Assessing the performance of bio compost as soil media in extensive green roof

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Abstract. Composted green waste is a recycled material which can be produced locally, adding value to the environmental credentials of a green roof system. As the organic component of green roof growing media, composted green waste can contribute positively to the physical requirements as well as improve environmental performance. In addition, it can contain nutrients for plant growth and survival. These will not typically be provided by an inert inorganic substrate and will help establish vegetation. This study is aimed to investigate the performance of bio compost as soil media in extensive green roof with respect to different composition. Runoff were tested for total suspended solids (TS), turbidity, chemical oxygen demand (COD), pH, and color measurements. The results showed that 50% of bio compost in soil media has the best performance in term of plant growth and runoff quality.

1. Introduction

Urbanization process has significantly increases the stormwater runoff and pollutant build-up at the catchment surface area [1-4]. Urban heat island (UHI) phenomenon also happens at the urban city when impervious surfaces absorbs and then returns back the solar radiation. Compared to the surrounding landscape, the average air temperatures recorded in urbanized areas are higher [5]. As a result, greater expenditures are needed to keep the buildings cool via air-conditioning systems. Therefore, green roof have been highly promoted for controlling the urban stormwater runoff and enhancing the environmental quality at the urban city [6-8]. Green roofs are generally classified into three types which are intensive green roofs, semi-intensive green roofs, and extensive green roofs [9]. These different types of green roofs vary in terms of the vegetation growing on them therefore requiring different depths of growing medium used [8,10]. Extensive green roof plants would typically fulfil the characteristics of reproducing efficiently, having a short height as well as mat-forming, having shallow and spreading roots, and having succulent leaves which are able to store water [6, 11].

Understanding regarding the effect of soil composition in the green roof growing medium remain limited and have vital gaps. For example, limited studies are available on the effect of growing medium composition when it comes to evapotranspiration mechanisms. The same can be said about research on the role of depth or composition of growing medium as well of type of vegetation grown on air pollution. In addition, there is no literature on the evolution of the growing medium in terms of microorganism presence which plays a huge role in the nitrogen cycle. It is significant as growing medium which are different from natural soils in terms of mineral composition and organic compounds may cause specific varieties and activities of microorganisms [12]. So far, it is argued that the growing medium plays a vital component in extensive green roof designs. More specifically, the available water in the growing medium needs to be controlled to an acceptable amount to meet the requirements of the selected vegetation. As such, this can be achieved using two methods; i.e., manipulating the composition of the growing medium or more typically, limiting the depth of growing medium [13]. There is limited studies on the usage of bio-compost for green-roof media in Malaysian. Therefore, this study is aimed to investigate the performance of bio compost as soil media in extensive green roof with respect to different composition with the environmental parameters being total solids, turbidity, chemical oxygen demand.
The performance of bio-compost as a potential soil substitute or additive for the growth of Portulaca grandiflora or known locally as “ros jepun” in extensive green roofs, in the context of Malaysian high temperature and moisture weather conditions was investigated. The monitoring period of the experiments is 3 months. The growth media was prepared by mixing bio-compost (BC) and clay soil (S) at different ratios. Clay soil was chosen considering its wide use as soil medium in extensive green roofs. Five BC: S growth media mixtures (on a volume basis) was prepared as: Model 1 (BC:S =0) ie. 0% bio-compost, Model 2 (BC:S =0.25) ie. 25% bio-compost, Model 3 (BC:S =0.5) ie. 50% bio-compost, Model 4 (BC:S =0.75) ie. 75% bio-compost, and Model 5 (BC:S =1.0) ie. 100% bio-compost. The bio-compost were produced from composting food waste from municipalities in Putrajaya. Thus the bio-compost used were fully organic. Green roof models were set up with a uniform 10 cm depth of growth medium. All five green roof models have dimensions of 30 cm (depth) x 30cm (width) x 50cm (length). Filter membrane was put between the soil medium and drainage layer to prevent the losses of soil medium along with runoff. Collecting tank were connected to the discharge point of the green roof model. The schematic diagram of green roof model is shown in Figure 1. The five models were located at the open space beside the civil engineering laboratory of Universiti Tenaga Nasional.

![Figure 1. Schematic diagram for green roof model](image)

The experiments were conducted throughout the months of August and September whereby the average rainfall in the region was around 200 to 250mm. The rainwater passed through the vegetation layer and substrate layer/ growing medium and then retained at the drainage layer in the green roof model. Rainwater runoff was collected from the green roof models via the collecting tanks that was installed. The runoff samples were then analyzed to determine the runoff quality from green roof models with different percentages of bio-compost. The runoff samples were tested for total solids (TS), turbidity, chemical oxygen demand (COD), pH, and color concentration.

