Performance of soil and compost mixture in leachate purification at intermediate cover layer of tropical landfill

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Abstract This research studied the performance of soil and compost as filter materials for preliminary purification of leachate at intermediate cover layer of tropical landfill. The experiments were conducted by using four columns filled with different types of filter materials, i.e. 1) soil (40% clay, 30% silt, 30% sand) 2) mixture of soil and planting soil 3) mixture of soil and compost at 2:1 ratio 4) mixture of soil and compost at 1:1 ratio. The performance of filter materials was evaluated at different water application rates equivalent to rainfall intensity of 25, 50 and 100 mm./d. The experimental results suggested that leachate quality was directly related to the water application rate. Leachate concentration was highest at the beginning of the experiment and decreasing with time. The use of mixed soil as filter materials initially helped improving leachate quality but their treatment efficiencies diminished when maximum soil adsorption capacity has been reached. Soil materials could remove BOD, color and TKN by 32.78, 48.93 and 72.61% in average at a rainfall intensity of 50 mm./day. Introduction of compost as filter materials could enhance COD removal efficiencies but also contributed color in treated leachate.

Keywords Compost; cover soil; leachate; lysimeter, tropical landfill

Introduction

Problems arise from pollution of solid waste disposal has been receiving more intention from responsible stakeholders especially in urban area of developing countries where total amount of produced wastes has been increasing significantly. In Thailand, more than 14.3 million tons/year or 39,200 tons d^{-1} has been produced in urban areas all over the country with an annual increasing rate of about 3% (Pollution Control Department, 2002). Currently, majority of wastes (about 65%) are being disposed in open dump whereas the remaining is being managed by sanitary landfill (35%). In order to improve the sanitary condition of waste disposal practice, several open dumpsites have been upgraded to engineered landfill together with the construction of new sanitary landfill facilities during the past 10 years. Despite those improvements, environmental impact from those landfills especially leachate problem still has to be solved. Most of the sanitary landfills in Thailand employed stabilization pond as the only main treatment unit. Under tropical climatic condition, heavy rainfall during monsoon season yield huge amount of leachate to be treated whereas the capacity of the existing treatment system is usually limited. Inadequately treated water is then discharged into the nearby water body, causing severe pollution problem.

Leachate treatment by natural soil employs physical, chemical and biological purification mechanisms including particle straining, adsorption and biological degradation of organic substances. This low cost treatment method has been proved as one of an effective way in dealing with problematic leachate. Ou (1989) found that natural clay could remove organic carbon and

suspended solids by more than 90%. Nevertheless, low infiltration rate is still the main task to overcome.

This study is focusing on the performance of intermediate cover soil in leachate pretreatment prior to discharge to the main treatment system. Different types of cover material, e.g. mixed soil, mixed soil with compost at different ratio, was used to examine their infiltration rate and retention capability of organic pollutants in leachate.

Methods and materials

Six laboratory-scale soil columns of 15-cm. diameter and 2.50 m. height were used in this study (Fig.1). They were filled with different types of soil materials, i.e. 3 columns with prepared soil (40% clay, 30% silt, 30% sand), one column each with 2:1 ratio (by weight) of soil and planting soil (hereafter called mixed soil), 2:1 ratio of soil and compost and 1:1 ratio of mixed soil and compost respectively to compare the performance of each type of soil materials in leachate purification. The depth of covering material was 0.80 m lying below a 0.80-m. layer of municipal solid wastes (MSW) with major composition of food wastes, paper and plastic. Rainwater is added into the column at different rate of 0.45, 0.90 and 1.80 liter/d which equivalent to 25, 50 and 100 mm./d of rainfall intensity. Leachate collected below the waste layer and treated water collected at the bottom of column were taken from the column and analyzed for their characteristics including pH, BOD, COD, NH_4^+, TKN and color according to Standard Method for the Examination of Water and Wastewater 18^{th} edition (APHA, 1992)

Figure 1 Experimental system used in this study

Results and discussion

Leachate characteristics at different water infiltration rates

Rainwater was applied to soil column at different rate of 25, 50 and 100 mm./d or 0.45, 0.90 and 1.80 liter/d to determine their effect on treatment performance of soil materials. As rainwater leached through the waste layer, leachate was formed and it was then infiltrated and treated by the soil layer. The determination of chemical characteristics of leachate at different rainwater application rates suggested that pH was ranged from 4.4 to 6.2 with an average of 5.3. At 50 mm./d

water infiltration rate, BOD was in a range between 2,050-14,000 mg/l with an average of 4,990 mg/l as compared to 640-5,600 mg/l (3,040 mg/l on average) of that at water application rate of 100 mm./d. Initial COD concentrations were found to be 20,000 and 10,000 mg/l at 50 and 100 mm./d and decreased with time as shown in Fig.2. In column 1 with 25 mm./d of applied rainwater, the volume of leachate was small and the sample could not be collected.

