

INFLUENCE OF LANDFILL OPERATION AND WASTE COMPOSITION ON LEACHATE CONTROL: LYSIMETER EXPERIMENTS UNDER TROPICAL CONDITIONS

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Abstract

In South and South East Asia more than 90 % of solid waste is disposed of in open dumps. Considering this region's specific climatic conditions, it is necessary to develop strategies to design and operate simple landfills, which are in-transition between dumpsite and engineered sanitary landfill. This approach demands comprehensive research on waste segregation, pre-treatment, control of leachate and landfill gas generation. This paper presents the primary experimental findings of six lysimeters operated under tropical climatic conditions. In these lysimeters, wastes with different pre-treatment, operational arrangement and top cover designs were evaluated. The lysimeter observation consisting of dry and wet climatic conditions reveals that waste pretreatment and operational mode play a significant role in leachate generation rate, and landfill settlement rate.

Introduction

In South and South East Asia the open dump approach is the most predominant waste disposal option creating considerable environmental problems. With the accelerated generation of waste caused by an ever increasing population, urbanisation, and industrialisation, the problem has become one of the primary urban environmental issues (Ranaweera and Tränkler, 2001). Typical characteristics of these dumpsites consist of: indiscriminate dumping, unplanned heaps of uncovered wastes, burning of waste on the dumpsite, pools of standing polluted water, waste scavenging at the dumpsite etc (Pugh 1999).

When waste disposal situations reach critical point, there is often a tendency to adopt a western approach to waste management. However, this approach is generally applied uncritically and rapidly resulting in

the malfunctioning and inefficient management of waste treatment and disposal facilities (Bodelius and Rydberg, 2000). Consequently, the cultural and climatic differences need to be considered, specific approaches pursued and strategies concerning landfill design and operation investigated if a transition from dumpsites to engineered sanitary landfills is to be successfully managed in an Asian context. This demands comprehensive research followed by an optimised design and the adaptation of cost effective locally available technologies.

Landfill Lysimeter Studies at AIT

Construction

The Lysimeters were set up in the Environmental Research Station on the Asian Institute of Technology (AIT) campus, Bangkok, Thailand. The lysimeters were constructed of concrete rings with the diameter of 1.4 m, 1 m deep below the ground level and 2.5 m. The concrete rings were reinforced with ferro-cement to withstand elevated pressure and plastered inside and outside with two coatings of waterproofing agent inside to avoid leakages and corrosion due to acidic environment. Refer to Figure 1, for these technical details.

Each lysimeter has a separate leachate collection tank consisting of a 20 cm PVC pipe buried approximately 2 m below ground. The leachate is pumped using submersible pump for quantitative and qualitative analysis. Further, the bioreactor lysimeter cell consists of aerator below the solid waste and leachate re-circulation system above the solid waste. At the bottom, the lysimeters are filled with coarse gravel ($D_p = 20$ mm) and fine gravel ($D_p = 5$ mm) to the height of 20 cm each to ensure proper leachate drainage. Above this a geo-textile blanket placed to avoid a rapid clogging of this drainage layer by sediments from the cell.

The lysimeters were filled with different types of wastes to study the following effects under tropical climatic conditions namely: 1) Pre-treatment and pre-sorting effect of the solid waste on leachate

generation and quality. 2) Effect of the top cover design on leachate generation. 3) Importance of the landfill settling aspects based on the above operational conditions.

