Biological degradation of a mixture of municipal wastewater and organic garbage leachate in expanded bed anaerobic reactors and a zeolite filter

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ABSTRACT

Municipal wastewater was amended with organic garbage leachates at a concentration around 700 mgCODsoluble/L and fed to three different anaerobic systems to compare their performance: a down flow fluidized bed (DFFB), an expanded granular sludge bed (EGSB) and a zeolite-packed anaerobic filter reactor (ZPF). The DFFB and EGSB reactors were operated at HRT of 6 and 4 h and the ZPF reactor at 12 and 36 h. Organic loads rate for the DFFB reactor were 2.3 ± 0.9 and 4.8 ± 1.8 gCOD/L·d, with removal efficiencies around 40% and a methane productivity of 0.2 ± 0.03 L/Lreactor·d. For the EGSB reactor, organic loads tested were 2.1 ± 0.9 and 4.3 ± 1.3 gCOD/L·d, removal efficiencies attained were of 77.6 ± 12.7% and 84.4 ± 4.9%, respectively at both conditions and total suspended solids were removed in 54.6 ± 19.3%, while methane productivity at 4 h HRT was of 1.29 ± 0.4 L/Lreactor·d. The ZPF reactor was operated at lower organic loading rates, 1.4 ± 0.27 and 0.42 ± 0.13 gCOD/L·d and attained removal efficiencies of 48 ± 18% and 83 ± 8%, respectively, reaching a methane productivity of 0.21 ± 0.09 and 0.12 ± 0.04 L/Lreactor·d, 83 ± 8.0% of total suspended solids were retained in the reactor and as HRT was increased ammonium concentrations increased in 39%. Specific methanogenic activity in all systems was around 0.2 gCOD-CH4/gVSS d.

Key words | expanded bed reactors, municipal wastewater, organic garbage leachate, zeolite filter

INTRODUCTION

In the Valley of Mexico, 1,256 million cubic metres of wastewaters per year are generated, 86.24% is municipal wastewater (CONAGUA 2007). The main pollution problem is due to the giant volumes that are generated, and in a lesser proportion is the organic matter concentration contained in this waste: from 200 to 1,000 mgCODtotal/L, found at the exit of the Gran Canal, the major sewer that conducts wastewaters out from the Valley to be used for irrigation (Monroy et al. 1997).

In addition, 4.5 million tons of garbage per year are also generated in the metropolitan area (INEGI 2007), that being exposed to rain or degradation processes produce leachates that may contain between 10 and 60 gCOD/L, and attain contents up to 100 gCOD/L in leachates originated after one month of stabilization (Turan et al. 2005; Aguilar et al. 2008). It has been reported that for 5,500 to 6,500 ton of garbage, around 1,700 m³/d of this residues are produced (Zhanjiang et al. 2007). Garbage leachates represent a great risk for the Valley of Mexico since its generation and lack of disposition and treatment is related to soil and aquifers pollution and public health problems.

There is a great variety of studies on anaerobic treatment for both wastes in individual processes (Kennedy...
\& Lentz 2000; Monroy et al. 2000; Seghezzo 2004; Turan et al. 2005), while co-treatment of both wastes are scant (Fueyo et al. 2003), regardless that garbage leachates have to be diluted for biotreatment. In contrast, municipal wastewaters show problems in the removal efficiencies attained in anaerobic processes associated with a low organic matter content.

Many anaerobic reactor prototypes have been proposed for municipal wastewater treatment, mainly the UASB reactor with a granular sludge bed. The expanded granular bed reactor (EGSB) is a modification by the increase of the upflow liquid velocity where the bed is expanded with superficial velocities of 10 m/h, can be operated at short HRT and has been used between other processes for the treatment of wastewater from the petrochemical industry that contains high concentration of recalcitrant compounds (Almendariz et al. 2005), although also has been used in the treatment of low concentrations municipal wastewater, or for anaerobic effluents posttreatment (Kato 1994; Kato et al. 2003; Pérez 2004).

Expanded beds also comprise the use of biomass immobilized onto a support such as fluidized beds, very light materials have led to the development of down flow fluidized bed reactors (DFFB). Polyethylene used a support has a density lower than water and floats at the top of the column, so the influent together with the recirculation flow are fed at the top to expand the bed or fluidize it in a descending direction. It has been used experimentally for the treatment of several effluents such as wine distillery, dairy wastewater, municipal wastewater, synthetic waters containing different substrates as glucose, acetate, whey, etc. (García-Bernet et al. 1998; Castilla et al. 2000; Arnaiz et al. 2003).

