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Biological stability of municipal solid waste from simulated landfills under tropical environment

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ABSTRACT

Biological stability of the Municipal Solid Waste (MSW) is assessed under tropical climatic condition using landfill lysimeters. Various landfill operating conditions and two different substrates were employed. Solid waste samples collected during different time intervals of landfill operation assessed for volatile solids (VS), organic carbon (OC), specific oxygen uptake rate (SOUR), and water extractable components. Organic carbon achieved faster stabilization than the nitrogen content in MSW within the various landfill operating conditions. At the end of 960 days of lysimeter operation, the MSW from different landfills were aerobically and anaerobically stable and results comparable with compost. Further, bioreactor landfill given better biological stability and high methane content than other landfill operating conditions with continuous leachate treatment is compelling benefit.

1. Introduction

Traditionally, landfills have been thought of as waste storage and containment systems, functioning primarily to entomb the waste. Recently, the focus has shifted to considering the landfill as a complex biological system capable of stabilizing the solid waste in a more proactive manner (Reinhart and Townsend, 1998). Landfill stabilization may require 50 years or longer for conventional landfills, while 5 years or less may be needed using landfill bioreactor technology (Kilmer and Tustin, 1999; Pohland, 1975; Watson, 1993).

Biological stability of solid waste is the extent to which readily biodegradable organic matter has been decomposed (Lasaridi and Stentiford, 1998). It is one of the main issues related to the evaluation of the long-term emission potential and the environmental impact of landfills (Cossu and Raga, 2008).

A suitable method for determining biological stability should be capable of numerically representing the actual point reached in the process of decomposition through the use of a measurement on a recognized scale of values, which in turn enables the comparison of different decomposition rates (Scaglia et al., 2007).

The biochemical and physical indicators evaluated to determine the rate of stabilization of the waste mass in landfill have historically been cellulose, lignin, C/N, pH, volatile solids and biogas composition (Decottignies et al., 2005; Kelly et al., 2006; Reinhart and Townsend, 1998; Sang et al., 2008). Indicators such as volatile solids are very simple and low cost to analyze, and take very little time while others such as biochemical methane potential are complex and require extensive time to obtain the result. Even though the list of parameters considered suitable for estimating the stability of solid wastes is large but the point at which waste is completely degraded and the landfill is stable is not yet clearly defined (Kelly et al., 2006).

A pilot scale lysimeter study was carried out at Centre for Environmental Studies, Anna University, Chennai, India, as part of the investigations on the concept of "Sustainable Solid Waste Landfill Management in Asia" under the Asian Regional Research Programme funded by Swedish International Development Cooperation Agency. This paper presents the findings of the study on the biological stability of the fresh and partially stabilized waste disposed in various simulated landfill conditions under tropical environment.

2. Methods

Six lysimeters with a height of 3 m and 1.3 m in diameter were constructed using reinforced concrete rings (Fig. 1). Coarse gravel layer of 0.2 m thickness was used at the bottom as the drainage layer and a PVC pipe was provided for leachate collection in all the six lysimeters. Manually segregated biodegradable fraction of fresh MSW from a residential area of Chennai and the partially degraded MSW (three years old) mined from the MSW Dumping Ground in Chennai at Kodungaiyur (KDG) were used as substrates in the lysimeters. Lysimeter loading details are summarized in Table 1. A composite cover consisting of compost, sand and partially stabilized waste from an open dumpsite, respectively were placed