The relationship between COD concentration in leachate with time can be described by first-order reaction as follows.

$$dC/dt = -kC \quad (1)$$

$$\ln(C/C_0) = -kt \quad (2)$$

where C = COD concentration at any time t (mg/l)
C_0 = Initial COD concentration (mg/l)
k = First-order reaction rate constant (day^{-1})
t = Time (day)

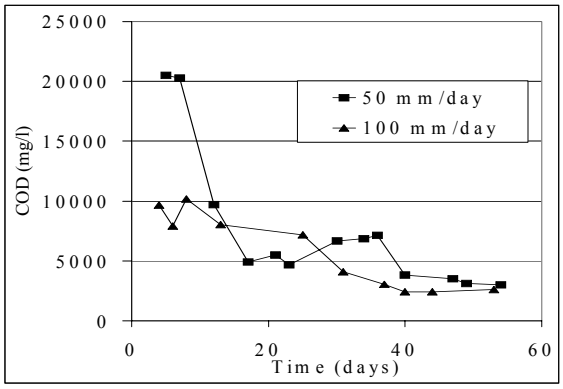

Figure 2 Variation of COD concentration with time

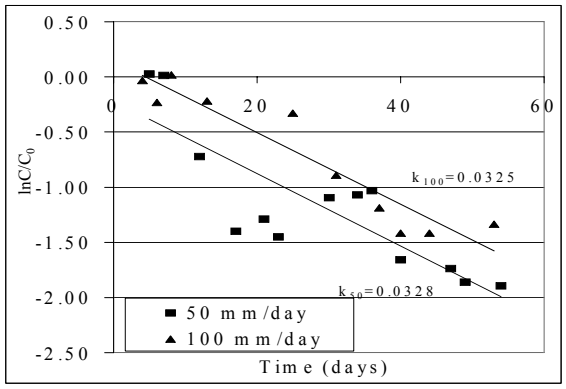

Figure 3 Relationship between $\ln(C/C_0)$ and t

As shown in Fig.2, COD concentration of leachate from waste layer was found decreasing with time. First-order reaction rate constants determined from Fig.3 at water infiltration rate of 50 and 100 mm/d were 0.0328 and 0.0325 d^{-1} respectively. It was found that initial COD concentration of leachate was inversely proportional to the rainwater infiltration rate and thus total organic loading of leachate from the waste layer was maintained relatively constant, independent of rainwater infiltration rate.

Color contained in leachate at different water infiltration rates was also found initially decreasing with time and remained relatively constant after 20 days (Fig.4). They were in range of 16.6-903.5 Pt/Co unit with an average of 186.4 and 138.2 Pt/Co unit at 50 and 100 mm./d respectively. The water infiltration rate did not significantly affect the color contained in leachate.

Average TKN concentration in leachate was 189.1 and 64.8 mg/l at 50 and 100 mm./d of water infiltration rate. Average ammonium nitrogen concentration was 82.8 and 51.8 mg/l, accounted for 44 and 80% of TKN respectively.

The experimental results suggested leachate characteristics was significantly influenced by water infiltration rate through the waste layer. Higher concentration of BOD, COD, NH_4^+-N and TKN was observed at lower water infiltration rate of 50 mm./d as compared to the higher rate of 100 mm./d. However, there was not much difference in terms of color in leachate at different water

infiltration rates. The concentrations of all pollutants were initially decreasing with time and remained relative constant after 20 days.