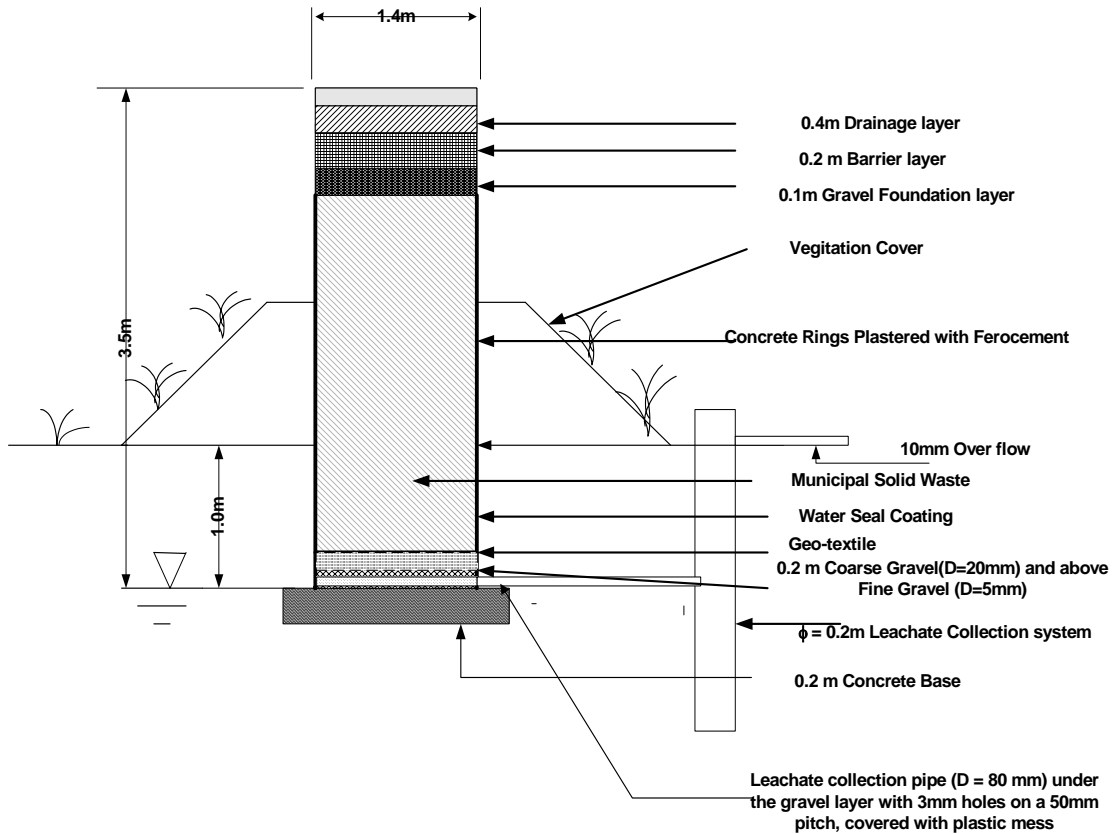


Figure 1: Landfill Lysimeter Construction Design

Details of the six lysimeter cells are presented below:

Cell 1: Reference Cell

In the reference cell municipal waste mainly consists of: with 59 % of organic, 24 % plastics, 5 % leather and rubber, 1% ferrous metal and 7% glass. The total volume of the waste filled was 3.7 m³ (height 2.4 m) with a manual compaction of 450 to 470 kg/m³. The moisture content of the waste was 47 % (wet basis). The top cover specification consisted of 10 cm gravel (D_p=5 mm) layer, 20 cm barrier layer (clay) and 40 cm cover soil comprising of sand, silt and a clay mixture in the ratio 70:15:15.

Cell 2: Top cover type-1 Cell

The type and the volume of the waste compacted in this cell is same as the reference cell. However, the basic difference is the top cover design, which consists of 10 cm gravel (D_p =5 mm) layer, and 60 cm cover soil comprising of sand, silt and a clay mixture in the ratio 70:15:15 without a barrier layer.

Cell 3: Top cover type-2 Cell

The type and the volume of the waste compacted in this cell is similar to the reference cell. However, the moisture content of the waste drastically reduced to 22 % (wet basis) due to 8 days delay in filling caused by labour constrain. The difference is in the top cover design, which consists of 10 cm gravel (D_p =5 mm) layer, and 60 cm cover soil comprising of compost, sand, silt and clay mixture in the ratio 40:30:15:15 without a barrier layer.

Cell 4: Bioreactor cell

This bioreactor cell was designed to operate as aerobic cells, which consist of special arrangement for leachate circulation and aeration. This lysimeter comprised of two types of wastes in equal ratio by weight, as organic reduced, pre-sorted, and shredded waste and mechanically shredded organic waste from a vegetable market. The total volume of the solid waste combination is 3.23 m³ (H= 2.1 m). The manual compaction attained was 388 kg/m³ and the top cover specifications are similar to the reference cell.

