LEACHATE STABILIZATION BY THE UNSTABLE AND IMMATURE COMPOST IN EVAPOTRANSPIRATION BED

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Abstract: This research was conducted by means of co-process of toxic leachate and the unstable and immature compost in evapotranspiration bed with the objectives to determine the composition of the bed and its design criteria. The methods included treatment variations in composition of compost and sand, hourly observation of evapotranspiration and evaporation rates, daily observations within a month and monthly in the year. Results revealed that compost/sand in maximum proportion of 50/50% by weight was an optimum composition for evapotranspiration bed that resulted in an optimum volumetric loading of leachate to maintain the growth of plants on the bed. Intermittent loading of leachate was able to recover evapotranspiration bed for long term processing. The co-process of toxic leachate and the unstable and immature compost increased biodegradability of both materials and achieved stability. Wastewater treatment system configuration was suggested for design, implementation, and research on plants diversity.

Key words*:* co-process, material proportion, bed capacity, volumetric loading, intermittent, stability.

1. INTRODUCTION

Leachate was a wastewater produced from waste decomposition process, so that the leachate contained extracts of various waste substances. Monthly monitoring of leachate quality has been carried out to condition the solid waste landfill site in Benowo of Surabaya, Indonesia. The monitoring results indicated the content of organic matter as BOD and COD, each of which exceeds 1.500 mg/L, in addition to other substances in high concentrations. The lecahate has been processed in sedimentation and filtration units, but the results were often below the standard quality of effluent and consequently, the receiving water body was often polluted (Sarudji, 2007).

The wastewater treatment plants used the facility, where efluent discharged into a single disposal site such as river. In fact, the disposal of effluent can be spread to multiple environmental media. A wastewater treatment plant in the form of evapotranspiration bed has the ability to spread the discharge into the river, air, soil, and plants. In the design and practical implementation of evapotranspiration beds, it composed of gravel and sand material and the top layer of soil to plant growth. Application of evapotranspiration beds in Indonesia was still limited to houses that have a large plot for disposing septic tank effluent. Large scale evapotranspiration bed for wastewater treatment was still in the proposal stage. The design adopted international practices (Bialowiec & Wojnowska-Baryla, 2008; Vesilind, 2003) that need to be adapted to tropical conditions and emerging issues in place.

One of unresolved problem was the processing technique for toxic leachate and the unstable and immature compost at the solid waste disposal site in addition to its quantity of leachate (Abdoli *et al.*, 2009). Research processing of various types of wastewater in evapotranspiration bed for tropical conditions in East Java has been conducted since 2005. The recent development showed that a mixture of leachate and clay, in certain proportions, could stabilize leachate (Sarudji, 2007). The development was the essential part of the methods for reducing recalcitrant and toxic organic matters by which wastewater became biodegradable (Priambodo & Karnaningroem, 2010).

In this research, the unstable and immature compost was mixed with sand in evapotranspiration bed, and the bed was intended to treat toxic leachate. Therefore, it was necessary to find out the optimum composition of compost and sand for treating leachate without significant negative effect on the growth of plants on it. Design criteria would be obtained and the treatment system configuration would be determined. The benefits of this research was not only solve the problem of processing leachate in landfills, but more than that was to support efforts to composting, recycled solid waste management, wastewater sanitation, and provision of greenspace area.

2. EXPERIMENTAL METHODS

Evapotranspiration and evaporation beds were made in PVC pots (figure 1).

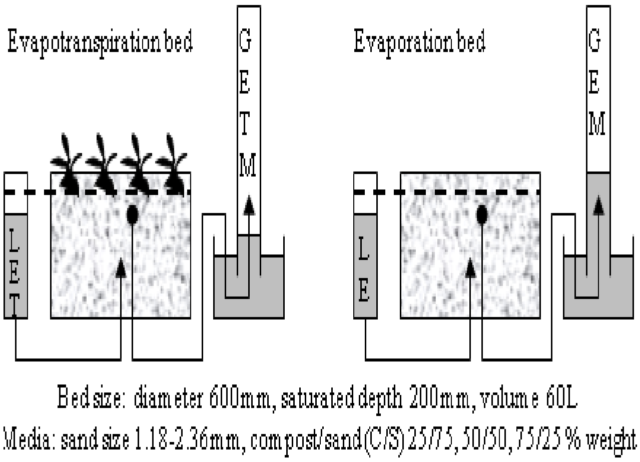

Fig. 1. Experimental evapotranspiration and evaporation beds

This research was the development of earlier studies since 2005. All the experiments were carried out in a greenhouse. Treatment variations were applied for three replicates and the results were averaged.

