Reception: **May 14, 2016** | Acceptance: **July 30, 2016**

REMOVAL OF ORGANIC LOAD IN LEACHATES USING AGED REFUSE BIOFILTER

—

Lozano-Caballero Grecia[1], Bautista-Ramírez Jesús[1], Díaz-García Mayeli[1], Gutiérrez-Hernández Rubén F.[2], Martínez-Salinas Rebeca I.[1], Nájera-Aguilar Hugo A.[1*]

[1*] Environmental Engineering. Universidad de Ciencias y Artes de Chiapas. Ciudad Universitaria, Libramiento Norte Poniente S/N, Col. Lajas, Maciel, C.P. 29000, Tuxtla Gutiérrez, Chiapas, México; Tel: 52 (961)1256033. e-mail: hugo.najera@unicach.mx.
[2] Department of Chemical Engineering. Instituto Tecnológico de Tapachula. Tapachula, Chiapas.

— Abstract—

The final disposal sites poorly operated cause damages in the environment and generate public health problems; these sites are general conceived as environmental passives. In this study solid waste were extracted, which has more than 8 years of age. The materials were extracted from the closed landfill of the city of Tuxtla Gutierrez, Chiapas, Mexico. The wastes were characterized in terms of moisture, total and volatile solids; finding a high biological stability. The wastes were used as packing material in a semiaerobic biofilter to explore the biological potential in the treatment of leachates. During eight months of operation, the biofilter recorded removal efficiencies of COD between 60 and 90%, while removal efficiencies of color was 60% with hydraulic loads in the order of 10 to 11 L / m^3-d. These results demonstrate that these biofilters using aged refuse as packaging material can be used as an attractive alternative pretreatment for landfill leachate in Mexico.

Keywords

Aged refuse; leachate treatment; biofilter; COD

Deficiency in the management of municipal solid waste and leachate emanation forms a significant risk to soil, water and air quality (Prantl et al., 2006). Within the integral management of solid waste, the final disposal stage presents the greatest challenges to overcome. It is therefore important to know the composition and characteristics of the waste, not only in its generation stage (fresh), but also in its evolution over time after having been arranged, in order to lessen the problems caused in its final disposal, as well as determine their potential for being exploited.

Sanitary landfills have evolved from open pit dumps to highly technical landfills where emissions (liquid and gaseous) are potentially hazardous to the environment. There are numerous examples of negative impacts from leachate (Cossu et al., 2001). This has led to the generation of national and / or regional regulations and legislation aimed at protecting water bodies from contaminants from sanitary landfills or from solid waste at final disposal sites, as well as the search and implementation of new treatment processes for this liquid, and thus reduce the impacts to the environment.

1.1 Stabilized solid waste

As it has been recently reported, "old garbage" or stabilized waste has great capacity for cation exchange (0.068 mol / g), high porosity (37.25%) and is rich in microbial communities (1.40x10 6 CFU / g) which have adapted over the years to the high concentrations of pollutants (Zhao et al., 2002). Table 1 shows the characteristics of the stabilized waste based on a study by Li Zhao et al shown. (2009).

In the last decade, have been developed and evaluated biofilters "old junk" or stabilized waste for decontamination of leachate as in the case of Zhi-Yong et al. (2011), who developed a semi-anaerobic biofilter with stabilized residues.

Tabla 1. Characteristics of stabilized solid waste

Parámetros	Residuo estabilizado
Humedad (%)	31.84
Cenizas (%)	54.42
Materia combustible (%)	13.74
Materia biodegradable (%)	11.08
Materia orgánica (g/kg)	65.57
Nitrógeno Total (g/kg)	5.38
Nitrógeno amoniacal (mg/kg)	22.40

Source: Li *et al*. (2009).

