Leachate Generation from Landfill Lysimeter using Different Types of Soil Cover

S. Karnchanawong and P. Yongpisalpop

***Abstract*—**The objectives of this study are to determine the effects of soil cover type on characteristics of leachates generated from landfill lysimeters. Four lysimeters with diameter and height of 0.15 and 3.00 m, respectively, were prepared. Three lysimeters were filled with municipal waste and three different cover soil types i.e. sandy loam soil, silty loam soil and clay soil while another lysimeter was filled solely with municipal waste. The study was conducted in the rainy season. Leachate quantities were measured every day and leachate characteristics were determined once a week. The cumulative leachate quantity from the lysimeter filled solely with municipal waste was found to be around 27% higher than the lysimeters using cover soils. There were no any differences of the cumulative leachate amounts generated from the lysimeters using three types of soils. The comparison of the total mass of pollutants generated from all lysimeters showed that the lysimeter filled solely with municipal waste generated the maximum quantities of pollutants. Among the lysimeters using different types of soils, the lysimeter using sandy loam soil generated the lowest amount of most of pollutants, compared with the lysimeters using silty loam and clay soils. It can be concluded that in term of pollutant attenuation in the leachate, a sandy loam is the most suitable soil to be used as a cover soil in the landfill.

***Keywords*—**cover soil, leachate, sandy loam soil, silty loam soil, clay soil.

I. Introduction

At present, the amount of solid waste generated has been increasing. In Thailand, the total amount of municipal waste generated in the year 2005 was approximately 14 million tons, comprising 24% from Bangkok Metropolitan Administration, 31% from municipalities, 45% from rural area outside the municipalities [1]. Currently, 35% of municipal wastes are disposed to landfill [1]. A new landfill is designed to have leachate collection and treatment systems. In landfill, soil has been used for daily cover and top cover in order to minimize the environmental impact resulted from landfill operation such as odour prevention, leachate and gas drainage enhancement [2]. Due to the high portion of organic waste composition in the waste, very high concentrations of pollutants in the leachate have been generated [3] [4] and cause a high cost of leachate treatment. The cover soil used in the landfill operation might be used as one of attenuation processes to decrease the pollutants' concentrations leached out in the leachate. In order to have a sustainable landfill technology for solid waste disposal with low cost, the objectives of this study are therefore to determine the effects of soil cover type on characteristics of leachates generated from landfill lysimeters.

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II. Materials And Methods

A. Lysimeter Preparation

Four lysimeters made of PVC pipe were prepared in this study. The cross section of each lysimeter is shown in Fig. 1. The heights and diameters of all lysimeters were 3.0 m and 0.15 m, respectively. The upper part consisted of a perforated pipe for adding rainfall. The lower part contained a gravel layer that served as the waste base and allowed the leachate to store and flow through the effluent pipe. Three lysimeters were filled with municipal waste and three different cover soil types i.e. sandy loam soil (MSDL), silty loam soil (MSTL) and clay soil (MC) while another lysimeter (M) was filled solely with municipal waste. The soils used in this study were classified as shown in Table I and Fig. 2. The analysis of soil was based on American Society for Testing and Materials ASTM Standards [5] and texture was classified in Table II. The density of soil filled in the lysimeters was 1550 kg/m^3.

B. Solid Waste Filling

Solid waste filled in each lysimeter was simulated according to the Chiang Mai municipal waste. Firstly, each component of the simulated municipal waste was chopped into small pieces; the different components were then mixed together according to the wet weight percentages in Table II. Two layers of waste were filled in the three lysimeters with three different cover soil types and each waste layer had 1 m height. The density of waste filled in was 600 kg/m^3. The heights of intermediate soil layer and top soil layer were 0.15 m and 0.30 m, respectively.

C. Rainfall Addition, Leachate Sampling And Analysis

In the study region, there are two seasons, the dry season from November to April and the rainy season from May to October. This study focused only on the 6-month period of the rainy season when high amounts of leachate are generated.