Cell 5: Compost Cell

The compost cell consists of pre-treated compost from organic concentrated, pre-sorted, mechanically shredded waste from a vegetable market. The manual compaction attained was 948.5 kg/m³ and the moisture content was 11 % (wet basis). The top cover

specification and the design parameter are same as the reference cell.

CELL 6: Open dump cell

The open dump cell consists of organic reduced waste with 64 % wet garbage, 22 % plastic and 14 % paper from a vegetable market. This waste was manually shredded to 5 to 10 cm., to attain a total volume of 3.69 m³ and compaction density of 215 kg/m³. The top cover of only 25-mm sand was placed to simulate an open dump.

Influence of Tropical Climate in the Region:

The climate of Thailand is under the influence of monsoon winds of seasonal character i.e. southwest monsoon and northeast monsoon. The southwest monsoon, which starts in May, brings a stream of warm moist air from the Indian Ocean toward Thailand causing abundant rain over the country, especially the windward side of the mountains. The northeast monsoon, which starts in October, brings the cold and dry air from the anticyclone in China over major parts of Thailand, especially the Northern and North-eastern sections which are higher latitude areas. In the Southern part, this monsoon causes mild weather and abundant rain along the East coast (Climatological Division, Thailand).

Local weather is of paramount concern and is best described as an alternation of an arid season (no rain up to 5 months) and a humid season with extreme rainfall events Tränkler *et al.* (2001). The influence of the climate on leachate production is complex: in relatively warm climates, for example, the increase leachate production after precipitation is generally quite rapid (Lema *et al.*1988). Thus, it is important to understand the effect of leachate generation and its characteristics due to the local climatic variations on the lysimeter studies. At the research site, the weather data has been continuously monitored through a weather station. The experimental runs were conducted from November 2001 to May 2002, and during this period rainfall and temperature data was continuously recorded.

Results and Discussion

Figure 2 presents the rainfall events and the temperature variation since November 2001 to May 2002. Figure 3 summarises the cumulative leachate production pattern in the lysimeters during the study period. Based on leachate generation, the experimental observation period could be divided into three different phases, namely: **Phase I**: the initial 10

to 15 days, where due to the high moisture content in the lysimeter (above the field capacity, leachate was e continuously generated. **Phase II:** a prolonged dry and hot climate during which no notable leachate generation occurred. During this period although two significant rainfall events occurred on the 25 February and 6 March, there was no effect on leachate production implying the lysimeters were operated well below the filed capacity. **Phase III:** Starting from the rainy season in early May 2002, which had direct effect on leachate generation and its characteristics.

The tropical climatic influence on the leachate generation could be observed in Figure 3. Here it can be noted that in the Cell 5 and 6 leachate generations ceased in phase II, followed by increased leachate production in phase III soon after the rainfall events. Considering the fact that Cell 1, 2 and 3 contained the same type of waste with similar compaction density, the leachate generation is not the same. It is mainly due to different moisture content of the waste as described in the “Landfill lysimeter studies” section.

However, it is interesting to note that leachate generation rate changes rapidly in Cell 3 after the start of rainy season in May, where the top cover soil design selection played an important role. The cover design consist a mixer of compost, sand, silt and clay in the ratio of 40: 30: 15: 15, which has a loose soil texture. Here without clay linear layer rain water rapidly infiltrated into the lysimeter compared to other cover types. .

Cell 5, due to its high compaction density expected to produce relatively low leachate, especially during the dry season. Nevertheless, soon after the rainy season, it can be observed that leachate production arguments linearly, indicating this cell reached its field capacity very rapidly, mainly due to the nature of the compost waste filled in the lysimeter, Where as the Cell 6, which did not have any specific top cover other than a single sandy layer of 10 cm, taken more time than the Cell 6 to reach the field capacity level. However, once the field capacity level is reached, leachate production continues in a linear mode.

