EFFECTIVENESS OF COFFEE RESIDUALS AS GREEN ROOF MEDIA

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SCHOOL OF CIVIL ENGINEERING
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By

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ABSTRAK

Proses pembandaran yang berkembang pesat telah menyebakan kawasan hijau yang telap air semakin berkurang. Ketika bumi sedang diancam krisis iklim, solusi berteraskan teknologi hijau adalah wajar diterokai. Bumbung hijau merupakan salah satu teknologi hijau yang mula diaplikasikan kerana dapat mengurangkan suhu bangunan, meningkatkan kualiti air hujan dan melambatkan aliran air hujan Namun perlu lebih banyak kajian terhadap keberkesanan bumbung hijau terutama melibat penggunaan bahan-bahan tertentu sebagai medianya. Oleh itu, hampas kopi dipilih sebagai bahan berpontensi meningkat keupayaan bumbung hijau ini. Beberapa model bumbung hijau berukuran 20cm x 20cm x 45cm dibina untuk kajian ini melibatkan sampel lajur kawalan dan sampel lajur hampas kopi. Pemerhatian dan uji kaji makmal dijalankan untuk tempoh lapan hari. Melalui uji kaji ini, peratusan purata penyingkiran beberapa parameter adalah direkodkan oleh hampas kopi iaitu 72% (Kekeruhan), dan 43.9% (Jumlah Fosforus) manakala untuk Warna dan Jumlah Nitrogen diperhatikan meningkat kerana beberapa factor termasuk ketidakstabilan sistem dan kandungan organik dalam media. Sementara itu, nilai pH dapat hampir dinuteralkan sekitar 6.9. Apabila dibandingkan dengan Piawaian Kualiti Air Kebangsaan rata-rata kelas air berada dalam kelas II bagi parameter Kekeruhan dan pH manakala parameter lain menjangkaui nilai ambang. Dapatan kajian mendapati hampas kopi mempunyai keberkesanan berdasarkan beberapa parameter iaitu Kekeruhan dan pH namun memerlukan kajian lanjut dan berterusan untuk parameter lain.

ABSTRACT

The rapid process of urbanization has led to a decline in water -permeable green areas. As earth is facing the climate crisis, green technology -based solutions are worth exploring. Green roof is one of the green technologies that widely applied because it can reduce building temperature, improve rainwater quality, and slow down the flow of rainwater among others. However, more research needed on the effectiveness of green roof, especially the application of certain materials as a its medium. Therefore, coffee grounds are selected as a material potentially increasing the effectiveness of green roof. There are four green roof models measuring 20cm x 20cm x 45cm were constructed for this study involving control column samples and coffee residual column samples. Observation and laboratory experiments were conducted for a period of eight days. From the experiments, the average percentage of removal for selected parameters was recorded by coffee residual which was 72% (Turbidity), and 43.9% (Total Phosphorus) while for Color and Total Nitrogen were observed to increase due to several factors including system instability and organic content in the media. Meanwhile, the pH value was observed to nearly neutral at 6.9. When compared to the National Water Quality Standards the average water class is in class II for the Turbidity and pH parameters while other parameters exceeding the threshold values. The findings of the study found that coffee grounds have effectiveness based on two parameters namely Turbidity and pH but require further and continuous study for other parameters.

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LIST OF ABBREVIATIONS

DID	Department of Irrigation and Drainage
IDF	Intensity-Duration-Frequency
NQWS	National Quality Water Standard
NTU	Nephelometric Turbidity Unit
TN	Total Nitrogen
TP	Total Phosphorus
pH	Potential Hydrogen
USM	University Sains Malaysia

CHAPTER 1

INTRODUCTION

1.1 Research Background

Accelerated urbanization has a negative impact on urban rainfall-runoff processes and flood hazards because of rapid and unplanned changes in land use patterns (Ertan & Çelik, 2021). Changes in surface cover caused by urban development disturb the city's hydrological cycle. Impermeable surfaces and the removal of vegetation restrict the ability of rainwater to be intercepted, stored, and infiltrated (Zölch et al., 2017). Today, erratic rainfall becomes ordinary due to the ranging effects of climate change with a direct relationship between the rainfall intensity and the stormwater quality (Murshed & Khan, 2011). A previous study indicates the implementation of green roofs is able to control urban stormwater runoff besides improving the quality of the stormwater (Gong et al., 2019).