Each pot had a surface area and saturated depth of bed 0.28m^2 and 0.2m respectively. Thus, the fixed bed active volume was 60L. Each bed was equipped with a leachate container and cylinder gas that was mounted upside down.

Leachate levels fell due to evapotranspiration (LET) and evaporation (LE). Water level in the gas cylinder down due to the produced gas from the process of evapotranspiration media (GETM) and evaporation bed media (GEM). Therefore, it was easy to measure evapotranspiration and evaporation rates by measuring the decrease in leachate level in each container.

Leachate loading was carried out continuously and intermittently. Continuous loading was conducted for hourly a day to determine bed capacity, and daily a month to observe the trend volumetric loading. Intermittent loading was conducted at intervals of one month, which was considered a resting period for recovery, for nine months. Leachate derived from solid waste landfills in Benowo of Surabaya. The leachate was concentrated and therefore, leachate used in this experiment was diluted two and four times, the so called leachate 50% and leachate 25%. In addition, dilution of leachate was intended to simulate conditions in rainy season, when solid waste landfill exposed to rain and affected by increasing ground water level.

The unstable and immature compost were taken from the local seller, chosen based on the BOD content of more than 250 mg/L, COD of more than 500 mg/L, BOD/COD ratio of more than 0.5 and C/N ratio of more than 15.

Total organic carbon as C was measured as carbon dioxide emissions during four days following equilibration period of three days at 30^{o}C incubation. Carbon dioxide entrapment leachate was sodium hydroxide and the collected sodium carbonate was precipitated as barium carbonate by the addition of excess barium chloride. The concentration of carbon dioxide evolved by the compost was measured by titration of the residual sodium hydroxide with standard acid using phenolphthalein indicator. The total nitrogen, i.e. organic and inorganic forms as N was measured in water extractable substances.

Titration for CO_2 measurement, organic matter content in the forms of BOD and COD, total Kjeldahl nitrogen, ammonia, nitrate and nitrite were measured according to APHA/AWWA/WEF (1995).

Plant used was elephant grass. There was no special objective of choosing the plant species except to drive evapotranspiration. The grass was grown in such a way that roots were distributed all over the surface area of the bed. The depth of root zone of 100mm was not unsaturated by leachate. There was no addition of fertilizer or pesticide into the bed to make the evapotranspiration bed was comparable with evaporation bed.

3. RESULTS AND DISCUSSION

3.1 The untreated quality of materials

The characteristics of leachate and compost quality in this experiment were presented in Table 1.

Table 1. Leachate and compost characteristics

Parameters / Materials	CO_2-C, g/kg	Total N, g/kg	BOD, mg/L	COD, mg/L
Diluted leachate (50%)	NA	174±12	982±27	5,767±41
Diluted leachate (25%)	NA	93±6	484±19	2,913±32
Compost	1,950±59	81±3	326±13	549±11

NA= not available

Leachate characteristics could be classified as toxic organic towards aerobic microorganisms (BOD/COD < 0.2). Compost was clasified as unstable (BOD/COD > 0.5) and immature material (C/N > 15) (Priambodo & Karnaningroem, 2010; Sarudji, 2007).

3.2 Optimum compositions of bed media

The results were fluctuation in the volume of evapotranspiration and evaporation on the daylight during the day. A typical observation for evapotranspiration and evaporation beds at the coldest day in tropical conditions (25°C) was presented in Figure 2.

