Performance of *Elaeis Guineensis* Leaves Compost in Filter Media for Stormwater Treament Through Column Study

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Abstract: Compost based materials arv e widely used in filter media for improving soil capability and plant growth. The aim of this paper is to evaluate different types of compost materials used in engineered soil media through soil column investigation. Three (3) column, namely C1 (control), C2 and C3 had different types compost (10%) which were, commercial compost namely PEATGRO, Compost A and Compost B were prepared with 60 % medium sand and 30% of topsoil. The diluted stormwater runoff was flushed to the columns and it was run for six (6) hour experiment. The influent and effluent samples were collected and tested for Water Quality Index (WQI) parameters. The results deduced that C3 with *Elaeis Guineensis* leaves compost (Compost B) achieved 90.45 (Class II) better than control condition which accomplished 84 (Class II) based on WQI Classification. C3 with Compost A (*African Mahogany* Leaves Compost) obtained only 59.39 (Class III). C3 with the composition of Compost B effectively removed most pollutants, including Chemical Oxygen Demand (COD, Ammoniacal Nitrogen (NH_3-N), were reduced by 89±4% and 96.6±0.9%, respectively. The result concluded that *Elaeis Guineensis* leaves compost is recommended to be used as part of engineered soil media due to its capabilities in eliminating stormwater pollutants.

Keywords: Elaeis Guineensis leaves compost, stormwater pollutants, soil column study, filter media.

1. Introduction

Compost based material has been introduced as part of engineered soil media composition in bioretention to alleviate the problem associated with stormwater contaminant. It was believed that compost material capable to provide microbial populations which allow more microbial activities and supply carbon source, nutrients and moisture [1]. Typically, engineered soil media composition has 10-20% of compost, 50-60% sand and 20-30%topsoil in the detention system. Compost consists of large amounts of organic matter offer significant functions in enhancing soil capabilities and vegetation growth.

However, the use of compost must need to take into consideration because it led to nutrient leaching out of their system. Compost properties also assist on remaining greater hydraulic conductivity as compared to topsoil in long term duration due to having a porous structure [2].

Compost is usually applied in an urban garden for energizing the soil. However, it always depends on the type and quality of compost which then effect on metal solubility [3]. Besides, it has potential to discharge contaminants which originally exist in the compost which resulted leachate flows to the surface runoff or groundwater [4].

Organic leaves are one of the potential materials that can be used in the composting process. Brown materials such as old leaves, woodchips and tree bark are good materials which act as a carbon source in compost while green material such as chicken manure or cow dung supplied nutrient and high organic content. Alcala et al. [1] found that compost product was effectively treated nitrate from surface water.

Oil Palm (*Elaeis Guineensis)* leaves is usually will be dumped as a waste nearby or being used for livestock feed especially for cattle and goats [5]. These waste would not constantly used effectively which lead to land filling and open burning to dispose the oil palm residues [6]. Sidik et al. [7] reported that Oil Palm leaves had potential in removing oil spill which had maximum adsorption capacity of 1176±12.92mg/g at 303 K. However, the use of Oil Palm leaves as compost type for infiltration purpose was less documented. For this reason, this is an opportunity to make these types of leaves as part of the organic compost. Hence, this paper present to carry out the potential of Oil Palm (*Elaeis Guineensis)* leaves compost together with typical soil composition in filter media which then enhancing stormwater quality.

2. Material and Methods

2.1 Compost Preparation

Three compost materials were chosen based on product availability and quality as shown in Figure 1. PEATGRO compost was obtained from local supplier as typical compost product. Another 2 (two) compost was prepared in the lab by grinding the brown materials (old leaves) into small pieces. Compost A consisted of 1:1 ratio of green material (cow grass) and brown material (African Mahogany (*Khaya senegalensis*) leaves), 1% of chicken manures and water. Compost B was prepared by 1:1 ratio of green material (cow grass) and brown material (oil palm (*Elaeis Guineensis*) leaves), 1% (by weight) of chicken manure and water. This compost preparation method was recommended by [14].

