the semi-arid regions of Mexico. In addition, agave is distributed from the USA to Bolivia and adapts to the climate by storing water and growing slowly. However, in Mexico, agave is cultivated for mescal (an alcoholic beverage similar to Tequila) production. According to the mescal industry, 64.8 million plants were cultivated for mescal in Mexico in 2007. Of these 64.8 million plants, 3.8 million were grown in the state of Durango (SEDECO 2008). Thus, this study aimed to test mescal industry by-products of agave fibers as organic packing materials. These agave fibers are in the form of a solid waste and only require transportation costs.

In the biofiltration process, it is important to avoid clogging the filtration bed. This clogging is related to the deposition of suspended solids and the degradation of the packed organic material itself. Such processes favor filter media compaction, reduce empty space and increase the fluid flow resistance through the filtration bed. These processes were related to an increased pressure drop in the system. Schmidt *et al.* (2004) stated that this pressure drop increases when biofilters have less than 60% voids. Furthermore, Garzón-Zúñiga *et al.* (2007) reported clogging problems at TSS loads of 68 g m^{-2} d^{-1}. Therefore, using an appropriate TSS load rate may prevent clogging. To prevent clogging, acrylic plates were used, assuming that the weight distribution would decrease the compaction. The purpose of this study was to evaluate the biofiltration process performance of agave fibers as an organic filter media. A partitioned column with acrylic plates was used to determine the effects of compaction for treating municipal wastewater at two air levels and with five different hydraulic loading rates (HLRs).

MATERIALS AND METHODS

Biofilter setup

Each biofilter (BF) was constructed from PVC pipe (2.0 m tall with an internal diameter (ID) of 0.185 m) and a 1.80 m biofiltration column packed with agave fiber. The raw wastewater was pumped into the upper end of the reactor and the effluent flowed out the bottom of the reactor. Air was supplied in a current that was opposite to the wastewater flow and was monitored and calibrated daily with a Dwyer RMA-2 flow meter. The pressure drop was measured with a pipe connected to a hydraulic gauge, which was located on the bottom of the BFs. The biofilter column was partitioned with acrylic perforated plates. The ambient temperature was not controlled because biofilters were installed outdoors. Thus, temperature is considered as a covariate in this experiment. Figure 1 contains a schematic of an aerated BF that uses agave fiber as a filter media.

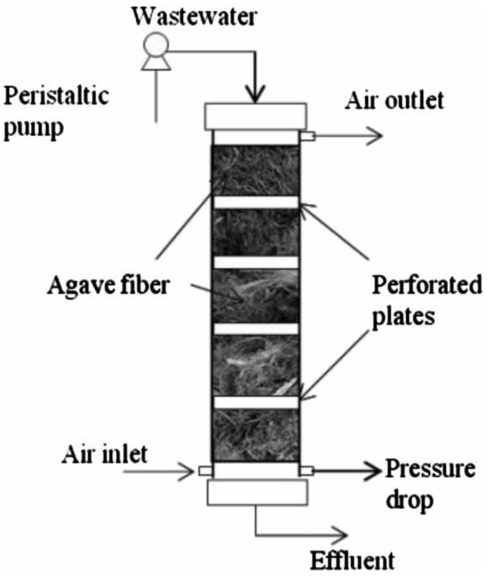

Figure 1 | Agave fiber biofilter system.

Packing material

The agave fiber was provided by the mescal industry in Nombre de Dios, Durango, Mexico. This agave fiber was transported to the laboratory, dried outdoors and passed through a 100-mesh sieve to remove small particles. The agave fiber was characterized for cellulose, lignin and acid detergent fiber concentrations by using the methods described by Tejada (1985). The apparent density and porosity were measured based on the dry weight of a known volume of fiber. In each BF compartment (between the perforated acrylic plates), agave fiber was packed at a moisture content of 65% previously wetted with tap water. The above measurements and the filling procedure of the biofilters were conducted by following the methods presented by Garzón-Zúñiga & Buelna (2011) and references cited therein.

