The Role of Bioretention Plant on Nutrient Removal of Stormwater Runoff

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Abstract. Stormwater pollutants are one of the main problems causing environmental damage. The accumulated pollutants on urban impervious surfaces are carried by stormwater runoff and enter water bodies, therefore, caused ecological damage. To decrease the pollution effect of stormwater, best management practices (BMP), and low–impact development (LID) principles were introduced. Bioretention technology as one of these practices has been used to control stormwater quality. This technology stills not widely used in Malaysia. However, the design of bioretention system that used in Malaysia follows a conventional design and stills in the early stage. Therefore, this paper reviews the role of plants and their effect on bioretention performance in terms of nutrient removal. Bioretention system that vegetated with the plant was very effective on nutrient removal than without plant. In Malaysia, there is a need to develop the conventional bioretention system. Applying multispecies plant in bioretention system would be more effective on nutrient removal. However, limited studies have been conducted on the types of plant that are suggested in (MSMA). This paper recommends applying multispecies plant (mixture plants) to enhance the performance of conventional bioretention system in terms of nutrient removal.

1. Introduction

In recent years, the world witness increasing in urbanization which caused the expansion of impermeable surfaces such as parking lots, roofs, buildings, and streets. Interestingly, these surfaces prevent the natural filtration process of stormwater that flows through ground layers. This issue caused increasing runoff volume and decreasing water quality. Malaysia as one of the developed and tropical countries has been witnessed economic growth and structural since 1957. This development caused the accumulate of pollutants in urban areas. Malaysia is a tropical country that has a higher stormwater pollutant concentration compared with a temperate countries such as Australia and the USA [1]. It is essential to mitigate stormwater pollutants to achieve clean water bodies [2]. In Malaysia, there is a descent in the number of rivers with good water quality and this problem should be taken seriously [3]. The quality of stormwater can be enhanced by applying advanced approaches such as management system practices (BMP) and low- impact development (LID) [4]. The Bioretention system is considered one of the best management practices [5]. The performance of bioretention system is widely variable on nutrient removal [6]. Some studies enhanced bioretention system performance by the usage of different plant species [7]. Due to the vital role of the plant on nutrient removal in bioretention system [8]. There is a need to review the effect of the plant on bioretention system performance. This paper reviews the role of plants on nutrient removal of bioretention system. Discusses the effect of using the plant on performance of bioretention system in Malaysia.

1.1. Non-Point Source Pollutants
Flowing stormwater runoff via impervious surfaces collect a large amount of accumulated pollutants that have produced by human activity, these pollutants cause a non-point source pollutant [9]. Stormwater pollutants account for the main part of non-point source pollutants [9]. Dissolved pollutants such as nitrogen and phosphorus represent a half stormwater pollutant [10]. These pollutants harm the ecological system and caused kill fishes in water bodies [11]. Stormwater pollutants still the main challenge that should be solved [11].

1.2. Low-Impact Development (LID) and Best Management Practices (BMPs)

Recently, stormwater management systems encourage more previous areas and raise the infiltration of rainfall[12]. Sustainable Urban Drainage System (SUDs) is implemented in UK which is associated with the stormwater management system. While in other countries such as the USA it is called Low Impact Development (LID) and in Australia carries out a similar concept names Water Sensitive Urban Design (WSUD). In Malaysia, DID introduce the same practices which are given in the Urban Stormwater Management Manual for Malaysia (MSMA) [12]. There are many types of Sustainable Urban Drainage System (SUDs) such as grassed swales, permeable pavements, infiltration trenches, tree boxes, wet ponds, sand filters, constructed wetlands, soak ways, extended dry detention basins, bioretention zones, infiltration basins, and rain barrels [4].

1.3. Overview of Bioretention System

One of the most popular best management practices (BMPs) is biofilters or names as rain gardens or bioretention system. Recently, bioretention technology has taken common attention due to its stormwater quality and quantity management [13]. Bioretention system fulfils the stormwater management goals such as mitigate surface and groundwater pollution however reduces runoff volume and peak flow [14]. Bioretention technology consists of several layers from bottom to top gravel, sand, soil, and mulch as well as different plant species. Table1 summarizes the role of each bioretention layer. The bioretention system is a combination of several processes such as physical, chemical, and biological. These processes including mechanical filtration, sedimentation, adsorption, plant and microbial uptake contribute to treat stormwater runoff [15]. Figure 1 shown bioretention components.

