14th WEDC Conference

Water and urban services
in Asia and the Pacific

Kuala Lumpur 1988

Municipal wastes disposal in groundwater

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INTRODUCTION

Refuse decomposition in a landfill is influenced by many factors. The main controlling factors are moisture and temperature. Moisture content, in many cases, is considered to be the most important variable affecting the rate of refuse decomposition and leachate production (Ref.1). Previous reported works on landfill simulation studies or lysimeter studies were primarily based on moisture contents which were at field capacity or below (Ref.2). In practice, however, many refuse disposal sites are situated below groundwater level. The use of mining pools in and around Kuala Lumpur as disposal sites is an example of the case. Therefore it is necessary to examine the decomposition processes under saturated moisture conditions.

MATERIALS AND METHODS

A leachate lysimeter was constructed from a PVC column with dimensions 4 m in height and 20 cm in internal diameter.

The construction of the lysimeter from the bottom upwards may be summarized as follows:

Top	0.05 m top pebble layer
	0.40 m covering sand
	2.50 m solid waste layer
	0.79 m underlying sand layer
Bottom	0.19 m supporting pebble layer

This lysimeter was equipped with temperature probes and leachate sampling devices at different heights of the lysimeter, and facilities for periodical measurement of pH, Eh, and gas production. One opening was provided at the bottom of the lysimter for the drainage and sampling of the leachate. At the top cover, two openings were made, one had a slightly lower projection tube for the input water, and the other for a gas outlet. Two water tanks, of 31 l capacity each, one at a level higher than the top of the lysimeter and the other at a lower level were used for feeding water into the lysimeter. Both tanks were connected to a pump, the lower tank was used for feeding the higher tank, and the higher tank was used for feeding the lysimeter.

Solid waste with a composition similar to the average composition of municipal waste was packed inside the lysimeter to a thickness of 2.5 m. The composition of the solid waste is shown in Table 1. A total of 43.775 kg solid waste was used for filling up the lysimeter with a packing density of 0.52 g/cm .

Table 1: Solid waste composition wet weight percentage. * (Ref.3)

Composition	In lysimeter	Range from 8* municipalities in Perth
Paper	24.0	21.6 - 34.5
Food waste	48.6	30.3 - 48.9
Garden waste	13.6	0.9 - 10.9
Metal	6.1	4.6 - 11.8
Wood	0.3	0.1 - 0.8
Rag	0.5	1.2 - 2.9
Others (glass, plastic and inert waste)	0.0	15.1 - 22.8

The solid waste was processed by cutting it into small pieces (average size between 1 and 2 cm) and mixing it thoroughly before packing.

Lysimeter Initiation

Water was introduced into the lysimeter gradually from the bottom part by using a plastic tubing connected to the higher tank through a control tap. A total of 49.9 l water was introduced into the lysimeter. The level of the water and the pressure inside the lysimeter was monitored by an open ended plastic tubing, connected to the lower part of the lysimeter, placed vertically at the side of the lysimeter to a level as high as the feed tank.

Monitoring And Analysis

The lysimeter was monitored over a period of two years. Gas production and temperature levels from four locations inside the lysimter were monitored. A gas meter was connected to the gas outlet tubing for the measurement of total gas production. The ratio between carbon dioxide and other gases (predominantly methane) was determined by bubbling the gas sample to and fro, for the removal of carbon dioxide by KOH, to a constant volume.

Leachate samples were collected from the bottom and middle taps of the lysimeter for quality analysis. The middle tap provided leachate samples from the middle of the refuse layer while the bottom tap provided leachate which had passed through the 1 m layer of sand. The parameters measured were pH, Eh, BOD, COD, ortho-P and ammonia.

A total of 7.8 l water samples were collected from the bottom drainage over the first year. During the second year, a total of another 7.1 l of samples were collected. The total water withdrawned from the lysimeter over the two year period was equivalent to 1.1 pore volume of the bottom pebble and sand column. Thus a slow rate of leachate introduction into the sand column was maintained in order to promote establishment of methane fermentation processes.

After six months, a steady methane content of approximately 55% (with variation around 3%) was achieved. Further determinations of the methane content indicated a gradual increase from 55% to about 65% after one year (Figure 1). The Eh level of the leachate dropped very rapidly to below - 250 mV (Figure 2). This Eh level was found to be consistently low throughout the study period. The pH of the leachate sample from the middle of the lysimeter was always low with an average of 5.3. However very slow release of leachate from the bottom tap was found to increase the pH from levels of around 5.5 to above 7 after six months operation (Figure 2).

The leachate from the middle of the refuse layer contained vey high levels of ammonia and COD. With minimal water circulation the levels remained very high even after 22 months operation (Table 2).

Table 2: The characteristics of leachate from the middle of the refuse layer.