The main characteristics of compost mainly moisture content, conductivity,and pH measurement were tested. Dry mass determination was generated to compute moisture content [1]. A 10g of the compost sample was dried for 24 hours in 105-110°C. Equation 1 is used to calculate moisture content. For pH and conductivity measurement, 5g dried sample was weighted and adding 25 ml of deioinzed water [1]. The solution was stirred for 2 minutes and leave to stable for another 5 minutes. Then, the samples were tested using YSI Professional Plus Multiparameter Instrument. The instrument was calibrated for pH measurement before measuring compost samples. Calibration was attained using two (2) buffer solutions of pH 4 and 7.

$$M_n = \frac{w_w - w_d}{w_w} x100 \qquad (1)$$

Where;

M_n	=	Moisture content of compost (%),
W_w	=	Soil weight during wet condition,
W_d	=	Soil weight after 24 hours dry

Figure 1. Three (3) different types of compost materials.

2.2 Soil column preparation

Three acrylic soil columns (160L, 0.16 m^2) were designated for the evaluation of various types of compost in engineered soil media. Four layers were consisted of ponding layer, engineered soil media layer, transition layer (coarse sand with 0.6 - 2mm diameter of grain size) and underdrain layer (gravel with 6-9 mm diameter of grain size) to mimic a typical impermeable system of bio retention as illustrated in Figure 1.

Various materials of compost (10 % only) were mixed with 60% of medium sand and 30 % topsoil. Medium sand and topsoil were dried at 105°C within 24 hours and sieved with a particle size range of 0.2-0.6 mm (BSI, 1990) and less than 2 mm of grain size [8]. Then, all materials were mixed uniformly with suitable composition using mechanical mixing drum. Once completed, the mixtures were filled in acrylic columns with 27 blows using fabricated light hammer at every 100 mm depth of engineered soil media to have uniform compaction since it also influence the hydraulic conductivity.

2.3 Stormwater collection

Approximately 500 L of raw stormwater runoff samples was collected at existing drain nearby Parit Buntar, Perak. The area is in urban areas with mixed development which has school, hotels, shop lots, restaurants and others. Then, the initial TSS concentration was tested to obtain the specific range of TSS before experimental work is carried out. In this study, the initial of mean TSS concentration was 1712 mg/L. A diluted runoff was prepared in a pollutant source tank with 0.8 times the average mean TSS concentration in Parit Buntar area.

2.4 Sampling and chemical analysis

All soil columns were flushed with tap water with 1-2 day to obtain saturated condition. Then, it was dried for at least one day to ensure tap water was released into the system. Then, six (6) hour experiment was taking place with stormwater pollutant where a volume of 500 L stormwater runoff was discharged to the columns. The purpose of short duration experiment was to simulate a short duration storm event and following treatment of small amount of runoff [1].The flow was adjusted until constant ponding level is achieved. The influent was sampled at the beginning of experiment. The effluent samples were collected in every 10 minutes for the first 30 minutes and every 30 minutes thereafter [9]. There were six (6) WQI parameters were tested mainly, pH, DO, BOD, COD, TSS, and NH_3-N. pH and DO were measured during sampling work using YSI Profesional Plus Multiparameter Instrument. BOD was tested using 5-Day BOD techniques. Each sample was tested and analyzed for nitrogen and phosphorus concentration. The stormwater sample collected was from a drain outlet between a parking lot and an open field. The nitrogen concentration was tested using the Nessler Method where the unit is in mg/L NH_3-N.

Figure 2. A soil column experiment in treating stormwater pollutants.

2.5 Statistical Analysis

The results of water samples were analyzed using one-way Analysis of Variance (ANOVA) and Tukey's Test Method with $p<0.05$ using Minitab 16. The results were compared among the varying types of compost materials in engineered soil media.

3. Result and Discussion

3.1Comparison of Compost Products' Characteristics

Table 1 lists the physical components in compost materials. From the data, it can be concluded that PEATGRO and Compost B have similar moisture % content, 41±1% and 47±1% respectively. Compost A had the highest moisture content which was 68±4%. This presumably because of those higher substances for more quickly breakdown ''green" proteinaceous material [1]. The conductivity among three compost was significantly different through non parametric Kruskal Wallis test with median 757, 157.1 and 40.1 µs/cm, respectively. Greater pH was obtained in Compost B which indicated alkaline condition. Similarly to Alcala et al. (2009) reported that the pH ranged between 6.5 to 8while Murray et al. (2011) obtained pH of compost at 7.3.

