Waste Management 78 (2018) 698–707

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Influence of operations on leachate characteristics in the Aerobic-Anaerobic Landfill Method

Mitali Nag *, Takayuki Shimaoka, Teppei Komiya

Department of Urban and Environmental Engineering, Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

ARTICLE INFO

Article history:
Received 12 March 2018
Revised 28 May 2018
Accepted 21 June 2018

Keywords:
Municipal solid waste
Aerobic-Anaerobic Landfill Method
Intermittent aeration
Aeration rate
Leachate recirculation
In-situ treatment

ABSTRACT

Landfill aeration is an effective technique for the controlled and sustainable conversion of conventional anaerobic landfills into a biologically stabilized state associated with a significantly lowered or the near elimination of the landfill gas emission potential. For in-situ leachate treatment recycling back the generated leachate in the bioreactor is also a promising technique for reducing pollutants and cost of ex-situ treatment as well. This research has been conducted to ascertain the in-situ treatment of leachate in Aerobic Anaerobic Landfill Method (AALM) compared with aerobic landfill and evaluated the impacts of various leachate recirculation regimes on MSW degradation and to provide data for successful operation in landfill sites. The experiment was conducted using six Plexiglass® landfill simulation reactors with a height of 100 cm and a diameter of 15 cm. Air was injected at the rates of 1.6 l/kg DM/h (Low aeration rate) for reactors R-LA, R-LAA (recirculatory) and LAA (non-recirculatory) and 4.8 l/kg DM/h (High aeration rate) in R-HA, R-HAA (recirculatory), and HAA (non-recirculatory) until day 242. It has been evaluated that R-HAA at high aeration rate achieved higher leachate quantity reduction (36.9%) than low aeration rate reactor R-LAA (19.6%) and AALM provides a better solution to control the temperature within the landfill body. The final NH_4^+-N concentration in R-HA (214.5 mg/l) was eight times lower than in the R-LA (1741.0 mg/l) reactor, and R-HAA (842.5 mg/l) was about three times lower than R-LAA (2315.4 mg/l) reactor on day 242. The change in leachate recirculation amount at varying moisture content positively affected the stabilization process and in-situ leachate treatment efficiency. The combination of both technologies (intermittent aeration and leachate recirculation) is a feasible way for in-situ leachate treatment, decrease the cost of further ex-situ leachate treatment as well as a viable and cost-saving alternative to continuous aeration.

1. Introduction

The creation of sustainable landfills is one fundamental goal in solid waste management worldwide. In this respect, landfill aeration is an effective technique for the controlled and sustainable conversion of conventional anaerobic landfills into a biologically stabilized state associated with significantly lower or near elimination of landfill gas emission potential. This technology has been successfully applied to landfills in Europe, North America and Asia (Stegmann and Ritzkowski, 2007) following different strategies according to geographical region, specific legislation and available financial resources. This can be applied to new waste immediately following emplacement or to older sites as a remediation aeration technique to help achieve sustainable landfill practice. A variety of projects worldwide have successfully tested the possibilities of landfill aeration in achieving different objectives, such as reduction of emission potential with a view to reducing the aftercare period (Heyer et al., 2005), remediation of old abandoned sites (Cossu et al., 2003) and odor reduction (Jacobs et al., 2003). Additionally, the volume of leachate decreases during aeration because of water evaporation caused by elevated temperature within the waste (Read et al., 2001a,b). However, the main disadvantage of organic matter decomposition under aerobic conditions is the high energy consumption required to install and run an aeration system. Optimum conditions for decomposition of organic matter and minimizing energy consumption can be reached by appropriate selection of such operating parameters as the rate of aeration and leachate recirculation (Rich et al., 2008).

Increasing attention is being given to leachate recirculation in municipal solid waste (MSW) landfills as an effective way to enhance microbial decomposition of biodegradable solid waste. With leachate recirculation, a landfill can be used as in-situ treatment of leachate, accelerating waste stabilization and reducing the

* Corresponding author.
E-mail address: nag-m@doc.kyushu-u.ac.jp (M. Nag).

https://doi.org/10.1016/j.wasman.2018.06.044
0956-053X/

leachate volume by maximizing evaporative losses during recirculation (Pohland, 1975). Leachate recirculation frequency must be carefully selected to maximize waste stabilization. If too much leachate is recirculated, problems such as saturation, ponding and acidic conditions may occur. Limited data are available on the application of different leachate recirculation conditions to the waste matrix. However, it is recommended that leachate is introduced slowly, because high flow rates may deplete buffering capacity and remove methanogens. Additionally, in anaerobic landfills, increased flow rates and frequency of recirculation establish gas production (Reinhart and Townsend, 1998). Several studies indicated that waste decomposition can be improved by increasing moisture flow, due to increased flushing and dilution of inhibitory products, maintenance of favorable environmental conditions by uniform distribution of moisture and addition of higher quantities of inoculum and nutrients (Bolyard and Reinhart, 2016; Christensen and Cossu, 1989; Chugh et al., 1998). Leachate recirculation in bioreactor landfills was proposed initially to provide additional moisture to dry waste and enhance MSW degradation. However, moisture addition is not necessary for MSW containing moisture levels exceeding field capacity. Both positive and negative effects on methanogenic decomposition from leachate recirculation in wet waste have been observed (Hao et al., 2008; Benbelkacem et al., 2010; Shahriari et al., 2012; Xu et al., 2015; Huang et al., 2016). Leachate recirculation may be important in enhancing rates of hydrolysis and acidogenesis and redistributing nutrients and also stimulates mixing of solutes and bacteria within the waste body which removes inhibitions and transport limitations for degradation (White et al., 2011). Dissolved leachate compounds are furthermore removed by seeping of the leachate stream (van Turnhout et al., 2018).