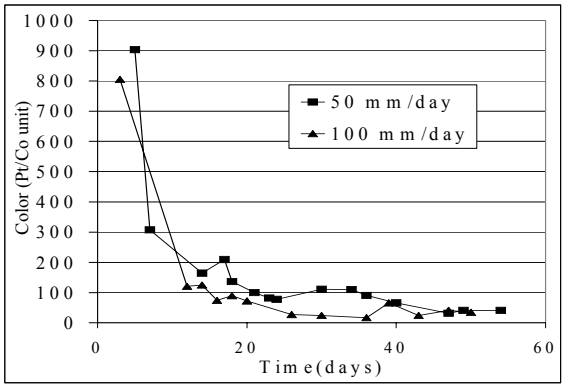

Figure 4 Variation of leachate color at different water infiltration rate

Performance of intermediate soil layer in leachate purification

The treatment performance by intermediate soil layer by using prepared soil (40% clay, 30% silt, 30% sand) was examined at different water application rate of 25, 50 and 100 mm./d. The hydraulic conductivity (k) of mixed soil was determined by variable head method as $1.39*10^{-4}$ cm/s.

Figure 5 shows the variation of leachate quantity at different water infiltration rates. It was found that in case of rainwater infiltration rate of 25 and 50 mm./d, average amount of leachate were 415 and 870 cm^3/d whereas for 100 mm./d water application rate, the infiltration rate of 1,750 cm^3/d was maintained during the first 20 days and dropped down to about 1,000 cm^3/d after 30 days. This experimental results indicated that maximum infiltration rate through mixed soil was 50 mm./d.

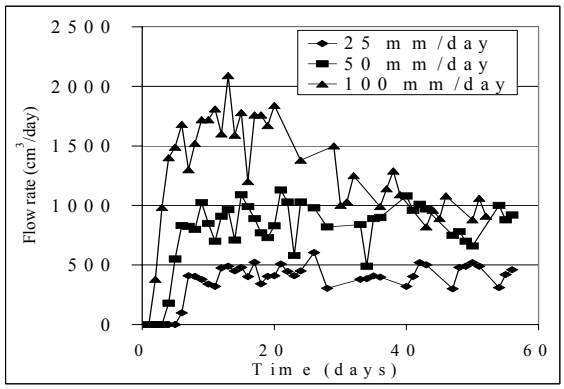

Figure 5 Variation of leachate quantity at various water application rate

The chemical analysis of treated leachate through soil column suggested that their BOD and COD concentration was maintained at relatively low range during the first 20-30 days. After that, their concentration has increased drastically to a maximum value of 10,000 and 16,000 mg/l and gradually declined afterwards to 1,000-5,000 and 3,000-6,000 mg/l respectively. This variation in organic substance concentration can be explained by the predomination of adsorption mechanisms during initial period, after which the organics was released when the maximum adsorption capacity of soil has been reached. The biodegradation was then responsible the removal of organic

substances when the soil adsorption capacity became exhausted. It was found that BOD removal efficiencies of intermediate soil at water application rate of 50 and 100 mm./d were 32.78 and 12.11% whereas COD were not significantly removed.

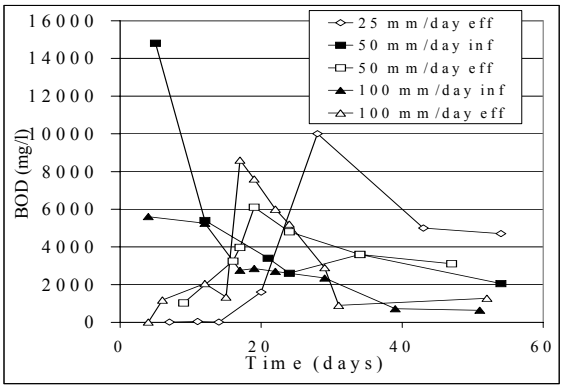

Figure 6 Variation of BOD before and after soil treatment

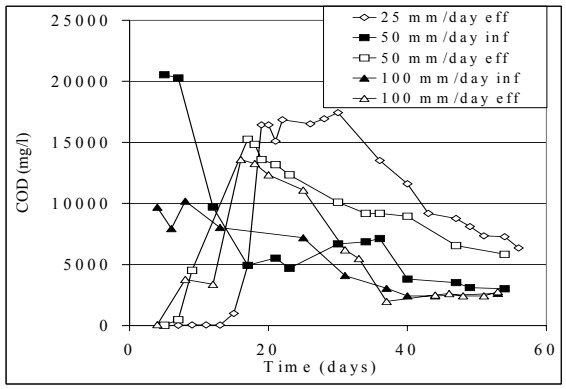

Figure 7 Variation of COD before and after soil treatment

The color contained in treated water was kept at low range with an average of 58.8, 95.2 and 36.2 Pt/Co unit at infiltration rates of 25, 50 and 100 mm./d respectively. The average removal efficiency of 48.93% was obtained at water infiltration rate of 50 mm./d. The adsorption capacity of mixed soil was determined in batch experiment in which Langmuir Isotherm was employed as described by Equation 3.