Wastewater influent

The wastewater influent was provided by the WWTP in Durango City, Mexico. This influent was collected after primary treatment (screening, sedimentation and homogenization) weekly during the first peak mass-loading (Metcalf & Eddy, Inc. 1991). Next, these samples were transported to the laboratory and placed in a 400 L polyethylene tank, which served as the feeding tank. The influent was pumped to the top of each biofilter with peristaltic pumps (MasterFlex Model 751800).

Experimental procedure

Two different series with three biofilters each were conducted. The first series was conducted with an aeration rate of 0.62 $m^3 m^{-2} h^{-1}$ and was labeled BF1, BF2 and BF3. In addition, the second series was not aerated and was labeled BF4, BF5 and BF6. To evaluate the effects of the HLR, five wastewater flow rates (5, 10, 15, 20 and 25 mL min^{-1}), equivalent to five HLRs (0.27, 0.54, 0.80, 1.07 and 1.34 $m^3 m^{-2} d^{-1}$), were evaluated because operational information regarding the best HLR with natural fibers was lacking. Before conducting these tests, BFs were conditioned for 3 months at 3 mL min^{-1}. Finally, to estimate the effects of the number of divisions within each biofiltration column, a series of BFs were installed with 4, 8 and 12 divisions. All BFs were run for 17 continuous months.

Analytical methods

Samples were collected weekly from the influent and effluent of each biofilter. Samples were analyzed for BOD_5, COD, TSS and FC by following *Standard Methods for the Examination of Water and Wastewater* (APHA 1995). However, HE were analyzed every 15 d by flotation with zinc sulfate based on the NOM-003-SEMARNAT-1997 method (DOF 1998). The following physical parameters were recorded daily: pH, electrical conductivity (EC), temperature, pressure drop and air flow rates.

Experimental design

Three variables were considered in the experimental design, including aeration (two levels: with and without air); the number of filtration column plates (three levels: 4, 8 and 12 plates) and the HLR (five levels: 0.27, 0.54, 0.80, 1.07 and 1.34 $m^3 m^{-2} d^{-1}$). These variables were tested by using a strip plot design in a factorial experiment. Temperature (T) was a covariate in this experiment. The observations were described by the following linear statistical model (Equation (1)):

$$Y_{ijkl} = m + a_i + b_j + g_k + a_{i*}b_j + a_{i*}g_k + b_{j*}g_k + a_{i*}b_{j*}g_k + dT_{ijk} \pm e_{ijkl} \qquad (1)$$

where Y_{ijkl} is the lth observation of the response variable taken from the ijkth treatment of the a_i,b_j and g_k factors; m is the overall mean effect; a_i is the effect of the ith level of the air factor; b_j is the effect of the jth level of the separation plates factor; g_k is the effect of the kth level of the HLR factor; $a_{i*}b_j$, $a_{i*}g_k$, and $b_{j*}g_k$ are the double interactions between the factors; $a_{i*}b_{k*}g_j$ is the effect of the triple interaction between the factors; T is the temperature; d is the linear regression coefficient that indicates the dependency of Y_{ijkl} on T_{ijk}; and e_{ijkl} is the random error. The statistical method and its sources of variation were evaluated with the Statistica software (StatSoft 2004).

RESULTS

Filter material characterization

At the beginning of the study, the agave fiber was composed of 55.0% cellulose, 10.7% lignin and 66.5% acid detergent fiber. At the end of the aerated and unaerated biofilter studies, cellulose was reduced to 46.3 and 45.3%; lignin increased to 32.4 and 34.0%, and acid detergent fiber increased to 79.1 and 79.4%, respectively. The fiber has a density of 0.36 g cm^{-3} and has void spaces that make up 82% of the total volume.

Wastewater characterization

The influent characteristics of the municipal wastewater that was used in this study are shown in Table 1.

Aeration effect on the pollutant removal efficiency

According to the covariance test that was performed with the Statistica software, the aeration effect was statistically significant for BOD_5, COD and FC ($p = 0.001$).