In anaerobic filters the packing material may play an important role; zeolite has been reported as a suitable material because improves metabolic activity of anaerobic microorganisms by supplementing necessary trace elements, also is a good filtering media for solids retention and has been extensively used as an ion exchanger for ammonium removal (Nguyen & Tanner 1998; Milán et al. 1999; Leyva-Ramos et al. 2004).

The objective of this study was to compare the anaerobic treatment of a mixture of low concentration municipal wastewater and organic garbage leachates in three prototypes, two expanded beds: a DFFB and an EGSB reactors, and a fixed bed: a zeolite packed filter reactor (ZPF).

**METHODS**

**Expanded and fixed bed reactors**

A DFFB reactor of 30 L was started up adding 4 kg of grounded polyethylene with a mean particle diameter of 0.6 mm and density of 0.4 g/cm$^3$. The reactor was inoculated three times with 200 mL of malting granular sludge (46.5 gVSS/L) and 200 mL of flocculent sludge from a pilot plant UASB reactor treating municipal wastewater (24.0 gVSS/L) for a VSS content of 42.3 g. Batch operation was carried out for 35 days, and after some biomass was immobilized continuous operation at 6 and 4 h HRT was initiated.

The EGSB reactor of 2.8 L, was inoculated with 840 mL of granular sludge (46.5 gVSS/L) equivalent to 39.0 gVSS and operated at 6 and 4 h HRT at an upflow superficial velocity of 12.6 and 10.2 m/h, respectively.

The ZPF reactor of 13 L was packed at 80% capacity with zeolite rich in clinoptilolite. The support was added forming layers with different particle size: 2 to 3 cm at the bottom of the reactor, 2 to 1 cm in the middle section and 1 to 0.5 cm in the upper section. The reactor was inoculated twice with 130 mL of granular sludge for a 12.1 gVSS and operated at 12 and 36 h HRT.

**Substrates**

Organic garbage leachates contained, in g/L: 123 ± 23.2 COD$_{\text{soluble}}$; 8.58 TS; 17.8 acetic acid; 4.2 butyric acid; 0.5 valeric acid and 0.3 propionic acid; 0.45 NH$_4$; 21.4 total protein; pH of 5.09, were diluted with raw municipal wastewater that contained, in mg/L: 223 ± 91 COD$_{\text{soluble}}$; 120 TS; 25 NH$_4$; pH of 8.2. Both wastes were combined in a ratio 1:100 to form a mixture of 658.6 ± 225.4 mgCOD$_{\text{soluble}}$/L with a mean pH of 7.6, and was fed to all reactors.

**Analysis**

The reactor performance was followed up through soluble COD and volatile suspended solids content, pH, alkalinity
ratio, biogas production and composition (TCD gas chromatography). Immobilized biomass in the DFFB reactor was determined periodically by a gravimetric technique and reported as immobilized volatile solids (IVS) per m³ dry support. The specific methanogenic activity (SMA) for each reactor was calculated considering the immobilized or suspended VSS content, in each system.

RESULTS AND DISCUSSION

DFFB reactor

During start up the reactor was batch operated and fed with the mixture at 589.1 ± 224 mgCOD/L, biomass immobilization on the plastic support was promoted and reached 1.05 kgIVS/m³ dry support. Afterward and as shown in Figure 1a and b, the reactor was operated in continuous at 6 h HRT and fed with 579 ± 225 mgCOD/L mixture at an OLR of 2.3 ± 0.9 gCOD/L·d. Removal efficiency remained between 20 and 45% while biomass concentration increased to 1.7 kgIVS/m³ support.

By day 86 HRT was diminished to 4 h and the wastes mixture concentration was kept around 801 ± 306 mgCOD/L for an OLR of 4.8 ± 1.83 gCOD/L·d, at these conditions removal efficiency remained the same, even with an important increase in immobilized biomass to 6 kgIVS/m³ dry support found at the end of this stage. Biomass content was similar to that reported by Michaud et al. (2003) for an inverse turbulent fluidized bed fed with diluted vinasses (4 and 7 kgVS/m³) and six times higher than the biomass accumulated during municipal wastewater treatment (Castilla et al. 2000).

Although leachates contained a variety of nutrients (proteins, carbohydrates, short chain VFA, etc.) that favored biomass accumulation onto the support, were not the key factor to increase removal efficiencies, indicating that the down flow hydraulic regime and short HRT strongly determine the removal capacity of this prototype and could limit complex organic matter degradation since only simple compounds were removed. Anaerobic intermediaries such as acetic acid, were found only during start up, 89.5 mg/L in the influent and 134.6 mg/L in the effluent, no VFA were found in the effluent during continuous operation. Nevertheless, appropriate buffer capacity was observed, influent and effluent pH remained in 7.6 while alkalinity ratio was of 0.6 after start up and stabilized around 0.78 with slight variations.