Parameter	Concentration (mg/l)
COD	36,100
BOD	22,500
Ammonia-N	1,700
Ortho-P	12
pH	5.3

Leachate Stabilization in the Underlying Sand Layer

Introduction of the high strength leachate

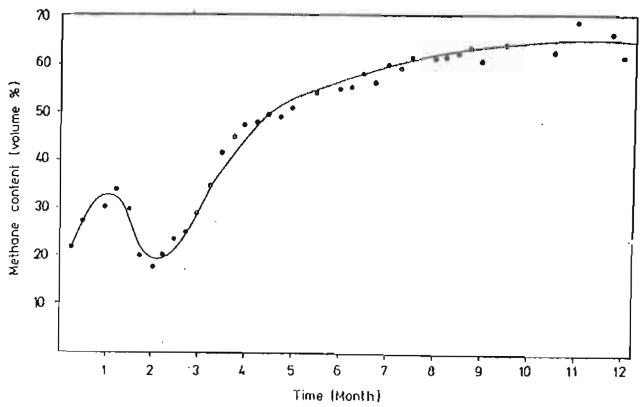

Figure 1 · Methane content of the lysimeter gas.

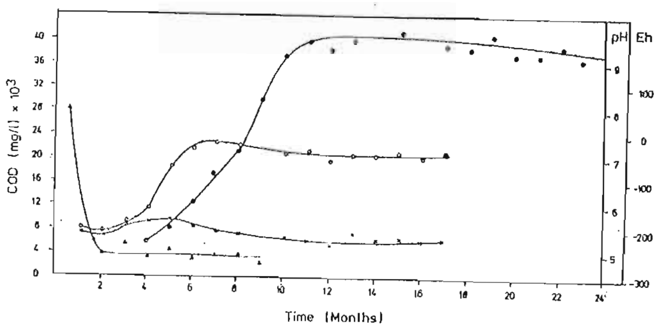

Figure 2· Characteristics of leachate from the lysimeter. (●), COD; (O), pH of samples from the bottom drainage; (x), pH of samples from the middle solid waste layer and (▲), Eh.

might result in a lowering of the pH of the sand layer hence inhibiting the methane fermentation process. This situation was taken into consideration and controlled by regulating the leachate movement so as to allow dilution of the organic load through diffusion.

The quality of the leachate collected from the bottom drainage indicated that the bottom sand layer had acclimatized to the conditions necessary for the methane fermentation process (Ref.4). The stability of this condition was tested by introducing one test load of COD.

After the test load and a rest period of about 8 weeks, a continuous loading experiment was carried out. Leachate generated by the solid waste layer was introduced into the underlying layer by weekly drainng 1.5 l of leachate from the bottom drainage. At this draining rate it was calculated that the leachate would have an average detention time of 9 weeks and an infiltration rate of 1.6 cm/day. This calculation was based on the total pore volume of the sand and the supporting pebble layers divided by the volume of the leachate collected weekly. Obviously gas was developing inside the sand layer and the effective pore volume had become smaller; therefore the actual detention time could be shorter than the calculated value.

The continuous loading experiment lasted for about 3 months. During the period, samples of leachate from the bottom drainage, the base of the solid waste layer and the middle of the solid waste layer were collected every week. The samples were analysed for pH, COD and BOD. Nutrient levels namely Ortho-P and Ammonia-N were also determined. Redox conditions (EH) were also detrmined during the collection of samples.

The volume of the leachate samples collected every week from the bottom drainage, the base of the solid waste layer and the middle of the solid waste layers were measured separately. The sum of the volume collected was recorded. Replacement water of similar volume was then introduced into the lysimeter through the top water inlet.

A total of 18.7 I of leachate was collected from the bottom drainage over the period of the continuous loading experiment. The total amount of leachate collected was equivalent to about 1.4 pore volumes of the underlying sand and pebbles layers.

RESULTS AND DISCUSSIONS

pH and Eh

Results of pH measurements of the leachate from the bottom and the middle of the solid waste layer indicated that the pH from both sources remained approximately constant throughout the extire experiment. The pH of the leachate samples from the bottom drainage was always higher than 7 with an average of about 7.3 while the pH of the leachate samples from the middle of the solid waste layer was always low at around 5.3.

Introduction of replacement water through the top of the lysimeter apparently did not affect the pH conditions inside the solid waste layer. At the existing pH conditions, methane fermentation was not likely to take place inside the solid waste layer. The most favourable condition for the methane fermentation to take place was at the base of the solid waste layer or in the underlying sand and pebble layers where the pH was around 7.

Redox conditions inside the lysimeter (Eh) showed a reducing trend as the leachate moved from the top to bottom. The Eh conditions in the middle and the bottom of the lysimeter were - 100 mV and - 265 mV respectively. Only three Eh measurements could be taken from the base of the solid waste layer. These measurements had an average value of - 208 mV. Further measurements were not possible because this part of the lysimeter was occupied by gas.