Organic matter (BOD_5 and COD) removal

The organic matter present in the influent (measured as BOD_5) was removed by the aerated BFs (Figure 2(a)) to an HLR of less than $0.80\ m^3\ m^{-2}\ d^{-1}$, which is the allowable HLR given by Mexican regulations. In the BFs without air (Figure 2(b)), the first HLR was not obtained for the allowable $30\ mg\ L^{-1}$ of BOD_5 (DOF 1998).

The average effluent COD removal efficiencies after the stabilization stage were 79.7 and 62.0% for the aerated and unaerated BFs, respectively. The average COD concentrations were reduced from 640 ± 170 to 128 ± 10 and $240 \pm 34\ mg\ L^{-1}$ for each biofilter series.

Pathogen microorganism (FC and HE) removal effects

When tested at the lower HLR ($0.27\ m^3\ m^{-2}\ d^{-1}$), the FC removal efficiencies reached 99.99 (4 log units) and 99.90% (3 log units) in the aerated and unaerated BFs, respectively. In contrast, when the HLR was $0.80\ m^3\ m^{-2}\ d^{-1}$, the maxima average FC removal efficiency from the effluent reached 99.95% (3 log units) and 99.56% (2 log units) in the aerated and unaerated BFs, respectively.

The greatest removal efficiency of HE occurred in the unaerated (100% equivalent to zero $HE\ L^{-1}$) and aerated BFs (98% at $<1\ HE\ L^{-1}$) for all HLRs applied between

Table 1 | Characterization of the raw municipal wastewater that was used in the biofilters

Parameter	Units	Average concentration ± S.D.	Sample number
Biochemical oxygen demand	$mg\ L^{-1}$	270 ± 38	100
Chemical oxygen demand	$mg\ L^{-1}$	640 ± 170	112
Total suspended solids	$mg\ L^{-1}$	201 ± 67	84
Fecal coliforms	$MPN\ 100\ mL^{-1}$	$5.47 \times 10^6 \pm 8.20 \times 10^6$	88
Helminth eggs	$No.\ HE\ 5\ L^{-1}$	8.60 ± 2.34	26
pH	pH units	7.03 ± 0.60	112
Electrical conductivity	$\mu S\ cm^{-1}$	817 ± 52	54

S.D. = standard deviation, MPN = most probable number.

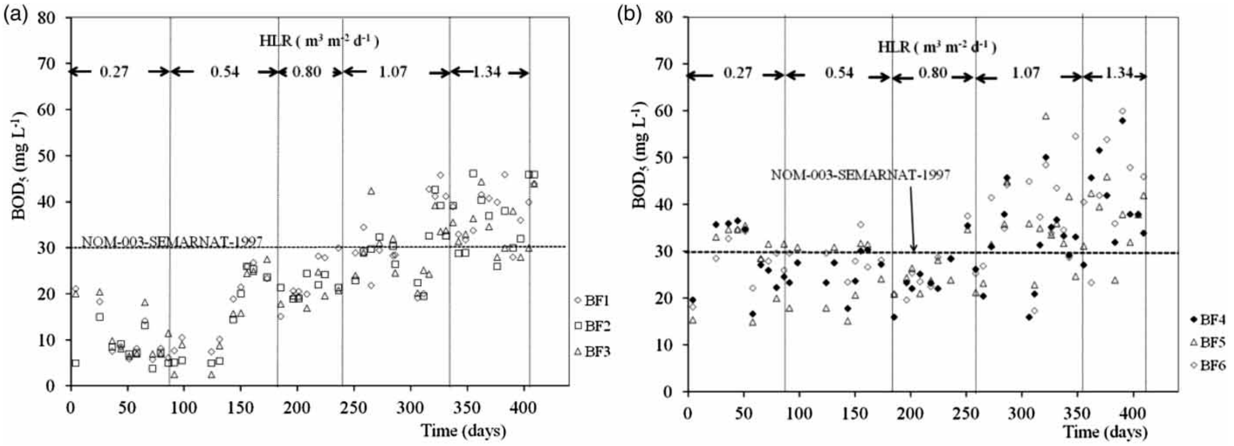

Figure 2 | Effluent BOD_5 concentration in the two biofilter series operated at five different hydraulic loading rates. (a) Aerated biofilters and (b) unaerated biofilters.