3.1 Stormwater Treatment Performance

Average treated stormwater runoff (Effluent) concentration for each different system were lower than raw stormwater runoff (Influent) excluding DO as presented in Table 2. It was found that DO levels were increased after the treatment. Based on Table 2, DO saturation was significantly different among the compost. C3 obtained higher DO (6.5±1.8mg/L) than control condition (C1) which has 5.3±1.7mg/L. DO in C2 was the lowest with only 2.6±0.6 mg/L. Higher DO indicated that the effluent samples were treated well in engineered soil media.

Table 1. Physical properties of compost materials (Values in mean + standard deviation (SD)).

Physical properties	Compost		
	PEATGRO	Compost A	Compost B
Moisture content (%)	41±1	68±4	47±1
Conductivity (µs/cm)	746±26	41.2±4	157.4±2.2
pH	7.2±0.2	7.0±0.0	8.2±0.6

Conversely, there was no statistically difference between TSS concentrations of treated storm water. In addition, all filter media satisfy the Water Quality Index (WQI) which fell under Class I (DOE, 2010).All the systems capable to filter physical sediments excellently regardless on the types of compost materials used in the system. This may be explained that the physical sediments were easily trapped at the top layer of filter media regardless the surface zone. However, higher volume of sediment trapped in the system might tend to clog pore sizes which affected hydraulic conductivity as highlighted by [10].

COD concentration of each treatment was comparable. Based on Tukey's test method, C1 and C3 are not statistically different because the confidence interval includes 0. However, there was a statistically different between the mean COD concentration of C1 and C2 and C2 and C3. This concluded that C3 has capabilities slightly similar to C1 as a control condition. In the early stage of the experiment, the effluent concentration of COD was greater than influent in column C2 which indicate negative removal efficiency. After half an hour running, the concentration, reduced and slightly constant until at the end of the experiment. It might be explained by COD concentration in the soil composition of C2 was higher and the filter media system yet to stabilize.

Treated stormwater from C1 and C3 were achieved Class II of WQI which the concentration of COD ranged between 10-25 mg/L (DOE, 2010). The lowest treatment was C2 which only felt under Class IV with value ranged 50-100 mg/L. Those progresses about COD demonstrated those effects from claiming influent mode of the carbon source distribution. COD could be firstly corrupted by vigorous microorganisms controlled by dissolved oxygen. [11].

Table 2. Water quality in raw stormwater (Influent) and treated stormwater (Effluent) (mean value ± standard deviation, *n*= 12 (Influent), *n*=36 per contaminants).

Parameters	Influent	Effluent		
		C1	C2	C3
pH	6.6±0.1	6.4±0.3	6.4± 0.1	6.5±0.2
NH_3-N (mg/L)	5.9±1.3	0.4±0.1	0.8±0.2	0.2±0.0
COD (mg/L)	123±4.2	14.9±3.5	70.2±6.9	13.5±4.9
TSS (mg/L)	1332±132	9.6±5.6	18.6±14.6	5.3±3.7
DO (mg/L)	1.5±1.3	5.3±1.7	2.6±0.6	6.5±1.8
DO_{sat} (%)	19.4±17	70.1±21	34.3±8.4	88.3±21
BOD (mg/L)	7.1±0.8	0.4±0.3	2.8±1.5	2.0±1.0
Overall Class	V	II	III	II
WQI	29.4	84.0	59.4	90.5

3.2 Treatment Efficiency

Urban runoff consisted of organic matters can be filtered, adsorbed and preserved for oxidative degradation by microorganisms [12] using biofiltration system. Hence, the capabilities of compost mixtures in filter media have been demonstrated in Figure 3. COD treatment efficiency was slightly similar in C1 (87.84±2.86%) and C3 (88.98±4.02%) which had no statistically different among both treatment. C2 which consisted of African Mahogany leaves compost obtained the lowest treatment efficiency with only 42.86±55.98%. Greater standard deviation (SD) is due to there was a negative (-) removal efficiency at the beginning of experimental work. This may be explained by filter media system in C2 yet to stabilize due to contain higher amount of organic matter in the system itself which insufficiently degraded by microorganisms.