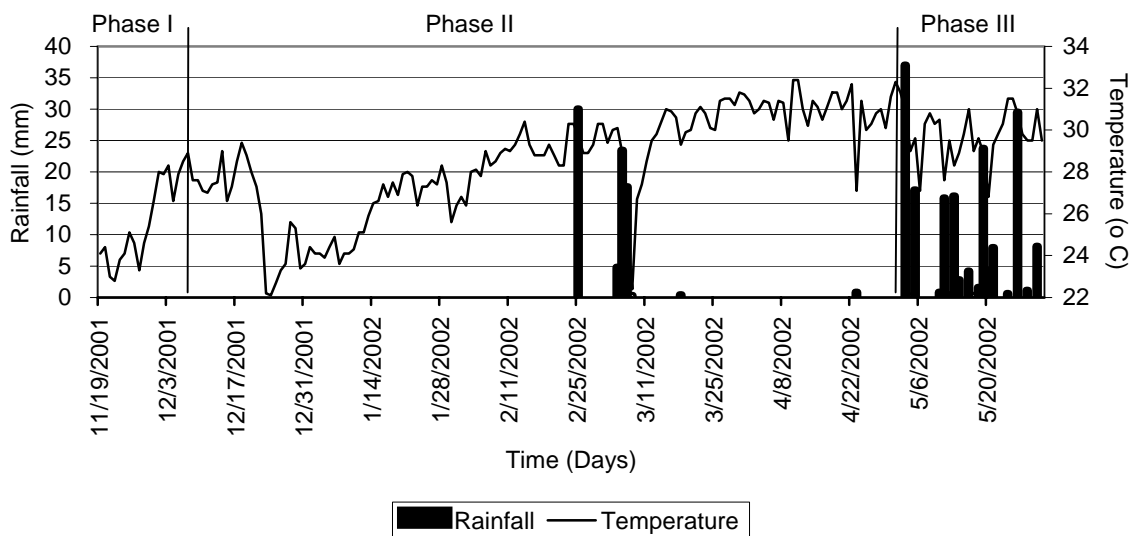


Figure 2: Daily rainfall and mean temperature variation

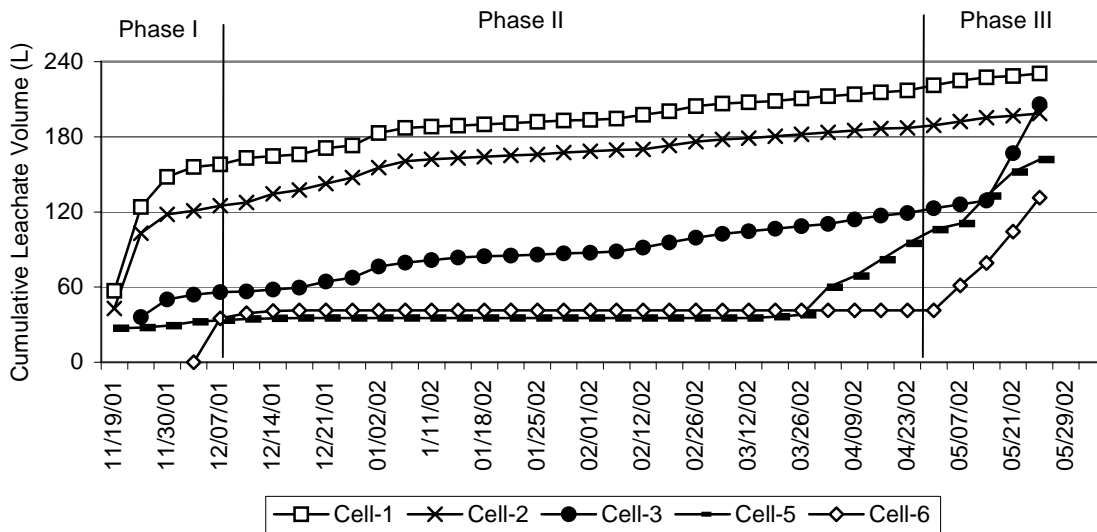


Figure 3: Cumulative leachate generation of various landfill lysimeters

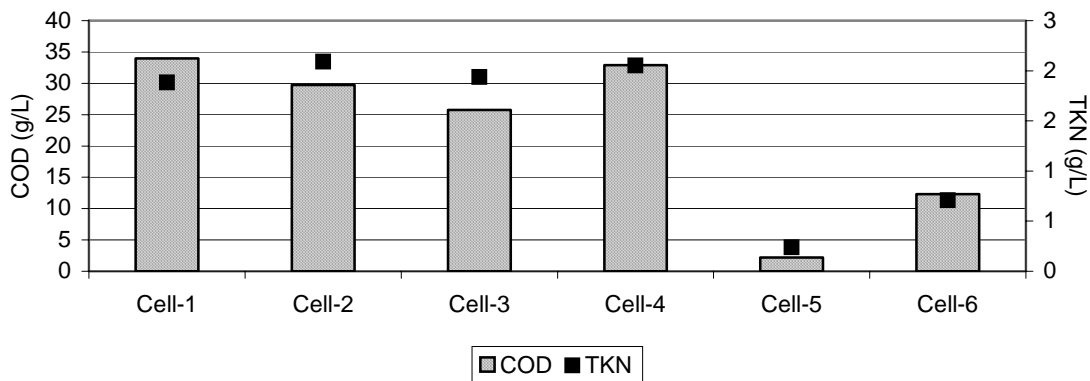


Figure 4: Average COD and TKN concentrations

The leachate quality was continuously monitored in terms of COD and TKN. Figure 4 summarizes the average value of the six lysimeter cells. This figure demonstrates the pre-treated, pre-sorted waste has a significant effect on the leachate quality. Due to the significant biodegradation in the composting stage the COD and TKN concentration in the Cell 5 is much lower than the other cells. This has a positive effect in terms of leachate treatment and management.

Figure 5 presents the cumulative TKN load for 5 cells. Since the leachate generated by the bioreactor (Cell 4) is recirculated, it is not included here. Significant changes in the cumulative TKN load in Cells 3 and 6 were observed in phase III due to the use of loose top cover. This loose top cover leads to excessive moisture within the cell followed by rapid biodegradation and leachate generation. On the other hand, Cells 1 and 2 display similar linear variation, possibly due to both cells containing same waste and top cover materials.

