Waste Management 32 (2012) 2080–2095

Contents lists available at SciVerse ScienceDirect

Waste Management

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

Characterization and tropical seasonal variation of leachate: Results from landfill lysimeter studied

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A R T I C L E I N F O

Article history:
Received 17 September 2011
Accepted 23 January 2012
Available online 19 February 2012

Keywords:
Landfill lysimeter
Municipal solid waste
Leachate quality
Tropical condition
Detection and collection system
Cap and base liner
Compacted clay liner

A B S T R A C T

This study aims to characterize the leachate and to investigate the tropical climatic influence on leachate characteristics of lysimeter studies under different seasonal variations at KUET campus, Bangladesh. Three different situations of landfill were considered here as well as both the open dump lysimeter-A having a base liner and sanitary landfill lysimeter-B and C at two different types of cap liner were simulated. The leachate characteristics, leachate generation and climatic influence parameter had been continually monitored since June 2008 to May 2010, these periods cover both the dry and rainy season. The leachate generation had followed the rainfall pattern and the open dump lysimeter-A without top cover was recorded to have highest leachate generation. Moreover, the open dump lysimeter-A had lower total kjeldahl nitrogen (TKN), ammonia nitrogen (NH_4-N) and TKN load, while both the COD concentration and load was higher compared with sanitary landfill lysimeter-B and C. In addition, sanitary landfill lysimeter-B, not only had lowest leachate generation, but also produces reasonable low COD concentration and load compared with open dump lysimeter-A. Result reveals that lysimeter operational mode had direct effect on leachate quality. Finally, it can be concluded that the knowledge of leachate quality will be useful in planning and providing remedial measures of proper liner system in sanitary landfill design and leachate treatment.

1. Introduction

The term ‘landfill’ is used herein to describe a unit operation for final disposal of ‘municipal solid waste (MSW)’ on land, designed and constructed with the objective of minimum impact to the environment. This term encompasses the other terms such as ‘secured landfill’ and ‘engineered landfills’ which are also sometimes applied to MSW disposal units (Tubtimthai, 2003). The term ‘landfill’ can be treated as synonymous to ‘sanitary landfill’ of MSW, only if the latter is designed on the principle of waste containment and is characterized by the presence of a liner and leachate collection system to prevent ground water contamination. Sanitary landfill is one of the secure and safe facilities for the disposal of MSW; however, it needs high standard of environment protection in the operation of landfill (Davis and Cornwell, 1998). Moreover, it is a well-suited method for managing of MSW all over the world and to investigate the performance of sanitary landfill the behavioral patterns namely; leachate generation, landfill gas (LFG) emissions etc. are required (Visvanathan et al., 2002). Lysimeter is a simulate form of sanitary landfill in the sense of control device. The word lysimeter is a combination of two Greek words “*Lusis*” *means* “*Solution*” and “*Metron*” *means* “*Measure*” and the original aim is to measure soil leaching (Rafizul et al., 2009a). Sanitary landfill plays a significant role for the disposal of MSW in most of the developing countries like Bangladesh (Alamgir et al., 2006 and WasteSafe, 2005). Most of the landfill in developing countries does not have any liners at the base or proper top covers, which results in the potential problems of ground water/surface water contamination due to the leachate generated from solid waste landfill (Horing et al., 1999 and McBean et al., 1995). The state regulatory authorities in most of the countries around the world have framed regulations to safe guard against the contamination of groundwater sources from the leachate generated from solid waste landfill (Rafizul et al., 2011). The leachate generated from MSW disposal sites is considered as one of the highly contaminated resources from physical, chemical and biological point of view. However, the best possible knowledge of leachate characteristics at a specific site is an essential management tool. This is not only important for new containment landfill needs designed in advance, where leachate will be extracted, but also important for the old landfill where the environmental safeguards rely on the natural attenuating properties of the geological strata, to reduce the level of contaminant to environment (Robinson, 1989 and Youcai et al., 2000). In that manner leachate may pose a severe pollution threat to ground water supplies (Kelly, 1976).

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0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.wasman.2012.01.020

Chemically contaminated leachate is one of the byproducts in landfill degradation reactions (Alamgir et al., 2006). One of the severe problems associated with the open dumping of MSW is percolation of leachate into the surrounding environment, subsequent contamination of the land and water bodies (Walker, 1969; Chian and DeWalle, 1976; Kelly, 1976; Masters, 1998 and Kumar et al., 2002). El-Fadel et al. (2002) reported that composition of landfill leachate can exhibit considerable spatial and temporal variations depending upon the site, management practices, refuse characteristics (i.e. composition and age), and internal landfill processes (hydrolysis, adsorption, speciation, dissolution, ion exchange, redox reactions, precipitation etc.). Moreover, the variation of leachate quality in MSW landfill can be attributed to many interacting factors such as the composition and depth of MSW; decomposition and age of MSW; degree of compaction; landfill design and operation; liner (top and base) design and operation; MSW filling procedures; the availability of moisture content; available oxygen; rate of water movement (fluid addition) and temperature (Qasim and Chiang, 1994). Therefore, it is difficult to generalize the chemical composition of leachate that posses at a particular time of sampling. In addition, leachate quality may vary from time to time and site to site due to the variables such as waste composition, temperature, moisture content, climatic changes etc. (Alkalay et al., 1998). To these endeavor, the present study was aimed to characterize the leachate and to investigate the tropical climatic influence on leachate characteristics generated from MSW deposited in open dump and sanitary landfill lysimeter and hence compared with those results of similar cases available in the literature.

