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Effect of feeding strategy on the performance of a pilot scale vertical flow wetland for the treatment of landfill leachate

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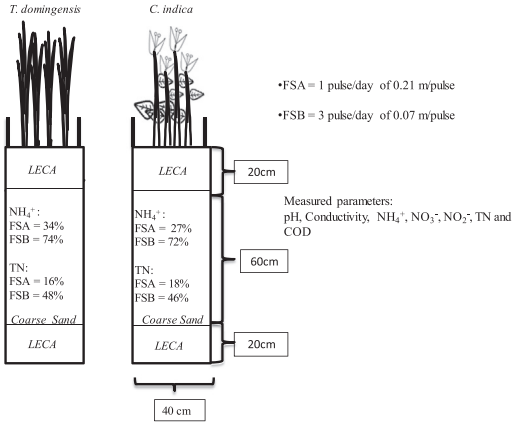
HIGHLIGHTS

- Diluted landfill leachate presented high pollutant concentrations.
- COD showed low removal due to its recalcitrant characteristics.
- Removal of NO_3^- and NO_2^- was not achieved due to a lack of anaerobic conditions.
- Ammonium and TN showed significantly higher removal in low HLR.
- Removal was not significantly different between VFW with the different macrophytes.

GRAPHICAL ABSTRACT



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ABSTRACT

Landfill leachate is one of the most challenging types of wastewater to treat using constructed wetlands. The objective of this study was to evaluate the effect of two feeding strategies on the treatment efficiency of a landfill leachate using vertical flow wetlands (VFWs) planted with *Typha domingensis* or *Canna indica*. The tolerance of these macrophytes to the leachate was also evaluated. Coarse sand and light expanded clay aggregates (LECA) were used as substrates. Two feeding strategies (FS) were applied: FSA = 1 pulse per day of 0.21 m pulse^{-1}, FSB = 3 pulses per day of 0.07 m pulse^{-1}. VFWs planted with *T. domingensis* presented removal efficiencies of 34/74% (NH_4^+) and 16/48% (TN) for FSA/FSB, respectively. VFWs planted with *C. indica* presented removal efficiencies of 27/72% (NH_4^+) and 18/46% (TN) for FSA/FSB, respectively. NH_4^+ and total nitrogen (TN) removal efficiencies were significantly higher in FSB than in FSA, but there were no significant differences between macrophyte species. COD removal showed no significant differences between FSs or between macrophyte species. *T. domingensis* and *C. indica* demonstrated to be tolerant to the leachate studied. VFWs planted with *T. domingensis* or *C. indica* are suitable to treat diluted landfill leachate with high ammonium concentrations using a feeding strategy of pulses. However, an anaerobic stage may be added after the VFW to get higher TN and COD removal.

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1. Introduction

Leachate is produced when rainwater percolates through landfill waste, thus washing out substances constituting the landfill. Leachate presents a high diversity in its composition that depends on landfill age, climatic conditions and solid waste rate of degradation. High concentrations of ammonium and recalcitrant COD are the main characteristics of leachate (Wojciechowska et al., 2016).

Landfill leachate is one of the most difficult types of wastewater to treat with conventional methods (Kadlec, 2003; Nivala et al., 2007). The expected volume and chemical quality of a landfill leachate is highly site-specific and may change over time. Therefore, the design and operation of constructed wetlands (CWs) needs to be well studied for each landfill leachate. Different CWs were used to treat landfill leachate, such as hybrid CWs (Speer et al., 2012) and single stage wetlands like free water surface wetlands (FWSWs) (Akinbile et al., 2012), horizontal subsurface wetlands (HSSWs) (Bialowiec et al., 2012) or vertical flow wetlands (VFWs) (De Feo et al., 2005; Lavrova, 2016). VFWs have proven to be effective, being the most used for the treatment of leachate (Kadlec and Zmarthie, 2010; Stefanakis et al., 2014). However, in Argentina there were not found studies using VFWs to treat landfill leachate.

The main benefits of VFWs are the lower area demands compared to HSSWs, and the fact that have a high capacity to oxidize ammonium due to the typical aerobic conditions obtained by loading them intermittently (Stefanakis et al., 2014). Yalcuk and Ugurlu (2009) compared VFWs and HSSWs for the treatment of landfill leachate and obtained better removals of ammonium in VFWs. A et al. (2017) studied at laboratory-scale a VFW for the treatment of a synthetic landfill leachate, and found ammonium removals of 44–73% in systems planted with *Juncus effusus* and 46–76% in systems planted with *Phragmites australis*. Lavrova (2016) studied the treatment efficiency of a landfill leachate by two laboratory-scale VFWs with and without additional carbon source. Significant removal efficiency according to COD (95%) and BOD (96%) was achieved. Complete nitrification of ammonium nitrogen into nitrite and nitrate occurred in both systems.