The daily precipitation data from May 2004 to October 2004 of Chiang Mai province were used to simulate rainfall in this study. To simulate the actual infiltration through the landfill, a runoff-coefficient of 0.22 (for compacted top soil with a slope of 3%) and an evaporation level of 28% of the total rainfall (estimated by [6]) were used. As a result, the infiltration to the landfill was estimated to be 50% of the daily rainfall. Therefore, in this study, distilled water with an amount equal to 50% of the daily-recorded rainfall in 2004 was fed every morning into every lysimeter according to the days that had rainfall.

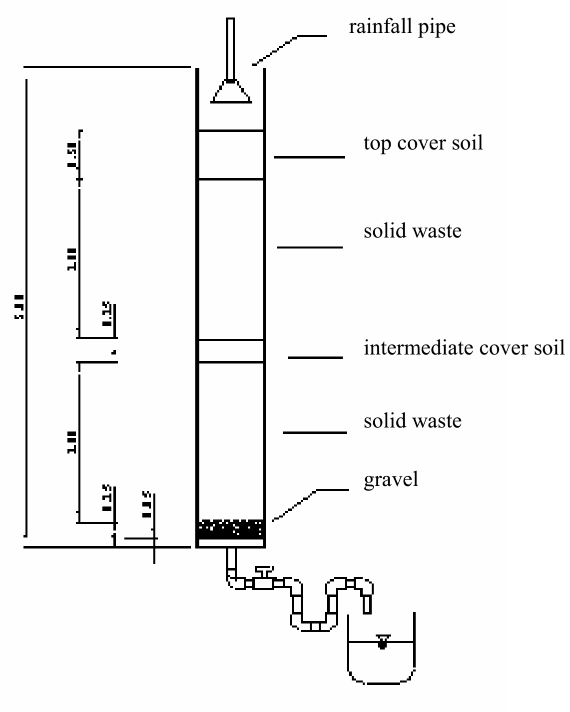

Fig. 1 Cross section of lysimeters unit

TABLE I
SOIL CLASSIFICATION

Physical characteristics	MSDL	MSTL	MC	Analysis method
Moisture content	10.18	2.09	21.94	ASTM D-2216
pH	6.71	7.01	6.39	-
Specific gravity	2.46	2.55	2.54	ASTM D-854
Sand:Silt:Clay	72:22:6	38:54:8	18:30:52	ASTM C-136, D-422
Soil classification	Sandy Loam	Silty Loam	Clay	USDA

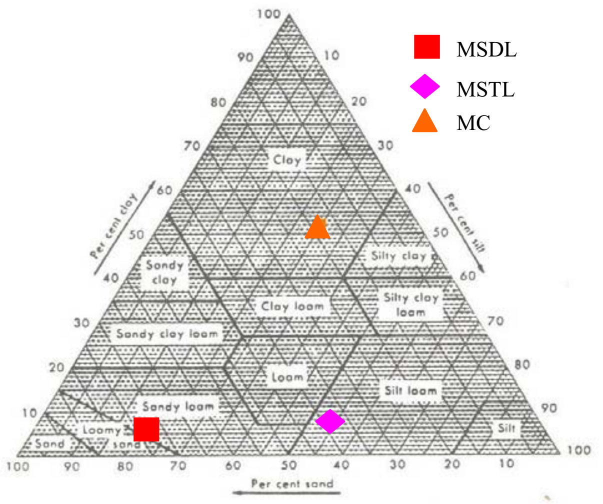

Fig. 2 Textural classification chart (U.S. Department of Agriculture) [7]

TABLE II
WASTE CHARACTERISTICS IN THE CHIANG MAI MUNICIPALITY, YEAR 2004 [8]

Physical component	% wet weight	Physical component	% wet weight
Food Waste	54.0	Rubber and leather	0.9
Papers	11.0	Cloth	2.6
Plastics	15.1	Garden Waste	1.2
Glass	9.6	Stone and ceramics	2.1
Metals	2.1	Miscellaneous	1.4
Moisture content		53.5%	

Leachate quantity was measured every day and leachate characteristics i.e. total solids, total volatile solids, total alkalinity, volatile fatty acid, COD, BOD and Org-N were determined once a week. The analysis was based on the Standard Methods for the Examination of Water and Wastewater [9].

