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Evaluation of monitoring indicators for the post-closure care of a landfill for MSW characterized with low lignin content

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ABSTRACT

To understand the applicability of the termination indicators for landfill municipal solid waste (MSW) with low initial lignin content, four different accelerated landfill stabilization techniques were applied to anaerobic landfilled waste, including anaerobic flushing with water, anaerobic flushing with Fenton-treated leachate, and aerobic flushing with Fenton-treated and UV/H_2O_2-treated leachate. Termination indicators, including total organic carbon (TOC), ammonia-N (NH_4^+-N), the ratio of UV absorbance at 254 nm to TOC concentration ($SUVA_{254}$), fluorescence spectra of leachate, methane production, oxygen consumption, lignocellulose content, and humus-like content were evaluated. Results suggest that oxygen consumption related indicators used as a termination indicator for low-lignin-content MSW were more sensitive than methane consumption related indicators. Aeration increased humic acid (HA) and (HA + FA)/HyI content by 2.9 and 1.7 times compared to the anaerobically stabilized low-lignin-content MSW. On the other hand, both the fulvic acid (FA) and hydrophilic (HyI) fractions remained constant regardless of stabilization technique. The target value developed for low-lignin-content MSW was quite different than developed countries mainly due to low residual biodegradable organic carbon content in stabilized low-lignin-content MSW.

1. Introduction

After a municipal solid waste (MSW) landfill is closed, long-term monitoring is required. This long-term monitoring is commonly referred to as post-closure care (PCC) and can last at least 30 years in many developed countries (Laner et al., 2012). Comparatively, sanitary landfilling is relatively new in developing countries therefore PCC challenges are just coming to light. Therefore, the sanitary landfills after closure still have an existing and future burden in environmental and financial aspects. Laner et al. (2012) indicated that PCC could not be terminated until the following were achieved: a significant fraction of biodegradable waste is consumed, settlement is constant over a certain period, and the concentration of heavy metals, ammonium, and trace organic pollutants in leachate will not cause adverse effects on human health and the environment. Literature suggests that reducing the PCC period of a landfill can be accomplished by accelerated landfill stabilization techniques. These stabilization techniques include leachate recirculation (Reinhart and Townsend, 1997), in-situ aeration (Berge et al., 2006; Heyer et al., 2005), and in-situ aeration combined with flushing (Batarseh et al., 2010; Bolyard et al., 2013; Ritzkowski et al., 2006).

Preliminary research has been conducted to develop termination indicators to identify the point in which PCC can be reduced or ended. The termination indicators summarized in Table 1 represent waste from developed countries (e.g., in USA (Kelly et al., 2006; Reinhart and Townsend, 1997), England (Knox et al., 2005), Germany (Ritzkowski et al., 2006; Stegmann et al., 2006), Italy (Cossu et al., 2007), and Austria (Prantl et al., 2006)). These termination indicators and their threshold values were determined through studies on local landfilled waste for each respective developed country, which has less biodegradable MSW components as shown in Table 2, and can be referred to as high-lignin-content MSW compared with Chinese MSW. Therefore, there is a need to evaluate whether MSW landfill termination indicators determined from

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high-lignin-content MSW are suitable for low-lignin-content MSW found in China. For instance, the target value of lignocellulose content based on high-lignin-content MSW may not be appropriate for low-lignin-content MSW. Additionally methane production potential of MSW for 21 days (GP_{21}) and O_2 consumption of MSW for 4 days (RI_4) of low-lignin-content MSW may not be sensitive enough since there are fewer recalcitrant organics remaining in the low-lignin-content stabilized waste. In addition to lignocellulose, there are high concentrations of humus-like substances (including humic acid, fulvic acid, and humin) in anaerobically stabilized MSW and leachate (Kjeldsen et al., 2002; Nanny and Ratasuk, 2002). However, little research (Huo et al., 2008; Juan and Walace, 1982) related to the evolution of humus-like substances (HS) has been done during the landfill anaerobic degradation phase, and is quite limited for accelerated landfill stabilization phase. Therefore, there is a clear need to determine whether termination indicators related to HS (e.g., HS content of MSW, the ratio of UV absorbance at 254 nm to TOC concentration ($SUVA_{254}$), and fluorescent excitation–emission matrix (EEM) spectra of leachate which can reflect the abundance of HS in dissolved organic matter (DOM)) are applicable for low-lignin-content MSW landfill management.

This study aimed to evaluate the applicability of current termination and HS related indicators for low-lignin-content MSW under different accelerated landfill stabilization techniques. Four different accelerated landfill stabilization techniques were applied to anaerobic landfilled waste, including anaerobic flushing with water, anaerobic flushing with Fenton-treated leachate, and aerobic flushing with both Fenton-treated and UV/H_2O_2-treated leachate.