As one of the essential components of the green roof system, selecting the type and thickness of the substrate is a critical factor in determining the effectiveness of the system deliverables (Nagase & Dunnett, 2011). A renowned study stipulates that there are significant influences of substrate selection on the water quality of green roof outflows. Hence it needs to be constructed based on suitable substrate materials in line with their function in improving runoff water quality (Liu et al., 2019).

Being the second most valuable traded commodity in the world, coffee production generates a large amount of trash and by-products which could be used for a variety of purposes, including incorporation as a component in the substrate (Blinová et al., 2017). The term used coffee grounds (UCG) is to picture the waste product from brewing coffee. Although lacking a wide range of research on the application of (UCG) in improving water quality, the post-roasting coffee by-products are proven to remove metal and phenol in stormwater as stipulated by (Grace et al., 2016).

The implementation of green roofs across the world and in Malaysia particularly has proven to be benefiting the environment, social and economic perspectives. For instance, Heriot-Watt University, Acapella Residence, and Putrajaya City Hall have manifested the feasibility to incorporated green roofs in local climate conditions with less maintenance needed (Ismail et al., 2018).

1.2 Problem Statements

The number of impermeable surfaces that do not allow water to infiltrate into the ground increases as cities grow. In such cases, increased stormwater runoff can have negative consequences for nearby lands and receiving streams. Flooding increased peak flows, increased stream velocities, and reduced water quality are all possible consequences (Agouridis et al., 2011). Numerous studies have demonstrated that green roofs can help reduce runoff from rainfall. Green roofs retain an average of 56 per cent of their moisture in many countries with different climate conditions (Gregoire & Clausen, 2011).

Coffee is one of the world's most consumed beverages. Every day, approximately 3.5 billion cups of coffee are consumed worldwide. However, the coffee industry generates significant amounts of solid waste where for every 1 g of ground coffee, approximately 0.91 g of spent coffee grounds are produced (Blinová et al., 2017). Therefore, to echo the circular economy concept in eliminating waste, it is crucial to further analyze coffee residuals as substrate elements in improving water quality.

Urban stormwater quality is influenced by but not limited to contaminants caused by the ground phase but also by contaminants induced by the atmosphere (Gunawardena et al., 2013). As the cities sprawled, the rising number of vehicles and human activity has contributed to notable degradation of air quality. The existence of harmful chemical particles in the air, namely Zinc (Zn), Lead (Pb), Cadmium (Cd), Nickel (Ni), and Copper (Cu), corresponds to the surging traffic volume and congestion (Gunawardena et al., 2013).

Green roofs are often regarded as one of the most sustainable alternatives for resolving many urban settings. Even so, their efficacy in treating stormwater is highly debated. As rainwater may contain a variety of dangerous substances, it is critical to decreasing the number of pollutants in gathered rainwater. Hence, more research on different types of media is necessary to ultimately justify the green roof system.

1.3 Objectives

I. To obtain the green roof leachate quality data based on selected parameters according to National Water Quality Standards for Malaysia (NWQS) which are Total Nitrogen, Total Phosphorus, Potential Hydrogen (pH), Color, and Turbidity.

II. To determine the effectiveness of residual coffee as a substrate of green roofs in improving the green roof leachate quality based on the compliance of NWQS.

1.4 Scope of Study

This research focuses on the design criteria for green roofs, focusing on the media in which the residual coffee ground is mixed with sand. Particularly for this research, the permeability of the mixture of residual coffee ground and sand will be assessed. To facilitate that, constant head permeability for the mixture is carried out with the purpose of obtaining the permeability coefficient, k for sand and coffee residual mixture.