D. Statistical Analyses

In order to analyze the data, a one-way ANOVA at a 95% confidence limit using least significant difference (LSD) was used to compare the results in this study.

III. RESULTS AND DISCUSSION

A. Leachate Generation

Fig. 3 showed the amount of leachate generation over time. The results from the experimental period of 6 months show that the quantities of cumulative rainfall added into each lysimeter was 10.7 L and cumulative leachate generated from lysimeters MSDL, MSTL, MC and M were 8.4, 8.8, 8.6 and 11.8 L, respectively. During the first week, the leachate amounts generated in a low amount even though a high amount of simulated was added due to the high void ratio in dry soil [10]. The quantity of cumulative leachate from the lysimeter filled solely with municipal waste was higher than the cumulative rainfall added and was found to be highest, compared with the three lysimeters using cover soils. The quantities of cumulative leachate from the lysimeters using cover soils were not significantly different. The absorption of leachate to the soil which could be seen from their increasing moisture contents were the cause of this finding (% moisture of soil at the beginning of the experiment, MSDL: 10.2,

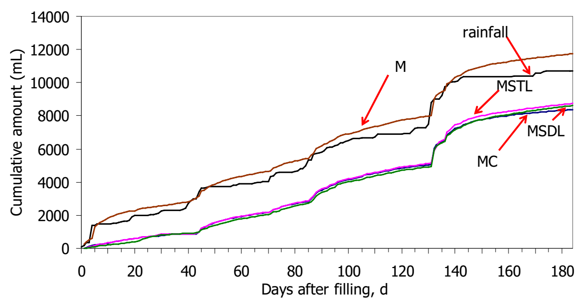

Fig. 3 Cumulative amount of rainfall added and leachate generation

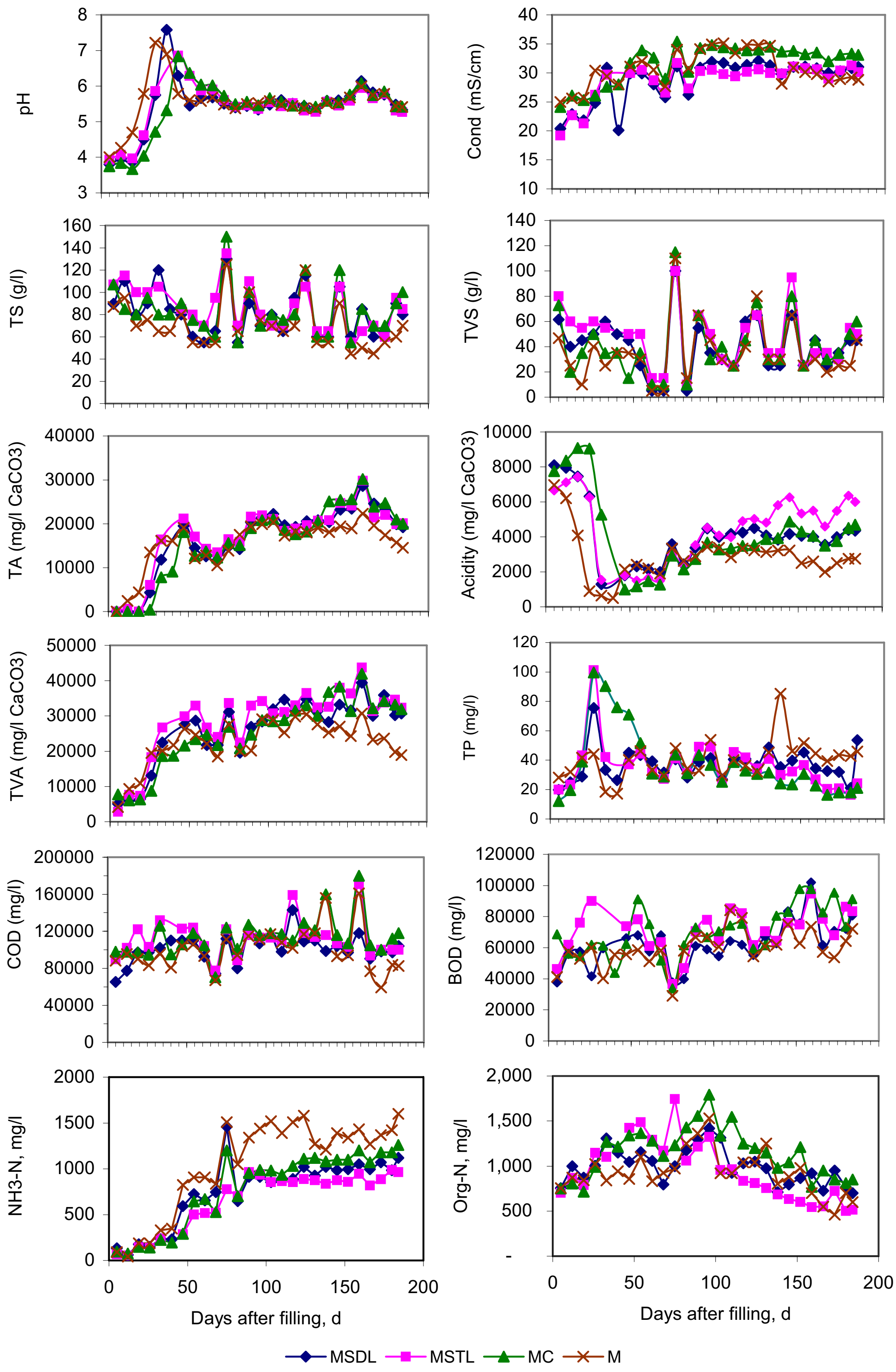

Fig. 4 Leachate characteristic variation over time