1.2 Leachates

In sanitary landfills, once the solid waste has been buried it is necessary to minimize the impacts of this practice, since the water that has been in contact with the garbage collects a large amount of the substances that were originally inside the residue, remaining thereby highly contaminated. This water is called leachate, and is one of the most contaminated liquids known. If not collected properly and then treated, the leachate can in turn contaminate groundwater, surface water and soil. For this reason, landfills are waterproofed, drained properly and the leachate collected by these drains must be treated (Giraldo, 1997). The strong correlation between the age of a landfill and some features in the composition of leachates provides an important tool that helps in choosing treatment processes (Renou et al., 2008). Leachates are often classified by age in new, intermediate and old or mature, according to the age of the landfill that originated them. In general, the degree of biodegradability of leachate is inversely proportional to age, being more biodegradable when new and less degradable when mature (Fatima et al, 2012; Ramirez - Sosa et al, 2013..).

The problem lies in the fact that this liquid usually contains high concentrations of pollutants, the main groups being: dissolved organic matter, macro organic components (including nutrients), and organic xenobiotic components which if not correctly collected and treated can cause serious problems in the bodies of surface water and groundwater sources (Modin et al., 2011).

The following study carried out the characterization of a sample of waste disposed more than eight years ago in the closed area of the sanitary landfill of the city of Tuxtla Gutierrez. These residues were used as packing material in the construction of a biofilter, and its potential application for the treatment of leachates was evaluated, measuring the removal of organic load measured as COD and color.

2. METHODOLOGY

2.1 Characterization of stabilized material

With the help of a backhoe, a waste sample was obtained at three points in the closed area of the Tuxtla Gutierrez landfill (Figure 1), with a minimum age of eight years. Prior to taking the sample, a route was taken to select the sampling points, considering the areas where the oldest residues are housed.

Figure 1. Closed area of the sanitary landfill.

The residues were extracted to a minimum depth of 1 meter, in order not to compromise the quality of the sample.

The extracted residues were dried for 6 weeks by spraying the material onto tarps in thicknesses of 6 to 8 cm. To speed up the drying process, the material was moved weekly and the remains of larger materials were removed in order to facilitate the screening and cleaning of the material, removing cloth, glass, cardboard, stones, iron, plastics, etc. And in general bulky materials that could hinder the process.

To verify the stabilization of the residues, a weekly sample was taken, pH determined, volatile solids (VS), ash and humidity according to the techniques established in Mexican norms (Table 2). The analyses were performed once a week.

Table 2. Techniques and methods for each parameter.

Parámetro	Técnica o Método	Frecuencia
Humedad	NMX-AA-016-1984	1 vez / semana
pH	NMX-AA-008-SCFI-2011	1 vez / semana
SVT	NMX-AA-034-SCFI-2001	1 vez / semana
SF	NMX-AA-034-SCFI-2001	1 vez / semana

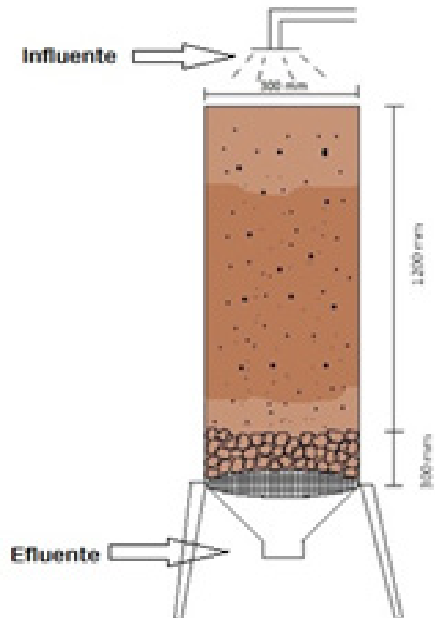
PH/ Hydrogen potential/ TVS: Total volatile solids / FS: Fixed solids.

Once dried, the residues were screened and separated according to the following particle sizes:> 40 mm, 16-40 mm and 2-15 mm.

2.2 Construction of the biofilter

A bioreactor was constructed with a PVC tube 30 cm in diameter and 1.5 m in height (Figure 2).

Figure 2. Dimensions of the bioreactor for the treatment of leachate.



In the bottom of the bioreactor a layer (about 30 cm) of support material (gravel), similar to that documented by Han et al was placed. (2011). The tube cap placed at the lower end was drilled to allow effluent to escape. In the upper and lower part of the support material, a mesh with a 2 mm opening was added to avoid excess trawling of the fine particles as these could obstruct the holes in the cover, making it difficult to remove the effluent. In the remaining volume of the tube there was added the filter bed (stabilized material). This finally resulted in a biofilter of 1.20 m in height.