0.27 and 1.34 $m^3\ m^{-2}\ d^{-1}$. These values met Mexican regulations that allow a maximum limit of <1 HE L^{-1}.

TSS removal effect

The TSS removal efficiency was slightly greater in the BFs without aeration (93.4%) relative to the aerated BFs (91.9%) ($\alpha = 0.05$), at an HLR of up to 1.34 $m^3\ m^{-2}\ d^{-1}$. The average effluent TSS concentrations in the unaerated and aerated BFs were 9.7 ± 3.3 and 16.0 ± 3.2 mg L^{-1}, respectively.

Hydraulic loading rate factor

The HLR effect significantly removed BOD_5, COD and FC ($p = 0.001$) and TSS ($p = 0.004$) and reduced the air*HLR interactions on BOD_5, COD and FC ($p = 0.001$). Figure 3(a) shows the effects of HLR on COD removal and indicates that the aerated BFs are more efficient. Applying an HLR of between 0.27 and 0.80 $m^3\ m^{-2}\ d^{-1}$ resulted in a constant FC removal efficiency (Figure 3(b)). In the aerated and non-aerated BFs, the FC removal efficiency decreased by 4 and 3 log units, respectively.

Filtration column division factor

Figure 4 shows the HLR*packing interaction. At an HLR of between 0.80 and 1.34 $m^3\ m^{-2}\ d^{-1}$, the highest COD removal efficiencies were obtained by using four separation plates. The removal efficiency decreased as the number of plates increased. The maximum pressure drop was 0.5 mm in the water column.

Covariate temperature effect

Temperature significantly influenced COD ($p = 0.005$), FC ($p = 0.049$) and TSS ($p = 0.001$) removal. The greatest COD removal efficiency occurred at 28 °C. At temperatures >21 °C, the average BOD_5 concentration was less than

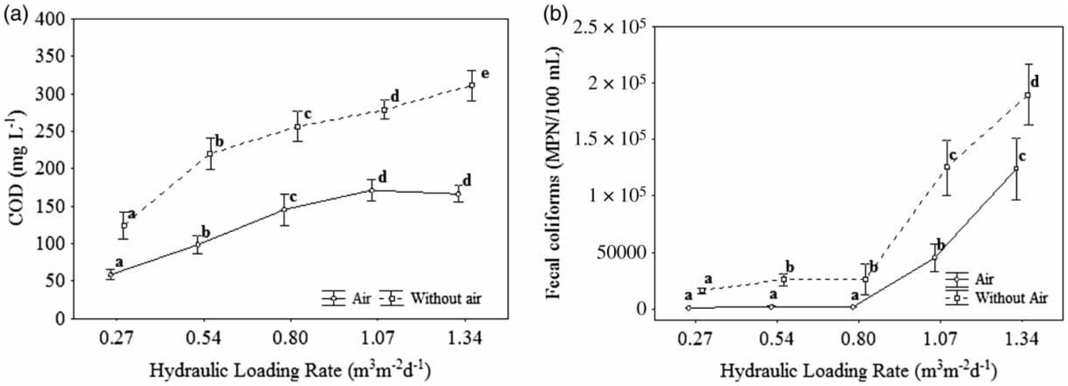

Figure 3 | Hydraulic loading rate*aeration effect on (a) COD removal and (b) fecal coliform removal (means with the same letters are not significantly different).