$$1/(X/M) = 90.628/C_e - 0.8341 \quad (3)$$

where X = Amount of color adsorped on soil (Pt/Co unit- liter)
M = Weight of soil (g)
Ce = Remaining color concentration in solution (Pt/Co unit)

It was found that maximum adsorption capacity of color by mixed soil used in this study was 2,800 Pt/Co unit. In soil column experiment, the total amount of color removed by soil was found exceeding the adsorption capacity of soil. As a result, there should be other mechanism such as biodegradation responsible for the removal of from leachate.

In term of nitrogen removal, it was found that average ammonium and total nitrogen in treated water were 24.3, 41.2, 49.6 mg/l and 47.1, 51.8, 56.8 mg/l at water infiltration rates of 25, 50 and 100 mm./d respectively. The concentration of nitrogen in treated water was increasing with time showing that the adsorption mechanism helped removing nitrogen effectively during the initial period, but as their capacity became exhausted, the removal efficiency mainly from biological activity could not be maintained at the same level. Average total nitrogen removal efficiency was 72.61% at infiltration rate of 50 mm/d, significantly higher than 12.3% at 100 mm/d.

Performance of soil and compost mixture in leachate purification

The experiment was conducted in soil column having different types of filter materials with relatively the same hydraulic conductivity, i.e. 1) mixed soil 2) mixture of soil and compost at 2:1 ratio 3) mixture of soil and compost at 1:1 ratio. The water application rate was set at 50 mm/d.

Figure 8 shows the variation of water infiltration rate in soil column with different soil composition. Over 52 days of experimental period, average infiltration rates of 765, 627 and 698 cm^3/d were observed for mixed soil, soil/compost mixture of 2:1 and soil/compost mixture of 1:1 respectively. Though some fluctuations were observed, the infiltration rate of all filter materials could be maintained over entire experimental period.

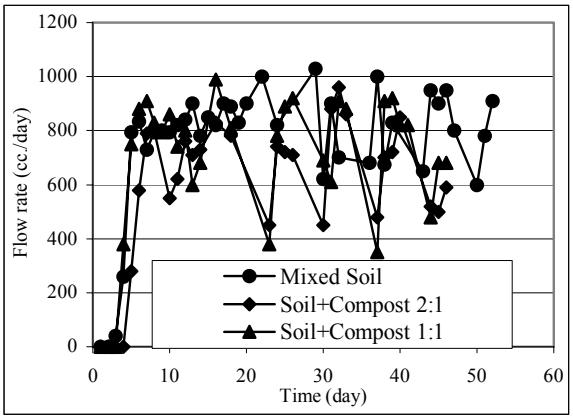

Figure 8 Water infiltration rate in soil columns with different soil composition

The variations of BOD and COD concentration after soil treatment are shown in Fig.9 and 10. It was found that BOD and COD in treated water was increasing during the first 10 days and reached maximum concentration of 2,000-4,000 mg/l and 4,000-8,000 mg/l. Afterwards, the concentrations were decreasing until the end of experimental period. Average BOD and COD concentration in treated water with mixed soil were 749 and 2,484 mg/l. They were 1,594 and 2,758 mg/l for soil/compost mixture at 2:1 ratio, 940 and 1,658 mg/l for soil/compost mixture of 1:1 ratio respectively. Comparing the purification performance of different filter materials, there was not much difference between BOD removal efficiency but COD removal efficiency of soil/compost mixture was higher than that of mixed soil. This suggested that compost material in filter material helped removing hardly biodegradable substance contained in leachate to some extent.