MSTL: 2.1 and MC: 21.9, % moisture of soil at the end of the experiment, MSDL: 20.1-26.7, MSTL: 14.5-22.8 and MC: 24.2-33.9). It was found that the lysimeter using cover soil can reduce the leachate quantities around 27%, compared with the lysimeter without cover soil. Tchobanoglous [11] reported that the field capacities of sandy loam soil, silty loam soil and clay soil were 14, 24 and 35%, respectively. The results obtained from this study did not correspond to the field

TABLE III
AVERAGE CONCENTRATIONS OF POLLUTANTS IN THE LEACHATE

Parameter	MSDL	MSTL	MC	M
pH	5.45	5.42	5.40	5.55
Conductivity (mS/cm)	28.80	28.80	31.70	30.60
Total solids (g/L)	81.50	86.60	83.80	71.00
Total volatile solids (g/L)	40.60	47.50	41.00	35.60
Alkalinity (mg/L $CaCO_3$)	18700	18600	18200	16000
Total volatile acids (mg/L CH_3COOH)	26200	28700	25600	22600
Acidiy (mg/L $CaCO_3$)	4100	4500	4110	2880
COD (mg/L)	101000	112000	114000	100000
BOD (mg/L)	62300	70900	70500	59700
NH_3-N (mg/L)	757	667	785	1050
Org-N (mg/L)	991	939	1140	924
TP (mg/L)	37.10	35.90	37.30	40.10

TABLE IV
CUMULATIVE AMOUNTS OF POLLUTANTS LEACHED FROM LYSIMETERS DURING 6 MONTHS

Cumulative pollutants leached (g/kg dry initial waste(	MSDL	MSTL	MC	M
Total solids	29.2	33.1	31.2	39.2
Total volatile solids	14.2	18.4	15.5	20.2
Alkalinity	6.78	7.42	7.19	7.69
Total volatile acids	10.3	11.9	10.9	11.3
Acidiy	1.47	1.75	1.46	1.87
COD	39.1	45.0	47.3	57.1
BOD	23.5	26.8	27.7	31.1
NH_3-N	0.311	0.284	0.341	0.510
Org-N	0.379	0.385	0.467	0.519
TP	0.0145	0.0146	0.0141	0.0229

capacity mentioned above. The clogging of particle in sandy loam soil and silty loam as well as the cracking of clay soil might resulted in the non-significant differences of leachates' amounts generated from MSDL, MSTL and MC.