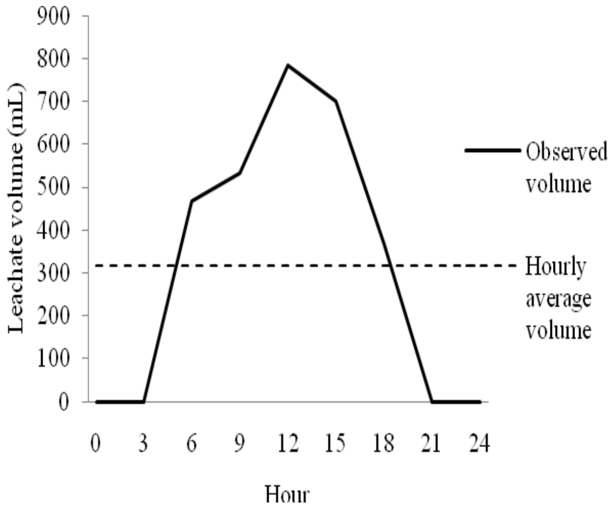

Fig. 2. A typical hourly fluctuation of leachate entering the evapotranspiration bed

The data were processed to determine the capacity of the media to store leachate as well as evapotranspiration and evaporation rates. The capacity of the media to store leachate (CMS) was determined by mass balance, ie area under the curve and above the dashed line, or total area above the curve and below the dashed line. Dashed line was none other than evapotranspiration rate (ETR) or evaporation rate (ER). The results of data analysis were presented in Table 2 for various compost and sand (C/S) compositions.

Table 2. The capacity of the media to store leachate and evapotranspiration and evaporation rates

	Evapotranspiration bed		Evaporation bed	
Media composition	CMS (L)	ETR (mm /day)	CMS (L)	ER (mm /day)
Diluted leachate (50%)				
C/S = 25/75	1.31[a]	9.43[a]	0.29[a]	1.71[a]
C/S = 50/50	1.30[a]	9.43[a]	0.33[b]	1.71[a]
C/S = 75/25	0.93[b]	6.86[b]	0.42[c]	3.43[c]
Diluted leachate (25%)				
C/S = 25/75	2.71[a]	19.72[a]	0.66[a]	5.14[a]
C/S = 50/50	2.80[a]	19.72[a]	0.69[a]	5.14[a]
C/S = 75/25	1.93[b]	13.72[b]	0.87[b]	6.86[b]

Numbers followed by the same letter at the same column were not significantly different ($p = 0.05$).

Data Table 2 described in general that the weight of the compost exceeds the weight of sand, significantly reducing the capacity of the media to store leachate and reduce the rate of evapotranspiration. It may be caused, first, the plant inhibits removable leachate into the air. The first possibility was supported by the fact that the rate of evaporation increases with the increasing weight of compost. Second, the process of compost and leachate which produces a lot of gas, thus inhibiting the release of leachate gas from the bed. The second possibility was supported by the fact that the accumulated gas in compost rich media was more than in less compost media for one month continuous loading (Fig. 3). This was similar to the work of Bialowiec & Wojnowska-Baryla (2008) that the application of sewage sludge into the soil caused the increase in the vapourisation efficiency.

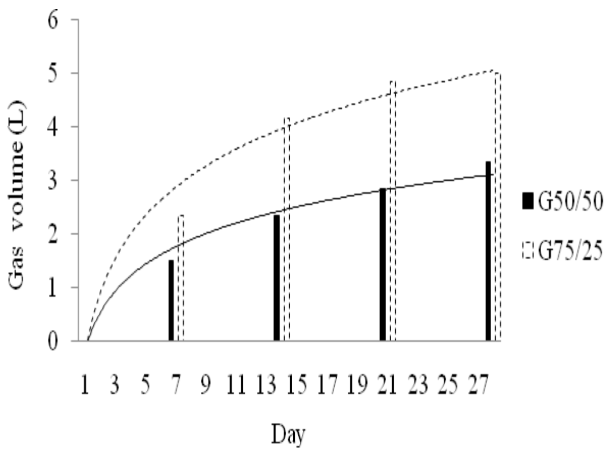

Fig. 3. Gas produced during leachate loading

Therefore, the optimum composition of the media was the weight of compost did not exceed the weight of sand.