Macrophytes in VFWs can bring several benefits: they take up contaminants, they provide carbon compounds in the rhizosphere, contributing to denitrification and fermentation pathways, but most importantly, they create conditions that promote heterotrophic and autotrophic nitrifying bacteria (Białowiec et al., 2014). The high diversity and activity of these types of bacteria facilitate nitrogen removal from CWs (Huang et al., 2013). However, macrophytes have to tolerate influent conditions. Clarke and Baldwin (2002) proposed that toxic ammonium concentration for several wetland plants is above 200 mg/L N. This information is important since ammonium in leachate can achieve high concentration. Landfill leachate shows differences in chemical compositions between raw and diluted or open and closed landfill site (Renou et al., 2008). In literature, raw leachates showed ammonium concentrations of 941 mg/L (Wojciechowska et al., 2016), 591 mg/L (Białowiec et al., 2014), 642 mg/L (Bulc, 2006) and 5070 mg/L (Cheng and Wu, 2011), while the raw leachate studied in our work showed an ammonium concentration of 2500 mg/L. Thus, a dilution of the raw leachate was necessary in order to not affect the plant growth during our experimental period.

Hydraulic load is one of the most important factors that control nitrogen removal and performance efficiency of CWs (Almeida et al., 2017; Prochaska et al., 2007), while feeding strategy is an important issue to consider during the landfill treatment using VFWs. There are scarce studies that compare different feeding strategies in VFWs. Lavrova and Koumanova (2010) studied the treatment of a landfill leachate at a laboratory-scale VFW planted with *P. australis* at different feeding strategies (flow rates and recirculation ratios). The low flow rate (40 mL/min) and recirculation ratio of 1:3 allowed removal efficiencies of 96% for COD, 92% for BOD_5, 100% for ammonia and 100% for total phosphorus. The aim of this study was to evaluate the effect

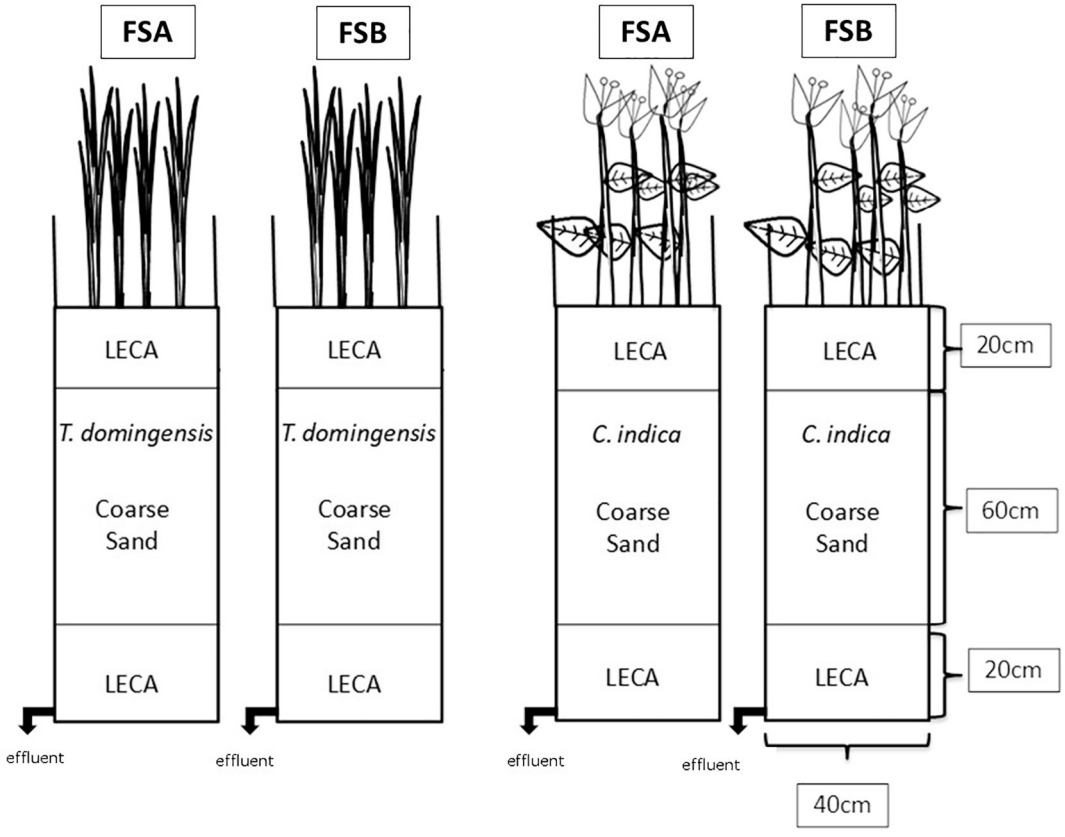

Fig. 1. Scheme of the pilot scale VFWs used in the experiment. This scheme was used in duplicate for the two feeding strategies studied (FSA and FSB).