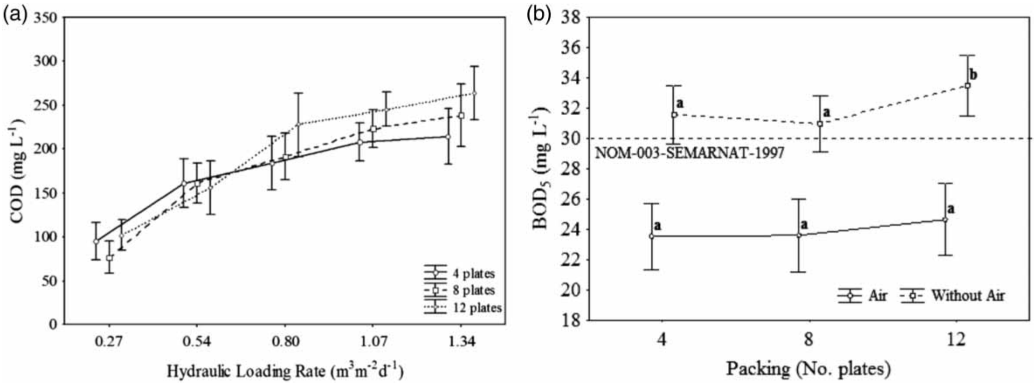

Figure 4 | Effects of the biofilter column separations. (a) HLR*packing interaction on COD removal. (b) Packing*air interaction on BOD_5 removal.

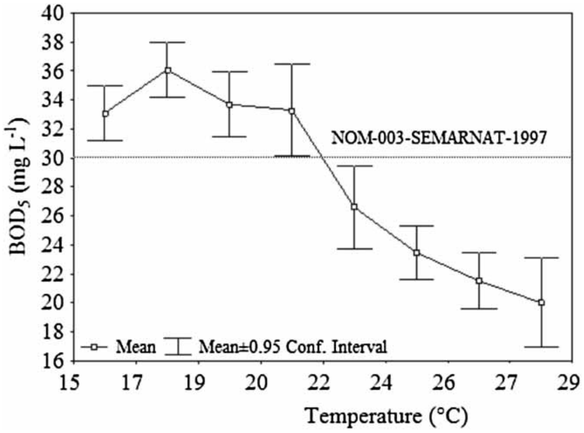

Figure 5 | Effects of temperature on effluent BOD$_5$ removal in the aerated biofilters.

30 mg L^{-1} and the maximum removal BOD$_5$ efficiency was between 21 and 28 °C in the aerated BFs (Figure 5).

pH and electrical conductivity

The average pH values of the municipal wastewater, aerated BF effluents, and unaerated effluents were 7.12 ± 0.05, 7.24 ± 0.04 and 7.00 ± 0.03, respectively. The average EC in the effluent of all the biofilters was 736 ± 14 μS cm^{-1}.

DISCUSSION

Filter material characterization

The cellulose was degraded by 18.1% in the aerated BFs and by 15.8% in the unaerated BFs after 17 months of continuous operation. This difference was potentially caused by the greater removal efficiency of the cellulolytic bacteria and fungi under aerobic conditions than under anaerobic conditions (Pérez *et al.* 2002). The porosity of the packing material was similar to that described by Garzón-Zúñiga & Buelna (2011), who used peat, dwarf poinciana (*Caesalpinia pulcherrima*) and jacaranda (*Jacaranda mimosifolia*) with 80, 75 and 85% porosity, respectively. The high porosity of the filter material prevented compaction in the BFs. After observing the degradation during 17 months, the agave packing material is expected to have a useful lifetime of at least five years due to the low organic filter media degradation rate similar to that obtained by Talbot *et al.* (1996) and Schmidt *et al.* (2004).

Wastewater characterization

The average organic matter concentrations (expressed as BOD$_5$ and COD), pathogen microorganisms (FC and HE) and TSS were similar to those that were considered for medium-concentration wastewaters by Metcalf & Eddy, Inc. (1991). The BOD$_5$ values were greater in this study than in studies (Buelna & Bélanger 1990; Lens *et al.* 1994; Garzón-Zúñiga & Buelna 2011) that were conducted in developed countries. For example, Garzón-Zúñiga *et al.* (2008) reported that sewage contained greater pollutant concentrations because the drainage network captured both rainwater and municipal wastewater. An initial raw wastewater COD/BOD$_5$ ratio was 2.37, similar to the data of Metcalf & Eddy, Inc. (1991), and changed after treatment to 5.00 and 2.67 COD/BOD$_5$ ratios for aerated and unaerated BFs, respectively.

