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Co-treatment of landfill leachate and domestic wastewater using a submerged aerobic biofilter

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ABSTRACT

This study used a pilot-scale submerged aerobic biofilter (SAB) to evaluate the co-treatment of domestic wastewater and landfill leachate that was pre-treated by air stripping. The leachate tested volumetric ratios were 0, 2, and 5%. At a hydraulic retention time of 24 h, the SAB was best operated with a volumetric ratio of 2% and removed 98% of the biochemical oxygen demand (BOD), 80% of the chemical oxygen demand (COD) and dissolved organic carbon (DOC), and 90% of the total suspended solids (TSS). A proposed method, which we called the “equivalent in humic acid” (Eq.HA) approach, indicated that the hardly biodegradable organic matter in leachate was removed by partial degradation (71% of DOC Eq.HA removal). Adding leachate at a volumetric ratio of 5%, the concentration of the hardly biodegradable organic matter was decreased primarily as a result of dilution rather than biodegradation, which was confirmed by Fourier transform infrared (FTIR) spectroscopy. The total ammoniacal nitrogen (TAN) was mostly removed (90%) by nitrification, and the SAB performances at the volumetric ratios of 0 and 2% were equal. For the three tested volumetric ratios of leachate (0, 2, and 5%), the concentrations of heavy metals in the treated samples were below the local limits.

1. Introduction

Many studies have demonstrated that sanitary landfills generate leachate, a pollutant wastewater that contains inorganic salts, heavy metals, TAN, biodegradable organics, and refractory compounds such as humic substances. Leachate typically presents a dark colour that can be attributed to the humic substances (Kjeldsen et al., 2002; Renou et al., 2008; Wu et al., 2011).

Leachate is classified as old when its characteristics include low BOD/COD ratios (0.3–0.01) and high TAN concentrations, but it is important to remember that these characteristics are not necessarily associated with the age of the landfills (Renou et al., 2008). TAN is one of the most important constituents of old leachate because of its possible toxicity to ammonia and nitrite-oxidising bacteria, which are used in biological treatment (Gabarró et al., 2012; Renou et al., 2008; Xu et al., 2010; Yusof et al., 2010).

Prior knowledge of the above-mentioned characteristics is mandatory when selecting a successful treatment technology for landfill leachate. The available technologies are based on biological, physicochemical, advanced oxidation (AOP), and membrane filtration processes (Marañón et al., 2010; Renou et al., 2008; Xu et al., 2010; Yusof et al., 2010).

To optimise the efficiency of the treatments and meet the regional discharge limits for landfill leachate, most of the cited processes have been combined. Leachate treatment using air stripping/AOP/biological processes resulted in 99% COD removal (Nurisepehr et al., 2012). Similar values were obtained for COD, colour, and nutrient removal from leachate treatment as a result of applying sequencing batch reactors (SBR)/coagulation/Fenton/biological aerated filtering (Wu et al., 2011).

Nonetheless, combined processes can be very costly because they require chemicals and electricity to produce high-quality treated leachate. It was reported that the operating costs of combining an SBR with ozonation or photo-Fenton were, respectively, 125% and 63% higher than the operating costs of an SBR treating leachate (Cassano et al., 2011).

Regarding the low-cost options that may be associated with obtaining a good final effluent quality, the co-treatment of leachate with domestic wastewater can be highlighted. This treatment alternative is advantageous because it can be employed in an existing wastewater treatment plant (WWTP) and can thus avoid the need to invest in a new facility. Because leachate is generally

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added to domestic wastewater at volumetric ratios that do not exceed 10%, the biological processes are less susceptible to the toxic effects of high TAN concentrations (Borghi et al., 2003; Çeçen and Aktas, 2004; Fudala-Ksiazek et al., 2011; Renou et al., 2008; Yu et al., 2010).

Most papers reporting leachate co-treatment with domestic wastewater have considered the use of activated sludge reactors. For volumetric ratios of leachate varying from 0.2 to 5%, the COD removals ranged from 80 to 92% (Çeçen and Aktas, 2004; Fudala-Ksiazek et al., 2010, 2011; Yu et al., 2010). Despite the important contributions of the previous studies, none of those studies clarified whether the hardly biodegradable organic matter of old leachates was indeed removed by biodegradation with the organic content of domestic wastewater or whether this matter was instead diluted.

Thus, the main objective of this study was to investigate whether the hardly biodegradable organic matter of old leachate was simply diluted or actually biodegraded with domestic wastewater. Differing from previous studies, this study evaluated the co-treatment of old leachate with domestic wastewater in pilot-scale submerged aerobic biofilters (SABs), which are known to offer better solid retention compared with activated sludge reactors (Gálvez et al., 2009; Metcalf and Eddy, 2003).

2. Material and methods

2.1. Wastewaters

2.1.1. Landfill leachate

This study used leachate from the municipal sanitary landfill of Sao Carlos, a medium-sized city located in Sao Paulo, Brazil, that has approximately 220,463 inhabitants and generates 160 tons of municipal solid waste per day. This municipal landfill has been in operation for 22 years and receives domestic solid waste containing organic matter (60% by mass), as well as glass, paper, plastic, and metals, though the city has a recycling program.