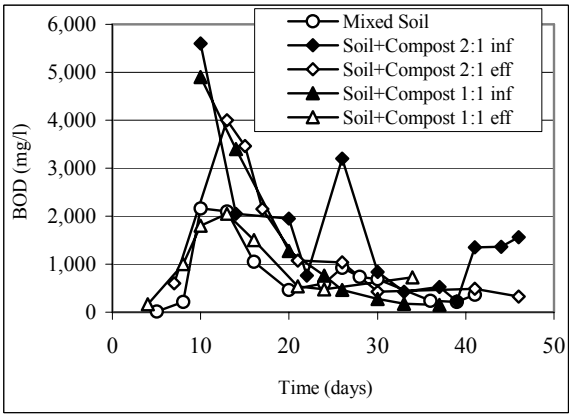

Figure 9 Variation of leachate BOD before and after soil treatment

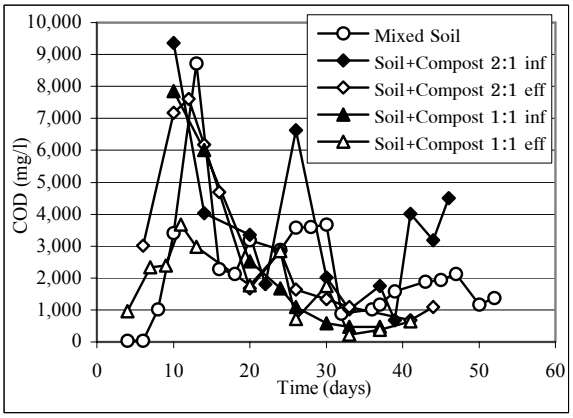

Figure 10 Variation of leachate COD before and after soil treatment

The variations of leachate color before and after soil treatment by different filter materials are shown in Fig.11. It was found that color contained in treated water from soil/compost columns were

much higher than that from mixed soil column. The color concentration was higher with the increasing amount of compost in filter material. In compost containing column, higher concentration of color concentration in the effluent as compared to the influent suggested that compost material contributed color in the treated water.

Determination of TKN in the effluent from soil column suggested that the leaching of nitrogen was decreasing with time. In soil column containing mixed soil and compost at 2:1 ratio, average NH_4-N and TKN concentration were 28.4 and 76.7 mg/l. For those with soil and compost ratio of 1:1, higher concentration of 77.9 and 111.9 mg/l was obtained. It was found that organic nitrogen has been mineralized to ammonium nitrogen within soil column resulting in higher ammonium nitrogen in the effluent as compared to the influent.

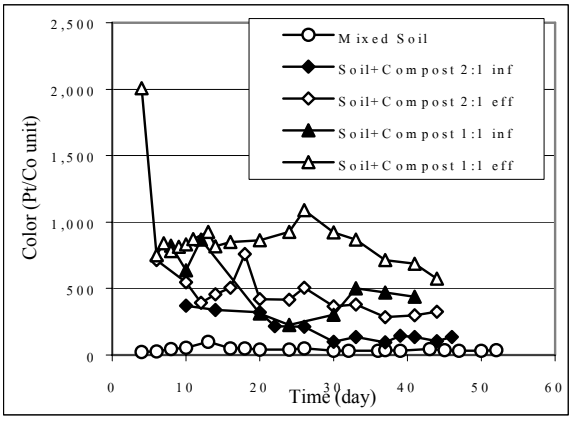

Figure 11 Variation of color before and after treatment by different soil mixture

Conclusion

From the experimental study of leachate purification by soil and soil/compost mixture at intermediate cover layer of tropical landfill, the following conclusion can be drawn.

1. The characteristics of leachate varied with water infiltration rate. The organic matter concentration in leachate was higher at lower water infiltration rate. At higher infiltration rate, the leachate was diluted, but total organic load remained relatively constant. The concentration of leachate also decreased with time, as the organic fraction of solid waste was being degraded and leached out from the waste layer.
2. The use of mixed soil with clay: silt: sand ratio of 40:30:30 has maximum infiltration rate of 50 mm/day. Average BOD, color and TKN removal efficiencies were found to be 32.78, 48.93 and 72.61% respectively. The organic substances were initially adsorbed by soil and released when soil became saturated. Moreover, biological degradation also helped removing a fraction of organic substances and color from leachate. The removal efficiencies were found higher at lower infiltration rate.
3. Introduction of compost as filter materials could enhance COD removal efficiencies but also contributed color in the treated water.

Acknowledgements

This research work is financially supported by Swedish International Development Cooperation Agency (SIDA) under Asian Regional Research Program on Environmental Technology (ARRPET).

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