The effectiveness of landfill in-situ aeration depends on proper control of aerobic conditions. A simple increase in aeration rate does not inevitably lead to the desired effect on waste temperature and moisture content (Read et al., 2001a,b; Raga and Cossu, 2013) on aeration performance in the field (Hrad et al., 2013). Selection of the air injection rate, pressure, temperature and moisture adjustment methods, and contaminant mobilization in both the gas and liquid phases must be considered before field implementation. Different landfill concepts (e.g., high pressure aeration, low pressure aeration and semi-aerobic concepts) can be realized once the operating values for the aforementioned parameters are selected (Ritzkowski and Stegmann, 2012).

The Aerobic–Anaerobic Landfill Method (AALM) is a novel method that incorporates the advantages of an aerobic-type landfill and lowers the high cost of continuous air injection, and its cyclic aeration is beneficial for ammonium nitrogen (NH_4^+-N) and total nitrogen (T-N) elimination (Nag et al., 2015). In this method, air is injected into a newly placed waste or anaerobic-type landfill at intermittent modes to enable the development of simultaneous nitrification–denitrification (SND) processes in only one landfill cell (Berge et al., 2006), rather than in separate anaerobic and aerobic cells. Moreover, provided that the temperature is properly controlled (Raga and Cossu, 2013), efficient N turnover can be achieved and hybrid conditions may create biostabilized landfills, thereby reducing the need for expensive perpetual landfill aftercare and energy consumption.

The effectiveness of AALM was evaluated by Nag et al. (2015), with consideration of annual precipitation. In order to enhance the stabilization of landfill waste and utilization of produced leachate recycle back into the waste, AALM with leachate recirculation was investigated in the present study. The leachate recirculation volume was changed periodically to compare the in-situ treatment of leachate in AALM with aerobic landfill (continuous aeration mode) at two different aeration rates. The impacts of various leachate recirculation regimes on MSW degradation to provide data for successful operation of landfill sites also evaluated.

2. Materials and methods

2.1. Experimental design

The experiment was performed using six Plexiglass® landfill simulation reactors of height 100 cm and diameter 15 cm (Fig. 1). The top 5 cm was kept as free space and 10 cm of gravel ($\phi < 20$ mm) was placed on top of the refuse for uniform distribution of leachate and water into the refuse, and the top was sealed. The leachate distribution system was installed at the top of the reactors. The lower part of the reactors consisted of 15 cm of gravel for easy efflux of leachate. The quantity of discharged leachate from reactors was measured and used for recirculation as well as samples being taken and kept at 4 °C in plastic bottles for chemical analysis. Air was injected into the refuse at the bottom of the columns in continuous and intermittent modes. Temperature monitoring was at performed using thermocouples (TDS-150 and FSW-10, Tokyo Sokki Kenkyujo Co. Ltd., Japan) placed in the middle of the waste mass connected to a portable data logger. Reactors were maintained at 30 ± 5 °C in a closed chamber and had a thermo-regulated insulation system covering the lateral surface.

2.2. Raw materials and waste filling

Synthetic MSW was compacted in each column to a total thickness of 70 cm and with average dry and wet densities of 0.5 and 0.7 t/m^3, respectively. The composition of MSW was modified (Fig. 2), according to typical values for the East Asia and Pacific region (World Bank, 2015). The fresh organic food waste (8 days old) was collected from a composting plant. The food waste was

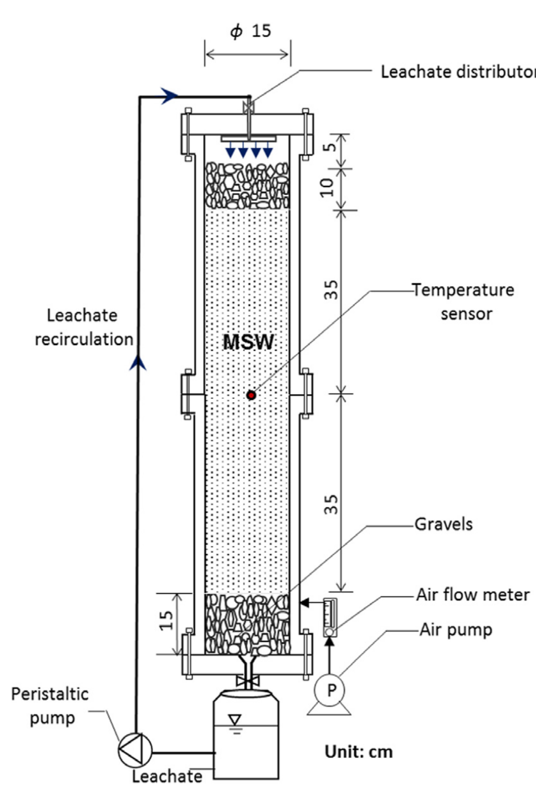

Fig. 1. Schematic diagram of experimental column bioreactor.