The sampling point was located at the landfill treatment pond. Before being mixed with domestic wastewater, the leachate was pre-treated by air stripping (for TAN removal) according to the procedures described by Ferraz et al. (2013a). Initially, the pH was adjusted to 11 by lime addition; the leachate was then recirculated in an aerated packed tower until its TAN concentration was reduced to approximately 100–150 mg L^{-1} (Ferraz et al., 2013a).

The leachate used in this study was classified as old, primarily because of its high TAN concentration and extremely low BOD/COD ratio of 0.1 (Table 1). The pre-treated leachate obtained through air stripping presented the same BOD/COD ratio as did the raw leachate. These extremely low BOD/COD ratios can be associated with the presence of the hardly biodegradable organics, such as humic and fulvic acids (Renou et al., 2008), which seem to remain in leachates that have been pre-treated by a pH adjustment with lime and air stripping (Ferraz et al., 2013a).

2.1.2. Domestic wastewater

Domestic wastewater was collected from the sewer system located in the neighbourhood of the University of Sao Paulo (EESC/USP) campus. This wastewater presented a large content of biodegradable organic matter compared with that of the leachate, resulting in BOD/COD ratios varying from 0.5 to 0.6 (Table 1).

2.1.3. Mixture leachate/domestic wastewater

Leachate was added to domestic wastewater at volumetric ratios of 2 and 5%.

Table 1
Physico-chemical characterization of wastewaters used in the experiments (adapted from Ferraz et al. (2013b)).

Parameter	Raw leachate		Pre-treated leachate		Sanitary sewage	
	Min	Max	Min	Max	Min	Max
pH	8.3	9.0	9.5	11	6.4	7.6
Total alkalinity (mg $CaCO_3$ L^{-1})	6000	7570	2649	5000	111	200
Conductivity (μS cm^{-1})	14,800	28,300	8450	12,300	363	505
$BOD_{5,20}$ (mgO_2 L^{-1})	433	588	218	304	115	269
COD_{total} (mgO_2 L^{-1})	4425	4860	2772	3900	216	440
TKN (mg L^{-1} N)	920	977	12	250	29	50
TAN (mg L^{-1} N)	790	821	9	150	27	37
Organic-N (mg L^{-1})	130	156	3	100	2	13
TS (mg L^{-1})	8446	15,980	6558	9140	562	1078
TVS (mg L^{-1})	4974	8447	5749	6976	120	390
TFS (mg L^{-1})	3472	7533	2118	3778	172	202
TDS (mg L^{-1})	8247	15,565	6248	8700	495	1003

BOD: biochemical oxygen demand; COD: chemical oxygen demand; Min: minimum; Max: maximum; TAN: total ammoniacal nitrogen; TKN: total Kjeldahl nitrogen; TS: total solids; TVS: total volatile solids; TFS: total fixed solids; TDS: total dissolved solids.

2.2. Pilot-scale submerged aerobic biofilters (SABs)

One of the SABs consisted of a PVC tube with a diameter of 38 cm, a height of 200 cm, and a working volume of 178 L. As shown in Figure S1 (Supplementary data), this reactor was divided into five modules. Two of these modules were packed with polyethylene corrugated Raschig rings, which were 1.5 cm in diameter and 5 cm in length. Each of these modules was inoculated with 25 L of activated sludge biomass.

Another SAB that was inoculated similarly to the first one and packed with the same material was used as a control reactor. This reactor was loaded only with domestic wastewater and had a working volume of 75 L (Figure S1).

The two SABs were operated under a continuous-flow regime, with an hydraulic retention time (HRT) of 24 h. Compressed air was injected into the SABs at a rate of 500 L h^{-1}, and the dissolved oxygen concentration inside the five modules was maintained above 2 mg L^{-1}.

2.3. Analytical procedures

The following parameters were measured according to the Standard Methods for the Examination of Water and Wastewater (APHA, AWA and WEF, 2012): $BOD_{5,\ 20}$ (Hach BODTrakII respirometric apparatus), method 5210 B; COD (Hach COD reactor 45600-00/Hach DR 2010 spectrophotometer), colourimetric method 5220 D; conductivity, method 2510 B; DOC (Shimadzu TOC 5000 A Analyser), method 5310 B; nitrate, method 4500 C – NO_3^- (Shimadzu UV-160A spectrophotometer); solid content, method 2540; total alkalinity, method 2320 B; TAN (Büchi distillation unit B-339), method 4500 C – NH_3 Nitrogen; total heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) (Varian AA240 FS atomic absorption spectrophotometer), methods 3111 B and D; and total Kjeldahl nitrogen (TKN) (Büchi digestion unit B-426), method 4500 C – Norg Nitrogen.

Fourier transform infrared (FTIR) spectroscopy was used to identify the functional groups present in the leachate structure. FTIR spectra were recorded from KBr pallets containing approximately 1 mg of a lyophilised sample and 100 mg of KBr. A BOMEM B-102 FTIR spectrometer was used. The FTIR spectra were obtained over the wavenumber range of 4000 to 400 cm^{-1}, at a resolution of 4 cm^{-1}, and in 16 scans. The spectra were plotted in Origin 8.0 (OriginLab).