Organic matter (BOD$_5$ and COD) removal

The aerated BFs with HLRs from 0.27 to 0.80 m^3 m^{-2} d^{-1} resulted in effluent BOD$_5$ concentrations of <30 mg L^{-1} (Figure 2(a)). In the BFs without air (Figure 2(b)), the concentrations allowed by Mexican regulations were not achieved initially. This effect was reported by Garzón-Zúñiga *et al.* (2008), who mentioned that high BOD$_5$ concentrations in the first stage were caused by the washing of the packing material and the lower anaerobic biofilm growth rate. However, effluent BOD$_5$ concentrations of <30 mg L^{-1} were obtained at the following two HLRs: 0.54 and 0.80 m^3 m^{-2} d^{-1}. Finally, the average BOD$_5$ removal efficiency at an HLR of 0.80 m^3 m^{-2} d^{-1} was 92.0% for the aerated BFs and 90.9% for the unaerated BFs. The removal efficiencies of BOD$_5$ with agave fiber were comparable to those of the organic filter materials that were used by Buelna & Bélanger (1990) in both series. Although Buelna & Bélanger (1990) treated wastewater that was five times more diluted (77 mg L^{-1} BOD$_5$) than in this study (270 mg L^{-1} BOD$_5$), they obtained 96% of the BOD$_5$, when using peat as a biofilm support. Lens *et al.* (1994) used aerated biofilters with bark and peat packing materials and reported a BOD$_5$ removal efficiency of 97% with 168 ± 25 mg L^{-1} of BOD$_5$ in the influent. Garzón-Zúñiga *et al.* (2008) used aerated biofilters with packing mixtures of tropical tree woodchips and natural fibers and obtained a BOD$_5$ removal efficiency of 98.5% at an HLR of 0.35 m^3 m^{-2} d^{-1}.

The discrepancies that exist between these studies occurred because the initial wastewater had different pollutant concentrations and smaller HLRs. However, the average effluent BOD_5 concentrations in these two BFs met the US (US EPA 2004) and Mexican standards (DOF 1998) at an HLR of $0.80\ m^3\ m^{-2}\ d^{-1}$. The maxima effluent BOD_5 concentration that is allowed by the Mexican regulations is $\leq 30\ mg\ L^{-1}$. The aerated and unaerated BFs had average BOD_5 concentrations of $22.0 \pm 2.3\ mg\ L^{-1}$ ($\alpha = 0.05$) and $24.0 \pm 1.9\ mg\ L^{-1}$, respectively.

Pathogen microorganism (FC and HE) removal effects

The FC removal efficiencies of the aerated BFs met the Mexican (1,000 MPN 100 mL^{-1}) and US standards at an HLR of $0.27\ m^3\ m^{-2}\ d^{-1}$ (equivalent to 99.99% or 4 log units). However, at an HLR of $0.80\ m^3\ m^{-2}\ d^{-1}$, the maxima average FC removal efficiencies were 99.95% (3 log units) in the aerated BFs and 99.56% (2 log units) in the unaerated BFs. These removal efficiencies did not meet irrigation water regulations. Therefore, these effluents must be disinfected. Nevertheless, these efficiencies are greater than the efficiencies that were reported by Lens *et al.* (1994) and by Buelna & Bélanger (1990). These authors obtained removal efficiencies of 90.00 and 99.00%, by using peat as a filter media. These results were similar to the results obtained (99.99%) by Garzón-Zúñiga *et al.* (2008), who used aerated BFs with tropical tree woodchip mixtures.

The removal efficiency of the HE was successful for all of the evaluated HLRs in both BF series (1 HE L^{-1}). These results are similar to those reported by Riahi *et al.* (2009), in which 98.0% HE removal was achieved by using date-palm fiber for tertiary treatment. In addition, these results were similar to those of Garzón-Zúñiga *et al.* (2008), who observed 96.9% HE removal in aerated biofilters. These results were likely caused by the greater HE size (García-Mesa *et al.* 2010) relative to the void size of the filter media (Schmidt *et al.* 2004).