3.3 Optimum volumetric loading

Volumetric loading was formulated as follows:

$$VL = Q*C/V_{bed} \quad (1)$$

The quantity of Q was evapotranspiration rate (ETR in Table 2 was converted into L/hour). The V_{bed} was bed active volume, which amounted to 60L. The amount of C in this calculation was parameters concentration (Table 1). Thus, the calculation of VL was based on the 16.4*Q*C (mg/day/L) for diluted leachate of 50% and the 8.1*Q*C (mg/day/L) for diluted leachate of 25%. The optimum volumetric loading for the parameters measured in the leachate was presented in Table 3.

Table 3. Optimum volumetric loading for the parameters measured in the leachate

Parameters / Materials	mg N /day/L	mgBOD /day/L	mgCOD /day/L
Diluted leachate (50%)	0.3	1.8	10.6
Diluted leachate (25%)	0.4	1.9	11.4

Volumetric loading for diluted leachate of 25% was greater than the volumetric loading for diluted leachate of 25%, but the differences were not very significant by considering at the ratio of VL_{BOD}/VL_{COD} each diluted leachate was the same. Therefore, the optimum volumetric loading depends on the ETR in conditions of optimum composition of the media.

3.4 Loading methods

Continuous and intermittent loadings were conducted for evapotranspiration beds of different media composition (C/S = 50/50 and 75/25) that were presented in Figure 4.

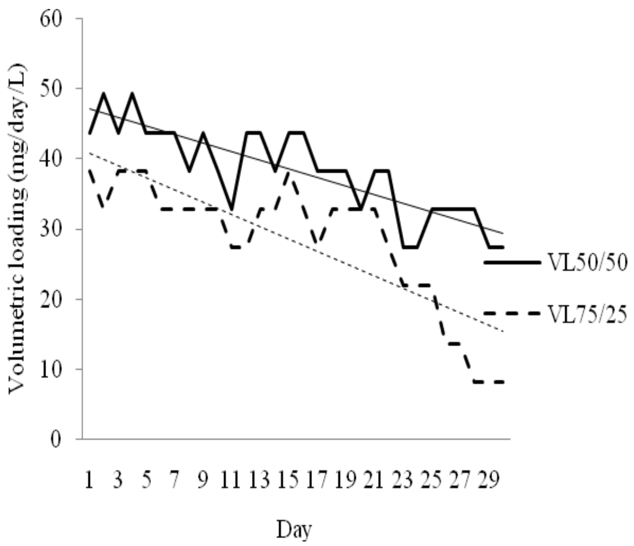

Fig. 4. Volumtric loading for continuous loading

For comparison purposes, the relative rate of decrease in volumetric loading (RRD_{VL}) was used because the initial volumetric loading was different among the treatments. The relative rate of decrease was calculated based on the initial volumetric loading (VLi) substracted by volumetric loading at the end of the loading period (VLt) divided by the initial volumetric loading and loading period (t) as follows:

$$RRD_{VL} = [(VLi – VLt)/VLi)]/t \quad (2)$$

Furthermore, the results of the process within the media bed stated as biodegradability indicator for compost and leachate mixture. The biodegradability indicator was measured based on the gas volume in the pipe upside down. The results of gas production in continuous loading was not shown in the Figure 4 due to low volume and complicated the figure. Since the beginning there was no gas, then the rate of increase in gas volume (RI_{GV}) was calculated based on the gas accumulated at the end of the loading period divided by the loading period (L/day).

The results of the relative rate of decrease in volumteric loading (RRD_{VL}) and the rate of increase in gas volume (RI_{GV}) were presented in Table 4 for diluted leachate of 50% and 25% by continuous loading. It was important to report that the continuous loading for leachate lasted for 30 days. After the loading period, the media did not produce gas, which revealed the process in the media stops.

Table 4. The relative rate of decrease in volumetric loading and the rate of increase in gas volume for continuous loading

	Diluted leachate (50%)		Diluted leachate (25%)	
Media composition	RRD_{VL} (/day)	RI_{GV} (L/day)	RRD_{VL} (/day)	RI_{GV} (L/day)
C/S = 50/50	0.16[a]	0.04[a]	0.11[a]	0.02[a]
C/S = 75/25	0.79[b]	0.06[b]	0.41[b]	0.03[b]

Numbers followed by the same letter at the same column were not significantly different (p = 0.05).