3. Results and discussions

The runoff qualities from the green roof models with different bio-compost composition percentages were determined over the 3 months monitoring period. From the results over nine weeks, green roof model with 0% of bio-compost has the highest total solid (TS) concentration while the lowest is the green roof model with 100% bio-compost as soil medium. This observation may explain that the sample with 0% of bio-compost consists of only soil which would contain a lot of inorganic materials like salt. Throughout nine weeks of monitoring period, the readings of total solids concentration were observed to be reduced slightly over time as shown in Figure 2.
Figure 2. Total solids concentrations for different green roof models over the monitoring period

Figure 3. Turbidity measurements for different green roof models over the monitoring period

Turbidity is used as the visible indicator of runoff quality for green roof models. Molineux [14] stated that clear water is usually considered as an indicator of healthy water. From the turbidity results as shown in Figure 2, the sample that has highest turbidity concentration is sample with 0% bio-compost concentration while lowest turbidity is the runoff sample from green roof model with 100% of bio-compost. This shows that the sample with 0% of bio-compost has a high amount of suspended solids.
The most commonly measured chemical attribute of water is its acidity or pH. The pH scale ranges from 1 to 14, with 1 being the most acidic and 14 being the most basic. Most streams have a neutral to slightly basic pH of 6.5 to 8.5. If streamwater has a pH less than 5.5, it may be too acidic for fish to survive in, while streamwater with a pH greater than 8.6 may be too basic. A change in streamwater pH can also affect aquatic life indirectly by altering other aspects of water chemistry. For example, low pH levels can increase the solubility of certain heavy metals. This allows the metals to be more easily absorbed by aquatic organisms as mentioned by Rostern [15]. A shift of pH in either direction from neutral may indicate the presence of a pollutant in a body of water.

Runoff samples from green roof models with 0% and 100% of bio-compost indicate high pH value as shown in Figure 3. Instead, the runoff sample from green roof model with 50% of bio-compost has the lowest pH value of 7.7 which is the nearest to neutral value. This result may suggest that 50% of bio-compost as soil medium can better control the pH value of the runoff water.

The runoff quality from the green roof models are also checked for colour, BOD and COD concentrations. The average values for these parameters are summarized in Table 1. For colour measurement, the unit is Pt/Co (platinum cobalt). From the results in Table 1, it is clearly shows that the higher the bio-compost percentage, the darker the color of the water sample. Similar observation was reported by Razzaghamanesh [16]. Biochemical oxygen demand (BOD) is used to measure the amount of oxygen used by aerobic bacteria during decomposition in the water. Lower BOD value means that the sample is less polluted. A higher BOD indicates a high content of easily degradable organic material in the water sample [17]. While, a low BOD indicates a low volume of organic materials substances which are difficult to break down. Among the five samples, the sample with 50% bio-compost composition has the lowest BOD measurement. Other than that, green roof model with 50% of bio-compost also shows the lowest COD concentration after the control green roof model with only soil medium. This shows that too much bio-compost may lead to an unwanted pollution to the environment.
Table 1. BOD, COD and colour measurements for green roof models with different percentage of bio-compost

| Sample (Bio-compost %) | BOD (mg/L) | COD (mg/l) | Color (PtCo) |
|------------------------|------------|-----------|--------------|
| 0                      | 98.2       | 78        | 71           |
| 25                     | 48.8       | 448       | 1630         |
| 50                     | 37.2       | 354       | 1650         |
| 75                     | 47.6       | 714       | 2016         |
| 100                    | 154.6      | 584       | 3536         |

In terms of physical growth of the plants, it can be observed that model with 50% of bio-compost shows the best plant growth while green roofs with 0% and 100% of bio compost show limited growth as shown in Figure 4. This is probably due to the lacking and over-abundance of nutrients for green roofs with 0% and 100% of bio compost, respectively. This observation is generally similar with previous studies done by Van Woert [18]. While bio-composting is a great way to give useful purpose to waste materials, care needs to be taken as not to pollute the aquatic environment when bio-compost is utilized as growing medium in green roof.

Figure 5. Plant growth conditions for (a) 0%, (b) 25%, (c) 50%, (d) 75% and (e) 100% of bio compost in green roof models
4. Conclusion
The green roof models with bio-compost inclusion show favourable results compared to the control model with only soil as the growing medium. The results showed that higher composition of bio-compost in the growing medium cause lower total solid and turbidity values. However, it is clear from experimental result that higher bio-compost also can lead to more intense color of runoff from the green roof models. The green roof model with 50% of bio-compost composition has the lowest pH value if compared to that models with 0% and 100% of bio-compost. The 50% bio-compost of green roof model shows the lowest BODs and COD measurements for the runoff quality. In addition, the plants grown on the model with 50% bio-compost appears to grow as the most healthily. Therefore, it is concluded that the ideal composition of soil to bio-compost is 1:1 in Malaysian tropical climate conditions.

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