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Landfill leachate treatment as measured by nitrogen transformations in stabilization ponds

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HIGHLIGHTS

- Stabilization ponds system was able to treat landfill leachate.
- Phytoplankton community had low diversity and predominance of *Chlamydomonas* genus.
- Nitrogen transformation and removal occurred mainly by dead/inert biomass settle.

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ABSTRACT

The treatment performance and nitrogen mass balance of a pilot-scale landfill leachate treatment system was evaluated. The system was comprised of a series of three ponds and a rock filter and was fed a continuous flow (200 L d^{-1}) during 111 weeks. Three different operational conditions were investigated: conventional operation (stage I), aeration (stage II) and aeration/recirculation (stage III). The system was able to treat landfill leachate with soluble chemical oxygen demand and ammonia removal between 35–82% and 75–99%, respectively, and the highest removal occurred during the recirculation stage. The nitrogen balance was calculated using total nitrogen applied load and the main transformation processes within the ponds. The main form of nitrogen transformation/removal was by dead/inert algae settle (64–79%), followed by volatilization (12–27%) and algae assimilation (1–6%). Nitrification/denitrification occurred in only stage II. Analyses of the phytoplankton community showed that the *Chlamydomonas* genera were dominant in the photosynthetic ponds.

1. Introduction

Landfill leachate is a hazardous substance produced by rainwater percolation and waste decomposition in landfills (Vilar et al., 2011). It contains large amounts of recalcitrant organic compounds (Thörneby et al., 2006) and has high nitrogen concentrations. The nitrogen present in landfill leachate is found mainly as organic nitrogen and ammonia (Guo et al., 2010), and ammonia is known to cause eutrophication, depletion of surface water dissolved oxygen (DO), toxicity to aquatic life, as well as public health concerns. Consequently, landfill leachate is extremely toxic and has a high environmental impact since it reaches both groundwater and surface water. Currently, the most common and cost-effective leachate treatment method is on-site pretreatment of activated sludge (Wiszniowski et al., 2006). New configurations in treatment systems have been studied in lab and pilot scale, such as modified sequencing batch reactors (Wang et al., 2013) or hybrid systems (Speer et al., 2012) for treatment of landfill leachate. However, stabilization ponds, a simpler effluent treatment method, have also shown promise as another form of landfill leachate treatment (Frascari et al., 2004; Thörneby et al., 2006; Renou et al., 2008; Mehmood et al., 2009; Leite et al., 2011). Studies of nitrogenous compound removal in stabilization ponds have employed three main processes: volatilization of the non-ionized ammonia (NH_3) under favorable temperature and pH conditions; assimilation and incorporation of algae biomass; and biological nitrification/denitrification (Sawaittayothin and Polprasert, 2007; Babu et al., 2011). Some doubts about the main mechanisms behind these nitrogen removal processes still persist, however. Ammonia volatilization may be the primary process of nitrogen removal (Maynard et al., 1999). On the other hand, part of ammonia removal may be due to algae assimilation during the growth and deposition of organic nitrogen in ponds (Ferrara and Avci, 1982; Mehmood et al., 2009). Additionally, many authors have described the importance of nitrification/denitrification for different types of effluent, particularly in ponds systems (Aguirre et al., 2004; Valero and Mara, 2007; Picot et al., 2009). Finally, although studies are conclusive about the effectiveness of ponds systems for treating sanitary effluents, few studies have been conducted in stabilizations ponds

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analyzing their effects on landfill leachates with a considerable lack of current publications (Parkes et al., 2007; Renou et al., 2008; Zhao et al., 2012).

Thus, the objective of this study was to evaluate landfill leachate treatment in a pilot-scale ponds system by focusing on the main nitrogen removal transformations in two photosynthetic ponds of this system.

2. Methods

The experiment was conducted using a pilot-scale treatment system of stabilization ponds for landfill leachate treatment. The system was located at the Federal University of Santa Catarina in the city of Florianópolis, and the raw leachate was collected from the Tijuquinhas landfill of Biguaçú. Both Florianópolis and Biguaçú are located in Santa Catarina, south Brazil (27°21′47 17″ S and 48°38′15 52″ W, respectively).

2.1. Leachate origin

The leachate used in this research was obtained from a landfill that has operated since 1990. The landfill receives domestic and hospital waste from 22 municipalities, totaling an average of 800–1000 T day^{-1}. The leachate was transported to the laboratory in a tank-truck where it was then transferred to an equalization tank with a volume of 1 m^3. From there, it was pumped into the treatment system with a flow of 200 L day^{-1}.