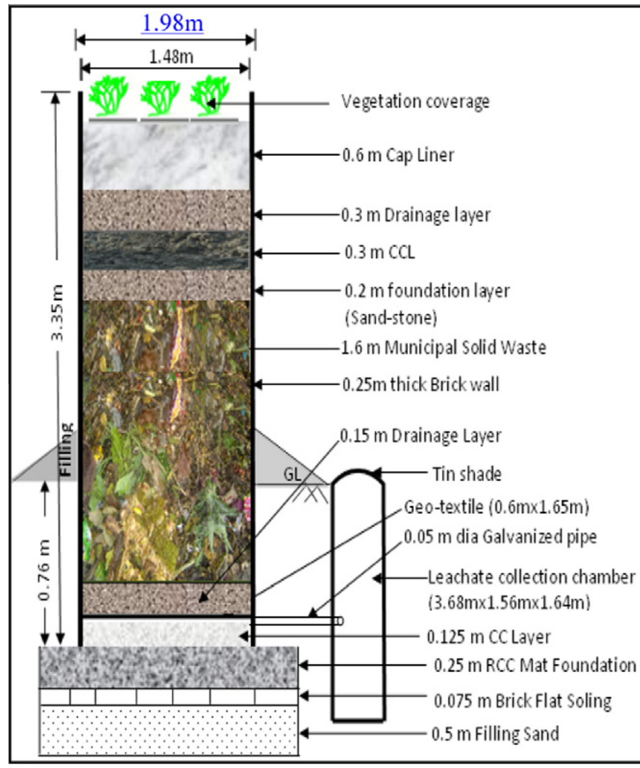

Fig. 1. Schematic diagram of reference cell for landfill lysimeter design.

2. Materials and methodology

2.1. Landfill lysimeter design and operation

Three landfill lysimeters designated as A, B and C were designed and hence constructed at KUET campus, Bangladesh based on a reference cell shown in Fig. 1, showing all the design components in details. The operational condition, liner specifications, simulation behaviour and the total weight of MSW deposited in each lysimeter are presented in Table 1. However, the detailed about landfill lysimeter design, construction and operational condition can be obtained in Rafizul et al. (2009b). The MSW deposited in lysimeter was collected from Khulna city and the average composition and moderate compaction density was maintained during the deposition of MSW in each lysimeter. The MSW deposited in lysimeter mainly consists of 93 (w/w) organic (food and vegetables), 3 (w/w) of plastic/polythene and 2 (w/w) of leather/rubber, 1 (w/w) of animal bone and rubber/leather as well as 1 (w/w) of rope/straw and egg pill. However, the organic content and moisture content of MSW was found 52 and 65%, respectively, and the total volume was 2.80 m^3 (height 1.6 m) with a manual compaction to achieve the unit weight of 1,064 kg/m^3. At the bottom of each landfill lysimeter, a concrete layer of 125 mm thickness was provided then the lysimeters were filled with stone chips (diameter 5–20 mm) and coarse sand (diameter 0.05–0.4 mm) to the height of 15 cm of each to ensure uniform and uninterrupted drainage. At the base of each landfill lysimeter after placing the perforated leachate collection pipe, a geo-textile sheet having 0.60 m wide and 1.65 m length was placed on the top to avoid a rapid clogging of this perforated pipe by the sediments from the lysimeter.

2.2. Landfill lysimeter-A (open dump)

The type and volume of MSW deposited in open dump lysimeter-A was exactly the same as deposited in the reference cell. In open dump lysimeter-A, a compacted clay liner (CCL) of 400 mm thickness was placed as the base liner and a layer of compost of 150 mm thick was used as the top cover to simulate the behaviour of present practice of open dumping in Bangladesh as depicted in Fig. 2. In this lysimeter the MSW was not covered by a top cover system to pervert the movement of air, water and generated LFG. Moreover, the thickness of the deposited MSW in lysimeter-A is such that it is expected the atmospheric air can move in the entire MSW deposited in this cell with negligible inference. Due to the mentioned practical situations, lysimeter-A, represents an open dump landfill condition comparing the counterparts i.e. sanitary landfill lysimeter-B and C.

2.3. Sanitary landfill lysimeter-B (cap liner I)

In sanitary landfill lysimeter-B shown in Fig. 3, the characteristics and volume of deposited MSW was similar to that of the open dump lysimeter-A. However, it differs with open dump lysimeter-A, by a top cover and without a base liner, because this cell aims to examine the applicability of the designed top cover to simulate the sanitary landfill condition. The top cover consists of stone chips (diameter 5–20 mm) and coarse sand (diameter 0.05–0.4 mm) layer each of 100 mm thickness, then a 300 mm CCL was provided. On the CCL, there were 150 mm thick coarse sand (diameter 0.05–0.4 mm) and 150 mm thick stone chips (diameter 5–20 mm), which was followed by 600 mm thick top soil. Due to the above mentioned practical situations, lysimeter-B represents a sanitary landfill condition comparing with open dump lysimeter-A as well as sanitary landfill lysimeter-B acts as a control device from where, the flow rate and the composition of landfill gas (LFG) is possible to measure and monitor. In sanitary landfill lysimeter-B, 38 mm diameter of gas collection and 25 mm diameter of leachate recirculation pipe were installed. During the installation of these pipes and penetration through the top cover, special arrangements i.e. disc shaped rubber gasket having 3 mm thickness and 300 mm