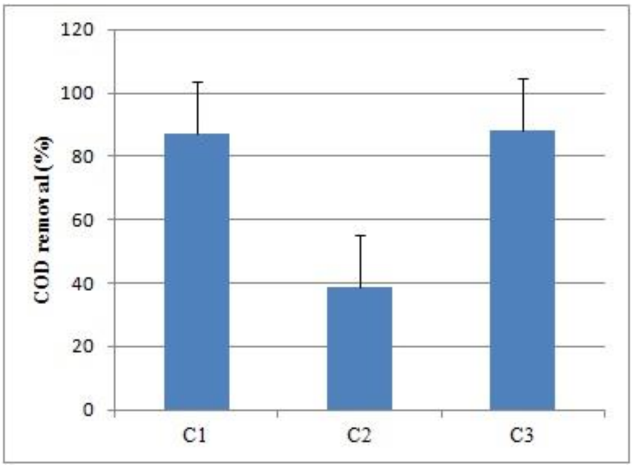

Figure 3. Treatment efficiency of COD among different types of compost materials.

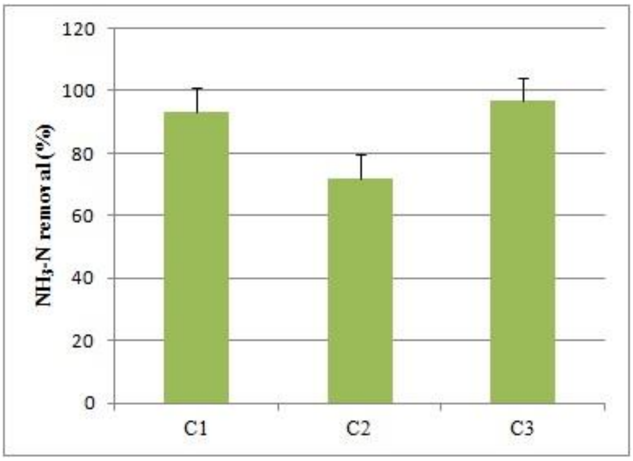

Figure 4. Treatment efficiency of NH_3-N among different types of compost materials.

Figure 4 illustrates the efficiency of the filter media system in treating NH_3-N. By comparing using Tukey Method, C2 and C3 had significantly different between these two treatments. C2 had 83.48±8.36% which was lower than C3 with 96.62±0.85%. However, there was no significant difference between C1 and C2 and C1 and C3. Based on this result, it was summarized that all media capable to remove NH_3-N excellently and C1 was successfully depleting NH_3-N concentration which slightly higher than C1(92.95±1.91%) as a control condition. This might be affected by the presence of an active community of ammonia oxidizing bacteria in the filter media system [13].

4. Conclusions

The comparison between the type of compost materials in the filter media system were obtained through soil column experimental work. Water quality analysis was carried out through standard laboratory testing and classified using WQI and removal efficiency.

C3 with existing oil palm leaves, compost in the engineered soil composition achieved successful performance, which fell under Class II in 90.5 of WQI indices which slightly higher than control condition (C1) that consisted of manufactured compost (PEATGRO) which only obtained 84.0. The mixture African Mahogany leaves compost, sand and topsoil had the lowest performance which only achieved Class III with 59.4 indices. The compost itself might contain higher organic matter which then contributes to the less performance in the treatment system.

Only COD and NH_3-N removal efficiency were discussed in this paper. COD in urban runoff was effectively captured by C1 and C3 with more than 85% removal. C2 probably had compost leaching problem in the early stage of experimental work which indicate by negative (-) removal. COD was treated less than 50% pollutant removal in C2. Conversely, NH_3-N removal performed better than COD. All treatment systems capable to reduce NH_3-N concentration very well with more than 80%. However, C1 and C3 excellently removed NH_3-N with more than 90% removal rates. Hence, oil palm leaves compost is recommended as a potential organic compost to be used as part of the component in the filter media system.

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