EGSB reactor

The fed for this system had a concentration of 679 ± 173 mgCOD/L (Figure 2a), and as shown in Figure 2b, during the first 10 days at 6 h HRT removal capacity was low due to initial sludge acclimation, lately between days 39 and 86 the reactor increased removal efficiency to 84 ± 5% and reached process stability. When HRT was diminished to 4 h, removal
efficiency did not decreased and the reactor removed in this stage 56 ± 24% of solids from the influent, suspended volatile solids in the effluent were 41.4 ± 15 mg/L. Influent mean pH was 7.44 ± 0.24, while alkaline pH was found in the effluent (8.14 ± 0.28), so alkalinity ratio stabilized in 0.75 ± 0.08, indicating almost no VFA accumulation.

Removal efficiency attained was twice of that reported by Pérez (2004) for an EGSB reactor operated at the same conditions but fed only with municipal wastewater (357 ± 35 mgCOD/L). These results showed that short HRT had no adverse effects on the reactor performance and that dilution of organic leachates with municipal wastewater is an option for the treatment of both difficult to degrade wastes.

ZPF reactor

Influent concentration was of 645 ± 199 mgCOD/L (Figure 3a). During operation at 12 h HRT, for 27 days removal efficiency increased slowly from 16% and remained around 60 ± 14%. By day 45, HRT was increased to 36 hours and removal efficiency also increased and stabilized in 80 ± 16% while suspended solids removal was of 80 ± 16%.

The influent and effluent pH at 12 h HRT reached 7.4 ± 0.22 and 7.56 ± 0.32, while at 36 h an alkaline pH
was found ($8.0 \pm 0.46$), indicating a higher organic matter mineralization. Also higher ammonia levels were found, increasing from 37.7 to 52.5 mg/L due to an extended digestion of organic matter containing nitrogen. The improvement in performance of this reactor was a result from the increase in HRT and the retention capacity of the filtering material and biofilm formed.

Comparing among systems (Figure 4a), organic matter removal efficiency in the DFFB reactor was low at both OLR ($2.3 \pm 0.9$ and $4.8 \pm 1.8$ gCOD/L·d), probably due to the short HRT applied. Methane quantified at 4 h HRT attained $6.4 \pm 0.9$ L/d, a methane volumetric productivity (MVP) of $0.2 \pm 0.03$ L$_{CH4}$/L$_{reactor}$·d (Figure 4b), although an important biogas amount remained trapped in the reactor due to the liquid down flow pattern characteristic of this prototype.

The EGSB showed removal efficiencies around 80% at both OLR applied ($2.1 \pm 0.9$ and $4.3 \pm 1.3$ gCOD/L·d). Methane production rate at 4 h HRT was of $3.6 \pm 1.25$ L/d and the highest MVP attained for all prototypes (see Figure 4b).

In contrast, when the ZPF reactor was operated at 12 h HRT and $1.4 \pm 0.27$ gCOD/L·d attained a slightly higher removal level than the DFFB reactor, due to the lack of acclimation of biomass to the organic load. After a diminution of OLR ($0.42 \pm 0.13$ gCOD/L·d) due to an important increase in HRT, the biomass was able to remove a higher amount of organic matter showing an efficiency similar to that of the EGSB reactor. The quantified methane was of $2.8 \pm 1.2$ and $1.5 \pm 0.3$ L/d at 12 and 36 h of HRT, respectively, with a productivity similar to that of the DFFB reactor. Nevertheless, all reactors attained a SMA around 0.2 gCOD-CH$_4$/gVSS·d (see Figure 4b).

EGSB and ZPF reactors showed removal efficiencies higher than those reported by Álvarez & Suárez (2006) for diluted leachates treated in a UASB reactor, and similar to those obtained at HRT between 24 to 12 hours reported by Kennedy & Lentz (2000).

CONCLUSIONS

The EGSB and ZPF reactors showed high removal efficiencies at HRT of 4 and 36 h, respectively, while the DFFB reactor attained a removal level that was the half of the other two prototypes, although both expanded bed reactors operated at short HRT, a convenient characteristic when large wastewater volumes are to be treated. The EGSB and ZPF reactors are suitable prototypes that may be used in the treatment of wastes hard to treat by anaerobic processes: the leachate of high content in organic matter and a diluted waste discharged in high volumes as municipal wastewater.

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REFERENCES


![Figure 4](https://iwaponline.com/wst/article-pdf/59/4/723/436931/723.pdf)