It was clear from Figure 4, that the volumetric loading decreases, where the relative rate of decline in volumetric loading (RRD_{VL}) was significantly greater for the composition of media C/S= 75/25 (Table 4) compared to RRD_{VL} for the composition of media C/S= 50/50. This fact strengthened the optimum composition of bed media for the C/S= 50/50.

Based on the fact of decreasing VL for continuous loading during one month and no more process at the end, then the next loading methods were conducted intermittently for C/S= 50/50. Continuous loading run for one month and followed for one month resting period was repeated within a period of nine months (Fig. 5).

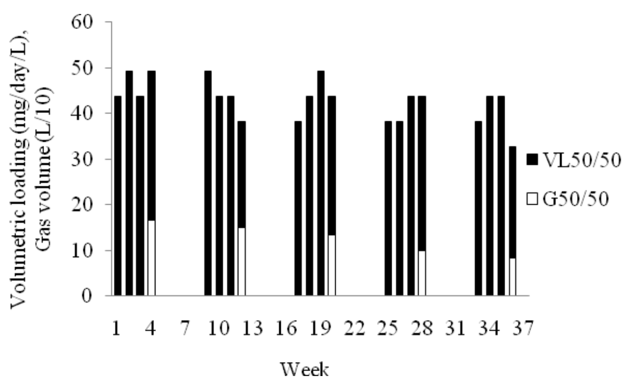

Fig. 5. Volumetric loading and gas produced for intermittent loading

Results showed that the volumteric loading for compost/sand proportion of 50/50 (VL50/50) could be maintained and the gas was produced. The fact revealed that the resting period was capable of restoring the beds to the repeated loading. The result was similar to the work of El-Sherbiny & Abed El-Lateef (2009) in investigating the effect of irrigation intervals and organic fertilization on soil physical properties.

3.5 Materials improvement

The quality of leachate and compost mixture in the media after continuous and intermittent loadings for optimum composition (C/S= 50/50) were presented in Table 5.

Table 5. The quality of leachate and compost at the end of loading

Loading methods	BOD (mg/L)	COD (mg/L	BOD/COD	CO_2-C (g/kg)	Total N (g/kg)	C/N
Diluted leachate (50%)						
Continuous	196 ±17	1,112 ±42	0.17	432 ±23	33.7 ±3	12.8
Intermittent	98 ±3	456 ±17	0.21	211 ±16	21.4 ±2	9.9
Diluted leachate (25%)						
Continuous	113 ±11	652 ±23	0.17	307 ±21	23.7 ±2	12.9
Intermittent	83 ±5	324 ±12	0.26	166 ±13	17.9 ±2	9.3

A quantitative measure for materials improvement used the common process efficiency (E), which was defined as follows:

$$E = [(Ci - Ce)/Ci]*100\% \quad (3)$$

where Ci was influent concentration (Table 1) and Ce was effluent concentration (Table 5). From eq. (3), it resulted in BOD, COD and N efficiency as presented in Table 6.

Table 6. Process efficiency for BOD, COD and Total N

Parameters / Loading methods	BOD %	COD %	Total N %
Diluted leachate (50%)			
Continuous	80	81	81
Intermittent	90	92	88
Diluted leachate (25%)			
Continuous	77	78	75
Intermittent	83	89	81

Table 6 showed that the evapotranspiration bed could reduce BOD, COD and N. Reduced substances in intermittent loading was greater than the continuous loading, indicating the resting period could enhance degradation. More importantly, the final quality of leachate and compost materials showed entirely biodegradable until stable and mature.

3.6 Process conditions

Evapotranspiration bed could be categorized as a biological treatment in granular media. The above experimental facts revealed that evapotranspiration bed had the ability to process the leachate with BOD > 1,000mg/L and COD > 5.000mg/L and the ratio of BOD/COD < 0.2. The quality was in the category of toxic organic towards aerobic microbes (Priambodo & Karnaningroem, 2010). The question arises, why the quality of leachate in the category of organic toxic for microbes can be processed biologically?.