Table 1. The role of each bioretention layer

| Design features | Role | Reference |
|----------------|------|-----------|
| Mulch layer | Plant survival, prevent clogging, moisture content, water holding capacity, nitrification | [1] |
| Plant | Aesthetics, infiltration, slow the runoff flow, nutrient uptake | [16] |
| Filter media | Survival vegetation, nutrient sorption, adsorption, filtration, nitrification, denitrification | [17] |
| Soil amendment | CEC holding capacity, bulk density moisture content PH, adsorption, nitrification, and denitrification | [18] |
| Transition | Prevent washout of soil media | [12] |
| Gravel | Collect and conveys treated water to the outlet pipe. | [12] |
1.4. The Role of Vegetation on Nutrient Uptake

The plant has a pivotal role in mitigating pollutants and stormwater runoff control [19]. Further, it protects the soil media from the erosion effect of rainfall and provides an aesthetic view [16]. There is evidence that vegetation plays a crucial role in the physical and chemical properties of soil media as well as microbial activity [20]. The efficiency of bioretention system is highly depending on the type of plant [8]. Selecting the type of plant is based on their effectiveness in treatment as well as the capability to withstand the environmental conditions [8]. The type of roots is contributed to highly increase pollutant removal [21]. Furthermore, the plants play a critical role in hydraulic conductivity and clogging [16]. Vegetation enhances NO3 removal by 0-47% [22]. Vegetated bioretention System enhances TP removal from 57% to 73% [23]. In Malaysia Red Hot Chinese Hibiscus (Hibiscus rosasinensis) is the number one plant among all types of plants. It is favourable to be planted in bioretention system due to high resistance to dry weather and high removal performance [12]. Hui Weng Goh et al. [24] conducted a study on the effect of the plant on nutrient removal efficiency and found that the enhancement media and plant increase TP removal from 84.9% to 93.3% and TN from 57.4% to 80.4%. However limited studies have conducted on other native plants that suggested by stormwater management guideline in Malaysia (MSMA) [12]. A study conducted on some plant such as, Ti plant (Cordyline fruticosa), Rosea variegate (Graptophyllum pictum), Bamboo grass (Bambusoideae), and Umbrella plant (Cyperus alternifolius) to assess their performance on nutrient and heavy metals removal and some of these plants proved a good performance [25].

1.5. Multispecies Planting in to Bioretention System

Applying a mixture of plants in one bioretention system is recommended [26]. Furthermore, diversity plants in bioretention system increase nutrient removal and enhance resistance to the environment condition [27]. Wu et al. [7] has proved that usage of two species of plant in one bioretention system is more nutrient removal than planting with one plant. The varies in root type and depth increase removal efficiency [7]. In Malaysia, stormwater management guidelines suggested many plant species for use in bioretention system, but a few studies have investigated the effectiveness of these plants [28].

2. Conclusion

This paper highlighted the role of the plant on the performance of bioretention systems and nutrient mitigation. Also discussed some of the related studies on bioretention system in Malaysia. Bioretention system with plants is better nutrient removal than without plant. In Malaysia, limited studies were conducted to assess the performance of the suggested plants by stormwater management guidelines (MSMA). Some of these plants proved good nutrient removal. The use of diverse plants in
one bioretention system is very effective in nutrient removal. Applying multispecies plants in one bioretention system is still not studied yet in Malaysia. To enhance a conventional bioretention performance in terms of nutrient removal, this paper recommends more investigation on mixing suggested plants by (MSMA) in bioretention system.

3. References

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Acknowledgments
The authors would like to acknowledge the support given by Yayasan Universiti Teknologi PETRONAS (YUTP) 015LC0-151 and Fundamental Research Grant Scheme (FRGS) 015MA0-070 under Ministry of Higher Education of Malaysia.