TSS removal effect

The influent TSS concentrations were low because the WWTP uses an efficient primary treatment. Thus, TSS concentration variations were mild. The TSS removal efficiency was better in the unaerated BFs (93.4%) than in the aerated BFs (91.9%) up to an HLR of $1.34\ m^3\ m^{-2}\ d^{-1}$. These efficiencies are statistically significant with $\alpha = 0.05$. This efficiency was related to the high percentage of voids in the filter material, which allowed for efficient retention of TSS (Nicolai & Janni 2001). García-Mesa *et al.* (2010) indicated that when good primary treatment in the WWTP occurs, the sizes of the particles are very small. These small-sized particles can be degraded by the biofilm to produce effluents that meet Mexican and US EPA regulations. The efficiency in this study was greater than the 72% obtained by Lens *et al.* (1994). In addition, the efficiency obtained in this study was lower than that reported by Buelna *et al.* (2011) (95%) and Buelna & Bélanger (1990) (98%). The maximum TSS allowed by Mexican standards (DOF 1998) is $<30\ mg\ L^{-1}$.

Hydraulic loading rate factor

The average effluent FC removal of unaerated BFs is stable up to an HLR of $0.80\ m^3\ m^{-2}\ d^{-1}$ and increases exponentially for the last two HLRs (Figure 3(b)), probably because the system exceeds its maximum treatment capacity because the processes of adsorption, absorption and shear stress are exceeded, as noted by Cohen (2001). The FC removal efficiency in this study is higher than that reported by Buelna & Bélanger (1990) who obtained 99% FC removal efficiency at the same HLR. Garzón-Zúñiga *et al.* (2008) obtained 99.99% FC removal efficiency, similar to this study at a lower HLR ($0.3\ m^3\ m^{-2}\ d^{-1}$). This removal capacity is also potentially influenced by biofilm detachment, which is caused by hydrodynamic shear stress forces (Cohen 2001). Effluents that are going to be used in agricultural irrigation and green spaces require disinfection to reach the standards of US EPA (2004) and Mexican standards (DOF 1998) of less than 1,000 MPN 100 mL^{-1}.

Filtration column division factor

Packing significantly influenced the COD ($p = 0.001$), BOD_5 ($p = 0.029$), and TSS ($p = 0.007$) removal. In addition, the HLR*packing interaction significantly influenced COD removal ($p = 0.048$). The greatest COD removal efficiencies were obtained by increasing the HLR and by using four separation plates (Figure 4(a)). The aerated BFs were more efficient for BOD_5 removal (Figure 4(b)). However, it was expected that 12 divisions would be more efficient for removing BOD_5. Due to limited previous research, this result could not be explained. The low pressure drop of all BFs resulted from the separation plates, which potentially increase the useful life of the filter media.

Covariate temperature

As shown in Figure 5, the BOD_5 removal efficiency increased with increasing temperature in the aerated BFs. This temperature dependency is characteristic of mesophilic microorganisms (Metcalf & Eddy, Inc. 1991; Datta & Allen 2005). Therefore, temperature should be considered for scaling up this system for WWTPs because temperature was not controlled in this study and is an important design parameter. Thus, in this study, temperature was considered as a covariate.

pH and electrical conductivity

Because pH remains constant, healthy biofilm growth is promoted in the agave fiber, which improves its microbial adsorption capacity (Cohen 2001). The acceptable value according to the NOM-003-SEMARNAT-1997 is 3,000 μS cm^{-1}. Thus, the effluent can be reused for agricultural and green area irrigation without influencing soil salinity.

CONCLUSIONS

The use of agave fiber as a packing material in the biofiltration process is adequate for the biological removal of pollutants from municipal wastewater. The treated water met the Mexican and US standards. Thus, the treated water could be reused in agriculture and green space irrigation and could be safely discharged into lakes if the effluents are disinfected. Agave fibers serve as a good filtering material because they exhibited low cellulose biodegradation in biofilters, had high porosity, were low cost and regionally available, and could potentially last for five years. The maximum HLR for both biofilter series, to fulfil the Mexican and US EPA regulation for BOD_5, was $0.80\ m^3\ m^{-2}\ d^{-1}$, but the effluents need disinfection to comply with the coliforms norm. The best results were observed in the BFs with four separation plates and temperatures above 21 °C. During the 17 months of this study, the systems had pressure drops below 0.5 mm H_2O. Overall, it was concluded that packing BFs with agave fiber is a novel technique that can be applied to small generators.

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