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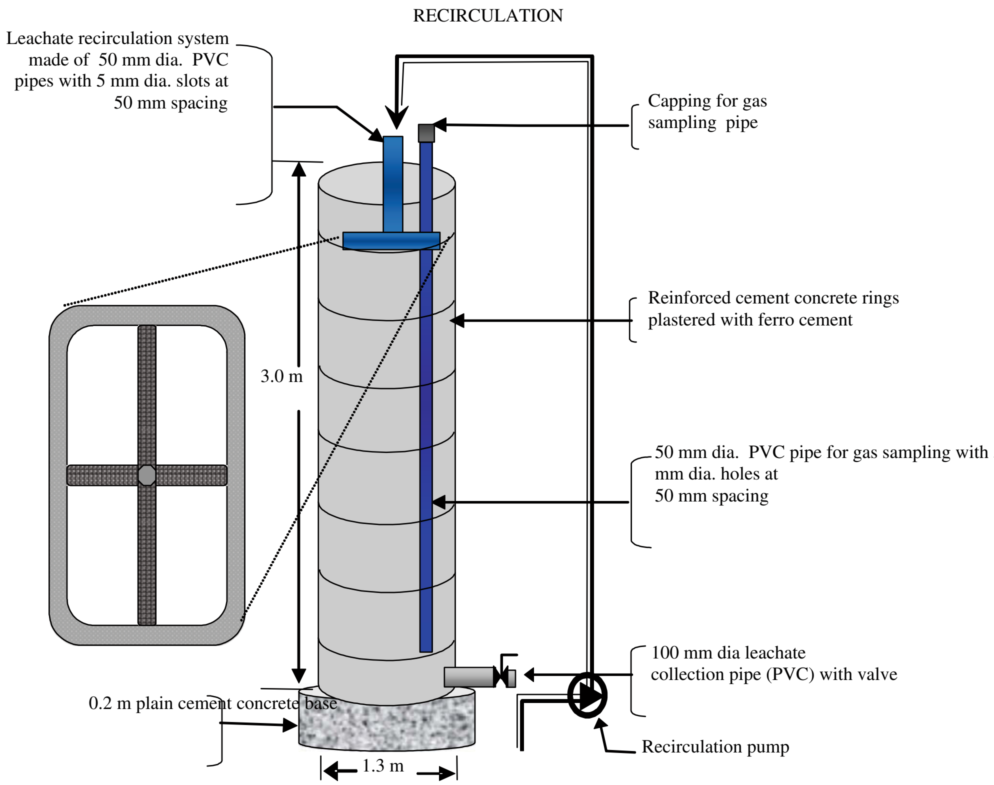

Fig. 1. Schematic view of lysimeter for landfill simulation.

Table 1
Lysimeter loading details and operating conditions.

Parameters	Lysimeter					
	R1	R2	R3	R4	R5	R6
Substrate	Organic fraction of MSW			Partially degraded wastefrom dumpsite		
Cover material (thickness)	Compost (0.3 m) Sand (0.1 m) Mined waste (0.3 m)			Compost (0.3 m) Sand (0.1 m) Mined waste (Nil)		
Operational mode	Open dump	Landfill bioreactors	Landfill bioreactors with phenol	Open dump	Landfill bioreactors	Flushing bioreactor
Height (m)	1.8	2.1	2.1	2.1	2.1	2.1
Wet weight (kg)	1751	1825	1870	2509	2641	2327
Volume (m^3)	2.40	2.79	2.79	2.79	2.79	2.79
Bulk density (kg/m^3)	730	654	670	899	947	834
Moisture (%)	62	58	60	28	27	28
Volatile solids (%)	55	55	55	30	30	30
Nitrogen (%)	1.2	1.2	1.2	0.8	0.8	0.8

over the fresh waste lysimeters. Compost and sand cover layers alone were placed at the top of the mined waste lysimeters. Provisions were made to recirculate the leachate into the lysimeters operated as bioreactor (R2, R3, R5 and R6). The lysimeters were operated as follows:

Lysimeter 1 (R1)	–	Controlled dump filled with fresh MSW
Lysimeter 2 (R2)	–	Bioreactor landfill filled with fresh MSW
Lysimeter 3 (R3)	–	Bioreactor landfill filled with fresh MSW + Periodic dose of Phenol
Lysimeter 4 (R4)	–	Controlled dump filled with mined MSW
Lysimeter 5 (R5)	–	Bioreactor landfill filled with mined MSW
Lysimeter 6 (R6)	–	Flushing bioreactor with mined MSW

All the lysimeters experienced infiltration of rainwater as they were installed under ambient conditions. Around 100 L of clean tap water was initially added to R4, R5 and R6 for increasing the field capacity of the waste to generate the leachate. The generated leachate was drained and disposed off every fortnight from the controlled dump lysimeters (R1 and R4). The leachate was recirculated in the bioreactor landfills (R2, R3, R5 and R6). Leachate recirculation was done once in a week for the first 2 months and then subsequently changed to daily basis for next 2 years and finally on weekly basis till the end of 960 days.

In R6, initially 30 L/day (then to week) of tap water was used for flushing, subsequently it was increased up to 50 L/week and then to 100 L/week during the course of reactor operation. The spiking of phenol into the leachate was practised in bioreactor landfill lysimeter (R3). The spiked concentration was in the range of 30–500 mg/L phenol in recirculated leachate.

2.1. Monitoring of waste stability in different lysimeter

Biological stability indicators such as settlement of waste, volatile solids (VS), organic carbon (OC), specific oxygen uptake rate