B. Leachate Characteristics

The leachate characteristics' variations over time are presented in Fig. 4. The average concentrations of pollutants in the leachates are presented in Table III. The statistical analysis using one-way ANOVA at a 95% confidence limit showed the following results. There were no any significant differences among the average values of pH, total volatile solids and total alkalinity in all lysimeters. The average values of conductivity levels in the leachate generated from lysimeters MSDL and MSTL were significantly less than lysimeters MC and M ($p<0.5$). The average values of total solids in the leachate generated from lysimeter M was significantly less than lysimeters MSDL, MSTL and MC ($p<0.5$). The average values of total volatile acids in the leachate generated from lysimeter M was significantly less than lysimeter MSTL ($p<0.5$). The average values of total acidity in the leachate generated from lysimeter M was significantly less than the other three lysimeters ($p<0.5$). The average values of COD and BOD in the leachate generated from lysimeters MSDL and M were significantly less than lysimeters MSTL and MC ($p<0.5$). The average values of NH_3-N and total phosphorus in the leachate generated from lysimeters MSDL, MSTL and MC were significantly less than lysimeter M ($p<0.5$) and the average values of Org-N in the leachate generated from lysimeters MSDL, MSTL and M were significantly less than lysimeter MC ($p<0.5$). Generally, the concentrations of the pollutants in the leachate generated from lysimeter M except NH_3-N and total phosphorus were significantly less than the other three lysimeters. The higher concentrations of pollutants leached out from the lysimeters using cover soils might be because of the leaching out of the pollutants from the soil themselves. In case of NH_3-N and total phosphorus, soil can highly fix with these two substances. Then, these two substances in the leachates generated from the lysimeters using cover soil were released out in the lower concentrations, compared with the lysimeters filled solely with municipal waste.

It should be remarked that the variations of rainfall amount added to the lysimeters highly influenced the leachate characteristics that corresponded to the results obtained from the previous researches [3] [4]. The leachate generated after a long-lacking period of rainfall had higher concentrations of pollutants. The moisture addition to the waste layer caused a higher activity of biodegradation process and resulted in a higher concentration of pollutant in the leachate. However, after continuously addition of rainfall to the lysimeters, the concentrations of pollutants in the leachate decreased due to the dilution effect.

C. Cumulative Amounts of Leachate and Pollutants Leached Out

Table IV presented the cumulative amounts of pollutants leached from all lysimeters during 6 months-period. The maximum quantity of cumulative amounts of pollutants from lysimeter M which was filled solely with municipal waste was found. In addition, the total masses of all pollutants extracted from lysimeter M were higher than the other three lysimeters, even though the concentrations of pollutants from this lysimeter were lower. High quantity of leachate generated from lysimeter M, compared with the other three lysimeters that used cover soil was the cause of this finding.

The comparison of the total mass of pollutants extracted per kilogram of dry waste generated from all lysimeters showed the following results. The minimum total mass of pollutants generated from lysimeter MSDL i.e. total solids, total volatile solids, total alkalinity, volatile fatty acid, COD, BOD AND Org-N were determined, compared with other lysimeters. The minimum total mass of pollutants generated from lysimeter MSTL i.e. TKN and NH_3-N were observed, compared with other lysimeters. The minimum total mass of pollutants generated from lysimeter MC i.e. acidity and total phosphorus were determined, compared with other lysimeters. It was clearly shown that lysimeter MSDL could generate the lowest amounts of most of the pollutants in the leachate.

IV. CONCLUSION

The effects of cover soil types i.e. sandy loam soil, silty loam soil and clay soil on leachate characteristics and cumulative amount of pollutants leached out generated from lysimeter filled with MSW were conducted in this study. The comparison of leachate quantities leached out from the lysimeters showed that cover soil can reduce the leachate amount around 27%. The comparison of the total mass of pollutants generated during 6 months-period from all lysimeters showed that the lysimeter filled solely with municipal waste leached out the maximum quantities of pollutants. Among the lysimeters using different types of soils, the lysimeter using sandy loam soil generated the lowest amount of most of pollutants, compared with the lysimeters using silty loam and clay soils. It can be concluded that in term of pollutant attenuation in the leachate, a sandy loam is the most suitable soil to be used as a cover soil in the landfill.

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