2.2. Pilot-scale treatment system

The pilot-scale stabilization ponds system was comprised of an anaerobic pond (P1), a facultative pond (P2), a maturation pond (P3), and a rock filter (RF) in series (Fig. 1). The main physical and operational conditions (flow and hydraulic retention time; HRT) of the treatment system are presented in Table 1. P1 was cylindrical while P2 and P3 were rectangular. Acrylic plates were installed in the inlets and outlets of P2 and P3 to guarantee flow direction and to avoid short-circuiting in the ponds. The rock filter was filled with gravel stones (commercial no. 4:38–76 mm diameter) for polishing the effluent which was applied to the filter at a hydraulic flow rate of 0.25 $m^3\ m^{-3}\ d^{-1}$.

Table 1
Physical and operational characteristics of the treatment system.

Characteristics		P1	P2	P3	RF
Length (m)		–	4.36	4.36	3.00
Width (m)		–	2.40	2.40	0.50
Diameter (m)		1.85	–	–	–
Depth (m)		1.85	0.80	0.60	0.50
Volume (m^3)		5.00	8.37	6.25	0.75
Flow rate (L day^{-1})	St I and II	200	200	200	200
	St III-50%*	300	300	300	200
	St III-100%*	400	400	400	200

* Percent of recirculation (P3–P1). St = stage.

2.3. Operation

The treatment system performed under three operational conditions of three stages for a total duration of 111 weeks.

2.3.1. Stage I – Conventional operation

The ponds system operated under normal conditions, without aeration and without recirculation, with ponds subject to loads and/or environmental (daily and seasonality) variations. This period was 42 weeks long.

2.3.2. Stage II – Aeration

The treatment system functioned as in stage I but with the use of aeration in P2. Two ceramic diffusers, located at the pond bottom at a distance 1/3–2/3 from the effluent inlet, were installed to provide air. These aerators were fed by an air compressor with an aspiration capacity of 77.5 L min^{-1}. In this stage, three different lengths of aeration were tested:

(a) *Stage II – 12 h of aeration:* P2 received nocturnal aeration for 12 h (9:00 pm–9:00 am). This period was 13 weeks long.
(b) *Stage II – 18 h of aeration:* P2 received aeration for 18 h (3:00 pm–9:00 am). This period was 15 weeks long.
(c) *Stage II – 24 h of aeration:* P2 received aeration for 24 h. This period was 11 weeks long.

2.3.3. Stage III – Recirculation

P2 remained aerated for 24 h each day, and the P3 outlet effluent was recirculated to P1 by a metering pump. Two conditions of recirculation were studied:

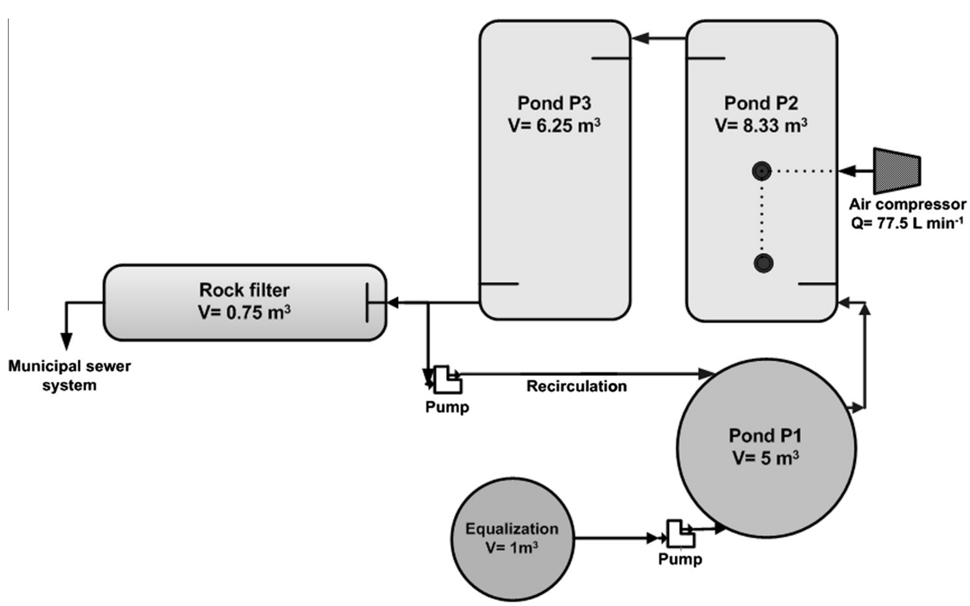

Fig. 1. Schematic of the treatment system.