2. Materials and methods

2.1. Anaerobically stabilized low-lignin-content MSW and leachate

Anaerobically treated MSW and leachate were used as initial materials. Leachate was collected from an anaerobic holding tank at the Laogang Sanitary Landfill in Shanghai, China (Coordinate: 31.07N, 121.88E). The collected leachate was centrifuged at 4000*g* for 15 min to remove suspended solids. The COD_{Cr} and BOD_5/COD_{Cr} of the supernatant was 976 ± 11 mg/L and 0.143 ± 0.002, respectively. Reinhart and her co-authors (Reinhart and Townsend, 1997; Reinhart and Grosh, 1998) indicated that a BOD_5/COD_{Cr} ratio less than 0.1 is associated with biostabilized leachate. Therefore, the collected leachate is considered biostabilized.

MSW was collected from the Songjiang Sanitary Landfill in Shanghai, China (Coordinate: 31.07N, 121.27E). At the time of sampling, the collected waste was approximately four years old. After collection, the waste was combined with the collected leachate, then manually sorted to remove plastics and metals. The processed MSW was then placed in a 1.5-m^3 stainless steel reactor. The reactor was purged with N_2 until an O_2 content of less than 1% was achieved, then sealed and incubated at 35 °C to further treat the MSW. During treatment, biogas production was monitored. After approximately three months, the biogas production ceased. The stabilized MSW was dried using a thermostatic drum wind drying oven (101-2-BS-II, YUEJING, China) at 60 °C. The dried waste was then shredded according to the method described by Zheng et al. (2013) to obtain a uniform sample size less than 1 mm.

2.2. Experimental procedures

2.2.1. Experiments simulating accelerated landfill stabilization techniques

Four experimental groups simulating accelerated landfill stabilization techniques were setup (i.e., anaerobic flushing with water, anaerobic flushing with Fenton-treated leachate, aerobic flushing with Fenton-treated leachate, and aerobic flushing with UV/H_2O_2-treated leachate) and are referred to as An-Flush, An-Fenton, Aer-Fenton and Aer-UV/H_2O_2 test. Schematics of the simulation experiments are shown in Fig. 1.

Four reactors were operated for each experimental group, set up in 500-mL glass bottles containing 20 g of dry shredded MSW and 350 mL of leachate. The liquid to solids ratio was significantly higher than that of a full-scale landfill to ensure saturated conditions.

Before the start of the An-Flush and An-Fenton tests, each reactor was sealed with a butyl rubber stopper and aluminum

Table 1
Comparison of landfill management termination indicators between previous and this research.

	Landfilled waste	MSW indicators					Leachate indicators			
		H[a]mg/g-DM[m]	C[b]mg/g-DM	C/L[c]	GP_{21}[d]mL CH_4/g DM	RI mg O_2/g DM	COD_{Cr}[g] mg/L	TOC[i] mg/L	NH_4^+-N[k] mg/L	TN[l] mg/L
Cossu et al. (2007)	Italian MSW				⩽10	⩽2.5[e]	<200		<300	
Knox et al. (2005)	Brogborough England MSW	⩽25		<0.2	⩽0.2				⩽10	
Prantl et al. (2006)	Vienna Austrian MSW		⩽15		⩽0.2	⩽0.7[f]				
Reinhart and Townsend (1997)	American MSW			<0.2						
Ritzkowski and Stegmann (2013) and Stegmann et al. (2006)	Northern German MSW				⩽10	⩽2.5[e]	⩽5–20[h]	150[j]	⩽2.5–10[h]	
An-Flush[n]	Chinese MSW	11.4	6.4	0.59				17	67	67
An-Fenton[n]	Chinese MSW	11.9	6.1	0.62				79	1018	925
Aer-Fenton[n]	Chinese MSW	1.0	0.8	0.59				63	449	633
Aer-UV/H_2O_2[n]	Chinese MSW	0.5	0.5	0.23				19	499	648

[a] H, Hemicellulose.
[b] C, cellulose.
[c] C/L, cellulose/lignin.
[d] GP_{21}, gas potential for 21 days.
[e] RI_4, four days respirometric index.
[f] RI_7, seven days respirometric index.
[g] COD_{Cr}, chemical oxygen demand on the basis of potassium dichromate.
[h] The unit of COD and NH_4^+-N is g/(m^2·yr).
[i] TOC, total organic carbon.
[j] TOC in the waste eluate.
[k] NH_4^+-N, ammonium-nitrogen.
[l] TN, total nitrogen.
[m] DM represented dry material.
[n] The end of this research.