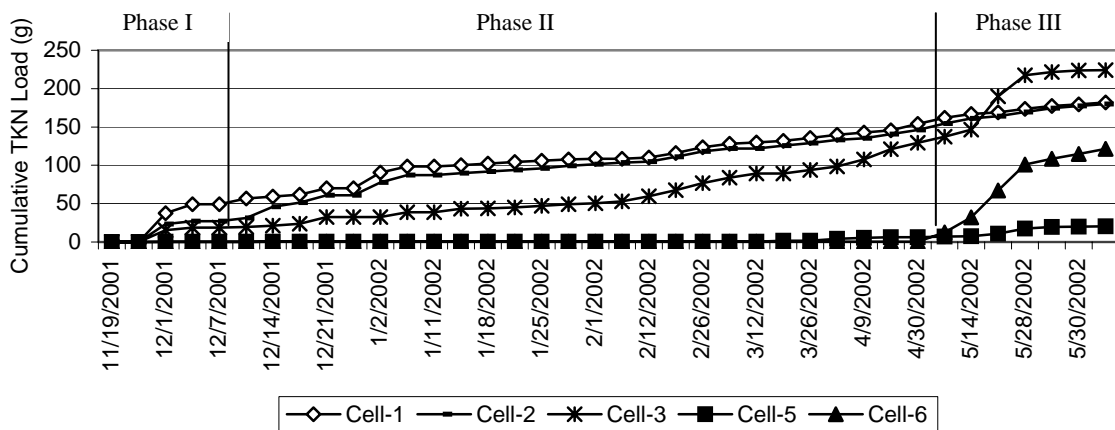


Figure 5: Cumulative TKN load

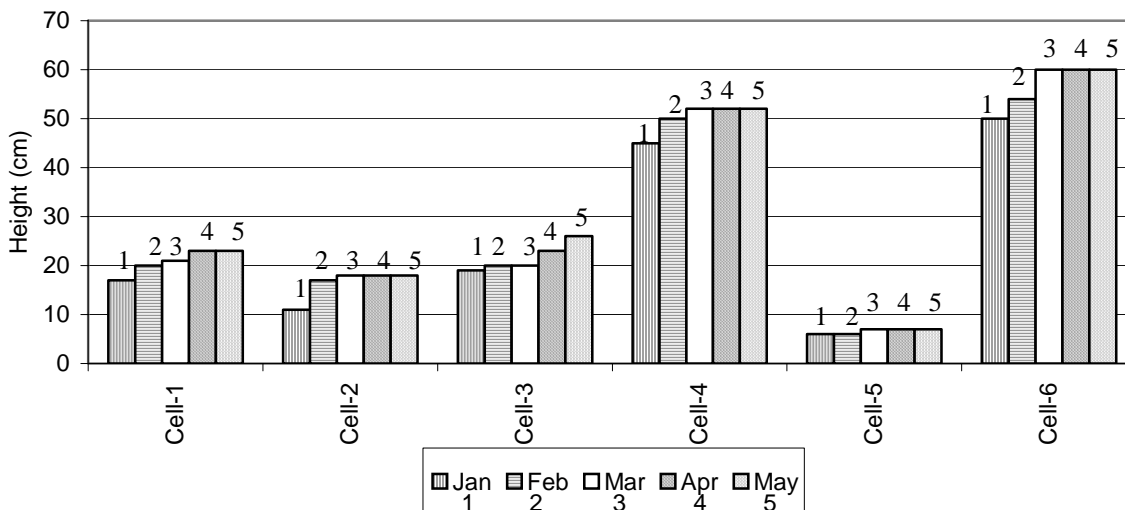


Figure 6: Settlement within the lysimeter

Ashford *et al.* (2000) indicated the importance of settlement of municipal solid waste in landfill. In their study, irregular characteristics of the settlement in various landfills in Thailand were observed. The study found large-scale settlement during the early stage of landfill construction, followed by substantial amount of secondary compression over an extended period of time. El-Fadel (1998) stated that the rate of landfill settlement depends primarily on the refuse composition, operational practices, and the factors affecting biodegradation of landfill waste particularly moisture content.

The Figure 6 summarise the settlement rate observed in the lysimeters during the experimental study period. Here it can be noted that Cell 5, with highest compaction density had, the lowest settlement, indicating the importance of pre-treatment of municipal solid waste prior to landfilling, Where as

lower compaction in Cell 6 has resulted in the highest primary settlement. It is important to note that, although Cell 4 had a same compaction density as Cells 1, 2 and 3, the settlement rate was significantly high. This is mainly due to the continuous recirculation of leachate, which facilitates rapid degradation of the MSW and continuous compaction of the waste. This indicates the importance of the operational mode of landfill and the stability of the landfill cells.

Conclusion

The primary field scale lysimeter studies with various type of pre-treatment and pre-sorting waste revealed that:

- a) Climatic variations have a profound impact on the leachate generation and its concentration

- b) The characteristics of leachate were influenced by the waste composition and the type of pre-treatment. Thus, the average COD and TKN of the leachate from the compost cell shows the minimum COD and TKN value as compared with other lysimeters.
- c) Seasonal variation and its influences on leachate quantity control. Rapid leachate productions in Open dump, and Cover type-2 (Cell 3) during the Phase III, indicates the importance of the barrier layer, and the cover material selection in landfill design in the tropical climatic zone.
- d) Comparative results of the settlement pattern of six landfill lysimeter cells have shown that the compost cell attains the minimum settlement as 2 % of the total height of the cell. The primary investigation undertaken in this study highlighted the following considerations in landfill design and management: 1) maximum achievable compacting density and waste pre-treatment should be of primary considerations; 2) settlement and leachate load can be optimised by pre-sorting and pre-treating of organic waste.

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