For the load of the influent, a simulator vessel was used to favor the distribution of the leachate over the surface area and its descent through the filter bed, reducing the creation of dead zones and / or "short circuits".

2.3 Monitoring the operation of the biofilter

The influent and effluent were monitored in the COD and color parameters, with a frequency of once and twice a week, respectively. On the other hand, as reported in previous studies (Zhi-Yong et al., 2013), hydraulic loads in the range 10-11 L / m 3 -d settled, feeding for 1 hour twice a day . This activity was conducted six days a week. Monitoring of the biofilter was carried out over 8 months (35 weeks).

3. RESULTS AND DISCUSSION

3.1. Characterization of stabilized material and leachate in the influent

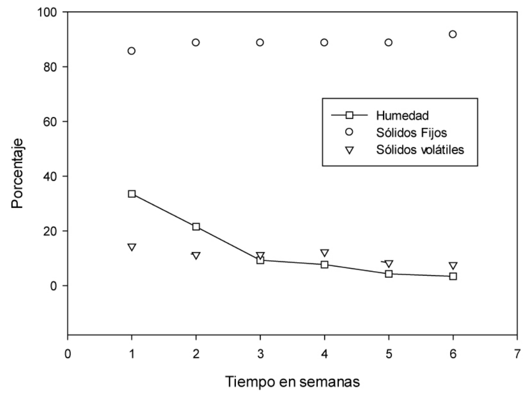
Solid residues showed a slight odor when extracted and laid, but during the first three days of the drying process at room temperature, the smell disappeared in its entirety without the presence of flies in the vicinity or leachate. These observations coincide with those reported by Zhao et al. (2007).

On the other hand, the initial moisture content (38%) observed in Figure 3 is similar to that reported by other authors (Han et al, 2013;. Chen et al, 2009;. Li et al, 2009;. Han et al, 2011;. Xiaoli and Youcai, 2006), and is considered an expected value as for being the material arranged in the subsoil, they are in contact with liquids (rainwater and re circulated leachate) that percolate through the different layers favoring the continuous generation of leachate. However, once removed and exposed to the natural drying process, in less than three weeks a rapid decrease in moisture content is observed, reaching almost constant behavior after this time.

As for the amount of FS and VS of the material, these materials practically did not change, because as expected these materials have reached their highest degree of degradation and as a consequence, the presence of organic matter is practically null which can be seen visually with the total absence of flies during the entire drying process, which may explain the almost constant behavior in their respective curves (Figure 3). In general terms, the material was observed to have few variations in its analyzed components.

For the characteristics that the evaluated waste presented, it can be said that it was physically and biologically stabilized, are rich in microbial populations (Zhao et al., 2002), and adapted to extreme and varied conditions.

Figure 3. Characterization of the extracted (stabilized) waste.



On the other hand, in order to know the different particle sizes in the dry basis (DB) residues, they were classified according to what is shown in Table 3. For the experiment, the bioreactor was packed with materials stabilized with a size of particle less than 40 mm.

Table 3. Classification by particle size in DB.

Tabla 3. Clasificación por tamaño de partícula en BS.

Tamaño de partícula (mm)	Cantidad	
	Kg	%
> 40	4.8	15.05
De 15 a 40	7.7	24.14
< 15	19.4	60.81
Total	31.9	100

From Table 3 it is observed that above 80% of them had a particle size below 40 mm, this fact is important because it allows to see that a high percentage of the stabilized materials once dry means it can be used in the construction of bioreactors. In laboratory level studies, authors like Zhao et al. (2002) have reported good results in the treatment of leachate using sizes of less than 20 mm particle, however, in more recent investigations and with scaled bioreactors at least at the pilot level (Li et al, 2009;. Xie et al ., 2010; Xie et al, 2012), the bioreactors were packed with stabilized waste of a larger particle size of the order of 40 mm, allowing better use of materials and reproducible results obtained at the laboratory level.