Reduction of Organic Materials

Results of the COD analyses are presented in Figure 3. Prolonged rest periods of several months resulted in production of excessive concentrations of organic acids. This non-methenogenic anaerobic process was likely to be the dominant process that took place inside the middle of the solid waste layer. Levels of COD higher than 53,000 mg/I in the leachate samples collected from this part of the lysimeter suggests that this is the case. At this level of COD and low pH, methane fermentation is not likely to take place.

Mobilization of this concentrated leachate through the underlying sand and pebble layers by controlled flow was found to have reduced the COD to an average level of about 2,000 mg/I (Figure 3). The COD of the leachate samples from the bottom drainage remained at about this level throughout the entire experiment.

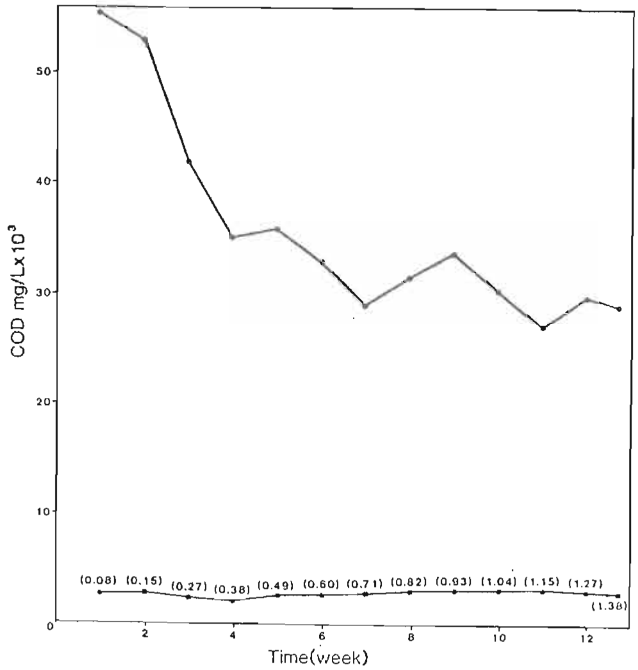

Figure 3: COD levels in leachate samples from the lysimeter collected from the middle of the solid waste layer (●) and the bottom drainage (■) during the continuous loading experiment; (x.yz) = pore volume drained.

COD removal was calculated from COD values of the leachate inside the solid waste layer as the influent and the leachate from the bottom drainage as the effluent. The removal was found to be between 92.2 and 96.2 percent.

The COD levels in the leachate from the solid waste layer decreased gradually from 55,500 mg/I to 30,000 mg/I as the leaching continued. The average COD level in the influent leachate was 33,800 mg/I. At the draining rate of 1.5 I/week, the organic loading into the underlying sand layer was found to be 50.7 g/week.

Results of the BOD analyses for leachate samples collected towards the end of the continuous loading experiment indicated that the average BOD in the effluent was 290 mg/I. The same analyses for the leachate collected from the middle solid waste layer provided an average value of about 20,000 mg/I. From these figures, it was found that a removal efficiency of 98.5 percent was achieved.

CONCLUSION

High strength leachate generated by a young landfill (<5 years) can be stabilized by controlled infiltration through the underlying sand layer under saturated conditions. Simulated conditions in a laboratory leachate lysimeter indicated that COD levels as high as 55,000 mg/I can be removed in the 1 m sand layer at the bottom of the lysimeter.

Removals of COD and BOD of greater than 92 percent and 98 percent respectively were achieved after 9 weeks detention with a leachate mobilization rate through the sand layer of 11 cm/week.

At this infiltration rate and with influent COD concentration of between 30,000 and 55,000 mg/I (based on the concentration in the middle of the solid waste layer), the organic loading rate to the underlying 1 m sand and pebble layers was equivalent to 476 g COD/m pore volume/day.

Rapid breakdown of organic materials by anaerobic fermentaiton resulted in a high rate of gas production (Ref.5). An average gas production 77 ml/day/kg wet weight of solid waste was achieved during the continous loading experiment. Under saturated conditions, rapid methane fermentation could take place inside the underlying sand layer or at the base of the solid waste layer but it unlikely to occur inside the middle of the solid waste layer. This was because of the low pH (around 5) inside the solid waste layer associated with the very high COD.

REFERENCES

1. LECKIE J D. PACEY J G. and Halvadakis C. Landfill Management with Moisture Control. Journal of the Environmental Engineering Div., ASCE, 1979, Vol. 105, 337-355.

2. HAM R K. and BOOKTER T J. Decomposition of Solid Waste in Test Lysimeter. Journal of the Environmental Engineering Div., ASCE, 1982 Vol. 108, 1147-1170.

3. HO G E. Predicting Solid Waste Quantity and Quality - A case study of the Perth Metropolitan Area. Civil Engineering Transaction, 1983, EIA, 261-267.

4. REES J F. Landfill Management and Leachate Quality. Effluent and Water Treatment Journal, 1982 December, 457-463.

5. FARQUHAR G J. and ROVERS F A. Gas Production During Refuse Decomposition. Water, Air and Soil Pollution, 2, 1973, 483-395.