First, the current research used evapotranspiration without infiltration and thus, leachate was stored in the media and disposed to air in the form of vapour. In such case, the possibility of the bed media was in an anaerobic conditions and the active microbes were anaerobic ones. Anaerobic microbes were capable to process the organic substances in high concentrations as studied by Chrobak & Ryder (2005) and Yordanov *et al.* (2010) in their work with wastewater, which contained BOD of 1,900-20,000mg/L and BOD of 750-900mg/L respectively

Second, the compost in the sand was biodegradable. Compost volume was 28L in the proportion of compost/sand at 50/50. Meanwhile the capacity of the media to store leachate was 2.8L in the same media conditions (Table 2). Mass balance for the combined materials could be formulated as follows:

$$(V*C)mixture = (V*C)compost + (V*C)leachate \quad (4)$$

Where V was volume and C was BOD or COD concentration (Table 1). From eq. (4), it resulted in BOD mixture of 386mg/L and COD mixture of 667mg/L for diluted leachate of 50%. The BOD and COD concentrations in a mixture were considered biodegradable and could be processed biologically.

3.7 Design criteria and treatment system configuration

Design criteria for the evapotrasnpiration bed, however, should take into account security in a sustainable biological processes. Therefore, strategies were needed which concentration of substances should not be toxic to microorganisms in granular media and plants on the bed. Consequently, the safe limit in processing leachate in evapotranspiration bed was BOD < 1,000mg/L, COD < 5,000mg/L and the ratio of BOD/COD > 0.2. If the leachate quality worse than these limits would require pretreatment such as physico-chemical treatment (Sarudji, 2007).

Thus, as evapotranspiration bed supplies, the wastewater quality must meet the quality of supply.
The treatment system configuration in safe conditions was presented to guide the implementation design (Figure 6).

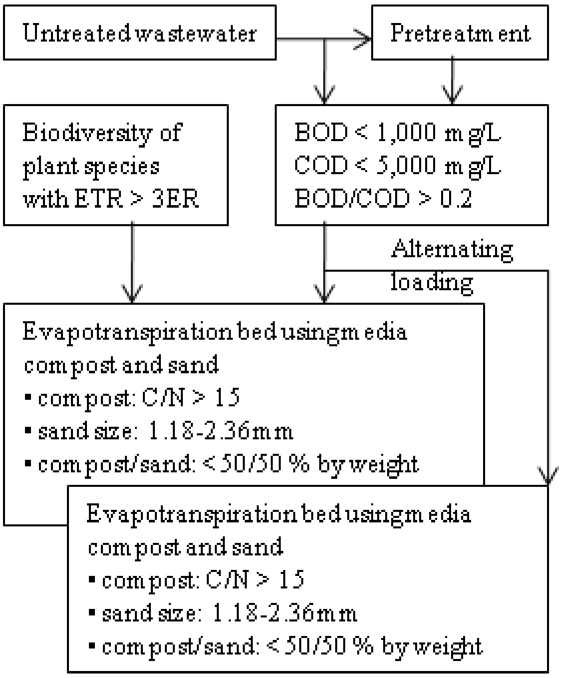

Fig. 6. Treatment system configuration

At the same time the required plants species should be determined based on the ability to produce high ETR. The current research by using elephant grass showed that ETR > 3ER (Table 2), however, it was based on the reduction of BOD, COD and N. Biodiversity of plants was recommended for capable of processing many substances that would actually present.
Furthermore, the compost was selected which has a ratio of BOD/COD > 0.5 (unstable) and C/N > 15 (immature). The quality of compost will reduce leachate toxicity and improving its stability. Sand particle size could use the size of the sand filter for drinking water treatment. The proportion of compost/sand should no more than the equal weight, in order to work optimally.
Next, put up a minimum of 2 beds, which operated alternately, after loading a minimum of one month. The intermittent loading and resting periods should consider the preparation of evapotranspiration bed, where plants have been growing well on it.

4. CONCLUSIONS

Evapotranspiration bed can be a means for treating leachate and compost for their stability and maturity. The optimum composition of bed media was a mixture of compost and sand at maximum equal portions, which would produce optimum volumetric loading. Intermittent loading method was recommended for operational continuity. This was the main steps to develop research in the near future, involving evapotranspiration bed with infiltration and native plants diversity that grown on the evapotrasnpiration bed.

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Received: December 06, 2010 / Accepted: May 30, 2011 / Paper published online: June 10, 2011
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