As for the characteristics of the influent shown in table 4, it is observed that they are typical of a type III or mature leachate, which is characterized by values of pH above neutrality, high alkalinity values and a low biodegradability index (<0.3) (Mendez et al . , 2004; Ntampou et al . , 2006 Ubaldo et al, 2014.).

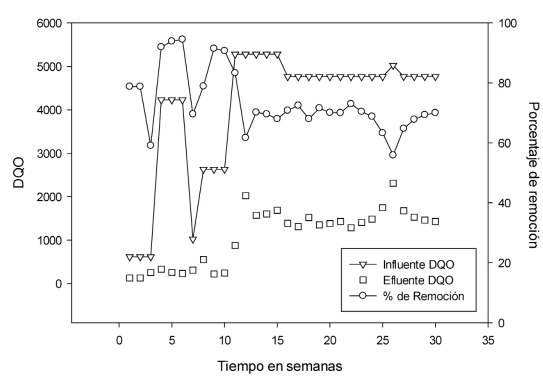
Table 4. Characterization of the influent.

Parámetro	Resultado
pH	8.0-8.4
DQO (mg/L)	4230 ± 630
Color (Pt-Co)	5 090 ± 820
Alcalinidad (mg/L)	1675
DBO_5 (mg/L)	800
DBO_5 / DQO	0.2

3.2. Process monitoring (biofilter)

Figure 4 shows the monitoring of the Biofilter over 35 weeks, observing the removal efficiency of organic matter (COD) in the leachate between 60 and 90% and reaching maximum removal (92%) after the week 6.

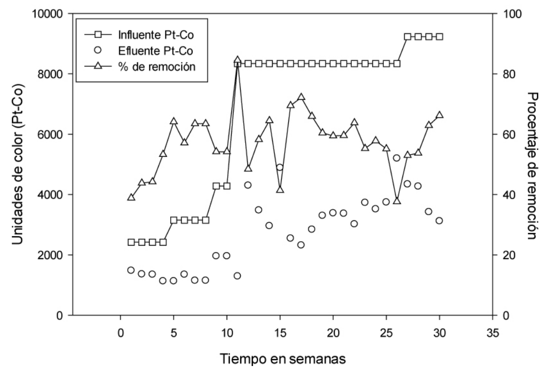
Figure 4. Results of COD removal.



From the graph (Figure 4) it is also observed that COD of the effluent ranges between 200 and 1600 mg / l, values that can be considered relatively fluctuating taking into account the variability in the influent (800-5000 mg / L). In general, the concentrations of both streams (influent and effluent) reflect stability of the bioreactor against important variations in the organic load supplied.

Another parameter used in the process as an indicator of the performance of the biofilter was color.

Figure 5. Color removal results.



From Figure 5 it is observed that during the first 12 weeks the color in the influent was predominantly black, with a value that ranged between 2400 and 4200 units of color (Pt-Co), with a slight odor, that after being admitted to the reactor it turned to a pale yellow color, similar to the color of the amber and without odor with units of color between the 1400 to the 1900 (Pt-Co). After these weeks the units of color in the influent were around 8,000 units of color, with an effluent quality between 2900 and 4800 units of color (Pt-Co), representing removals ranging from 40 to 75 %, with an average value of 60%. These variations may be due to non-ideal flow (Glynn and Heinke, 1999).

In practice, no reactor behaves as expected within ideal flows and for which deviations occur as a result of the pipeline. Short circuits can also occur because of the differences in the composition of the solid waste within the bioreactor, and finally another factor can be the appearance of stagnant zones. This type of alterations of the flow inside the reactor cause the average retention time to be smaller than the one calculated for its ideal operation, and with this certain particles present in the influent can circulate with greater speed, concentrating of greater way the color of the effluent. This also causes "dead volume" regimes to decrease the useful volume of the treatment system.

CONCLUSIONS

To date with eight months of monitoring, it has been possible to evaluate the COD removal of leachates from the Tuxtla Gutiérrez landfill, reaching removals between 60 and 90%. For the case of color, on average a 60% removal was achieved.

In general terms, given that these biofilters can be used as pretreatment units, the results obtained are acceptable in addition to taking into account that the materials that make up the biofilter come from the same waste, which provides a window of opportunity in the revaluation of urban solid waste disposed in landfills or any other disposal site. Finally, as far as our literature review was possible, these results represent the first of its kind in the national territory.

Thanks

To Engineer Omar Sánchez Fernández, Manager of PROACTIVA Tuxtla, for allowing access and the required machinery in the sampling of stabilized waste.

REFERENCES

Chen, Li., Wu, S., Wu, W., Sun, H., & Ding, Y. (2009). Denitrification capacity of bioreactors filled with refuse at different landfill ages. *Journal and Hazardous Materials*, 172: 159- 165.

Cossu R, Lavagnolo M, Littaru P, (2001), Removal of municipal solid waste COD and NH4-N by phyto-reduction: A laboratory-scale comparison of terrestrial and acuatic species at different organics loads, Elsevier Science.

Giraldo, E., (1997). Tratamiento de lixiviados de rellenos sanitarios. Volumen 2. Páginas 44-55.

Han, Z., Liu, D., Li, Q., Li, G., Yin, Z., Chen, X., & Chen, J. (2011). A novel technique of semi-aerobic aged refuse biofilter for leachate treatment. *Waste Management*. 31: 1827- 1832.

Han, Z., Liu, D., Li, & Q. (2013). A removal mechanism for organics and nitrogen in treating leachate using a semi-aerobic aged refuse biofilter. *Journal Environmental Management*, 114: 336-342.

Li, H., Zhao, Y., Shi, L., & Gu, Y. (2009). Three-stage aged refuse biofilter for the treatment of landfill leachate. J*ournal of Environmental Sciences*, 21: 70–75.

Méndez, R., Castillo E., Sauri M., Quintal C., Jiménez B. (2004). Tratamiento físico químico de los lixiviados de un relleno sanitario, *Ingeniería Revista Académica*, 8(02), 155-163.

Modin H., Perssona K.M., Anderssonb A., van Praagch M., (2011). Removal of metals from landfill leachate by sorption to activated carbón, bone meal and iron fines. *Journal of Hazardous Materials*. 189. 749-754.

Ntampou, X., Zouboulis, A., Samaras, P. (2006). Appropriate combination of physico-chemical methods (coagulation/flocculation and ozonation) for the efficient treatment of landfill leachates. *Chemosphere*, 62, 722-730.

Prant R, Tesar m, Huber-Hunner m, (2006). Changes in carbon and nitrogen pool during in-situ aceration of old landgills under varying conditions, *Waste Management,* 26, 373-380.

Ubaldo Vázquez, Nájera Aguilar y Gutiérrez Hernández (2014). Evaluación de la remoción de carga orgánica en lixiviados maduros mediante un sistema acoplado: coagulación-floculación-oxidación anódica. *Revista AIDIS de Ingeniería y Ciencias Ambientales*. Vol. 7. 170-178.

Xiaoli, C., & Youcai, Z. (2006). Adsorption of Phenolic compound by aged-refuse. *Journal and Hazardous Materials,* B137: 410-417.

Xie B., Lv Z., Lv B.Y. & Gu Y.X. (2010). Treatment of mature landfill leachate by biofilters and Fenton oxidation. *Waste Management*. 30. 2108-2112.

Xie B., Xiong S., Liang S., Hu C., Zhang X. & Lu J. (2012). Performance and bacterial compositions of aged refuse reactors treating mature landfill leachate. *Biosource Technology*. 103. 71-77.

Ying-xu Chen, Song-wei Wu, Wei-xiang Wu, Hua Sun, Ying Ding. (2009). Denitrification capacity of bioreactors filled with refuse at different landfill ages. *Journal of Hazardous Materials*, 172: 159-165.

Zhao, Y., Li, H., Wu, J., & Gu, G., (2002). Treatment of leachate by aged refuse-based biofilter. J. *Environ. Eng.* ASCE. 128, 662–668.

Zhao, Y., Song, L., Huang, R., Song, L., & Li, X. (2007). Recycling of aged refuse from a closed landfill. *Waste Management & Research*, 25: 130-138.

Zhi-Yong Han, Dan Liu, Qi-Bin Li. (2013). A removal mechanism for organics and nitrogen in treating leachate using a semi-aerobic aged refuse biofilter. *Environmental Management*, 114.