To replicate the rainfall intensity in the study area, a total of one-year rainfall data is obtained from the Department of Drainage and Irrigation (DID). The purpose is to have a greater control variable for the experiment to help ensure the results are fair and unskewed. Rainfall events data is analyzed from March 2021 to March 2022, with a peak rainfall event for each month selected to calculate the intensity.

Moreover, the focus of this research on water quality will involve several tests to assess the effectiveness of residual coffee grounds in improving the selected water quality parameters. Based on the National Water Quality Index (NWQS) by the Department of Environmental, the parameters will be tested from the water sample of raw stormwater and harvested stormwater from the green roof model. The selected parameters according to NWQS consist of Total Nitrogen, Total Phosphorus, pH, Color, and Turbidity that will be determined according to laboratory tests.

1.5 Limitation of Study

There are some limitations faced by the researcher throughout the study. The first obstacle of the experiment was to carry it out using a physical model of a real green roof. The cost and space constraints posed a significant difficulty in the model creation. As a result, a column study based on a true green roof design component was selected because it is more cost-effective and requires less area. In addition, the time constraints are another limitation as this study will involve the harvesting of first flush rainwater, which causes some of the experiments can only be carried out after a rainy day has passed, and sufficient sample volume has been gathered.

1.6 Dissertation Outline

To complete the research, there are a total of five chapters for the dissertation. The first chapter highlighted the introduction to the green roof and the vitality of the system for an urban setting, followed by problem statements, objectives, and the research limitations. The second chapter underscored the literature review based on previous studies regarding green roof systems. It will concentrate on the media studies for green roofs and the quality of rainwater samples collected. In this chapter, the focus is on the type of media of the green roof and the harvested rainwater quality. On top of that, the potential functions of residual coffee grounds in treating rainwater are also addressed. In chapter three, the methodology is described in detail method used in this particular research. In the fourth chapter, the author provides an explanation and discussion of the results obtained from the experiment done on the residual coffee grounds, as well as the quality of the rainwater captured from the green roof. Finally, chapter five brings this research to a close by noting the objectives that were met and making recommendations for future research in the area of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature review will underline explicitly the green roof technology, which will address its implementation in Malaysia, the type of green roof that has been implemented, the advantage of the green roof system and design criteria corresponding to the recognized code of practice. Moreover, the design of rainfall intensity is also featured to highlight the importance of replicating the real rainfall events as part of the control variable during the simulation process. As this study focuses on the media on the green roof, several types of media will be discussed based on how well they drain and how well they can treat rainwater. Lastly, the effectiveness of residual coffee ground for stormwater treatment is included in the literature review.

2.2 Benefits of Green Roof

Considering the increasing development of urban areas, the immense benefits and roles of green roofs are undeniable. As stipulated by Y. Li & Babcock, (2014a) that green roofs can reduce stormwater runoff volume, leading to the reduction of pollution, flooding and erosion. Concerning the air quality, Y. Li & Babcock, (2014b) found that the green roofs lower CO2 levels in the vicinity proving the system's ability to clearer the air quality. As the primary purpose of a green roof, the stormwater quality is significantly improved with a combination of suitable substrate and vegetation (Liu et al., 2019).

2.2.1 Reduce Stormwater Runoff

The green roof can reduce the stormwater runoff from expanding impermeable surfaces resulting from urban development. Roof areas account for approximately 40%–50% of total impermeable surfaces in developed cities (Stovin et al., 2012). The vegetation on the green roof and substrate will intercept the stormwater runoff (Nagase & Dunnett, 2012). A study by Y. Li & Babcock, (2014a) has proved that stormwater runoff volume is reduced by 30 to 86 per cent, peak flow rate by 22 to 93 per cent, and peak flow delay by 0 to 30 minutes. Thus, it is hypothesized that by minimizing surface runoff on the ground, pollutants can be prevented from infiltrating the adjacent receiving water bodies.

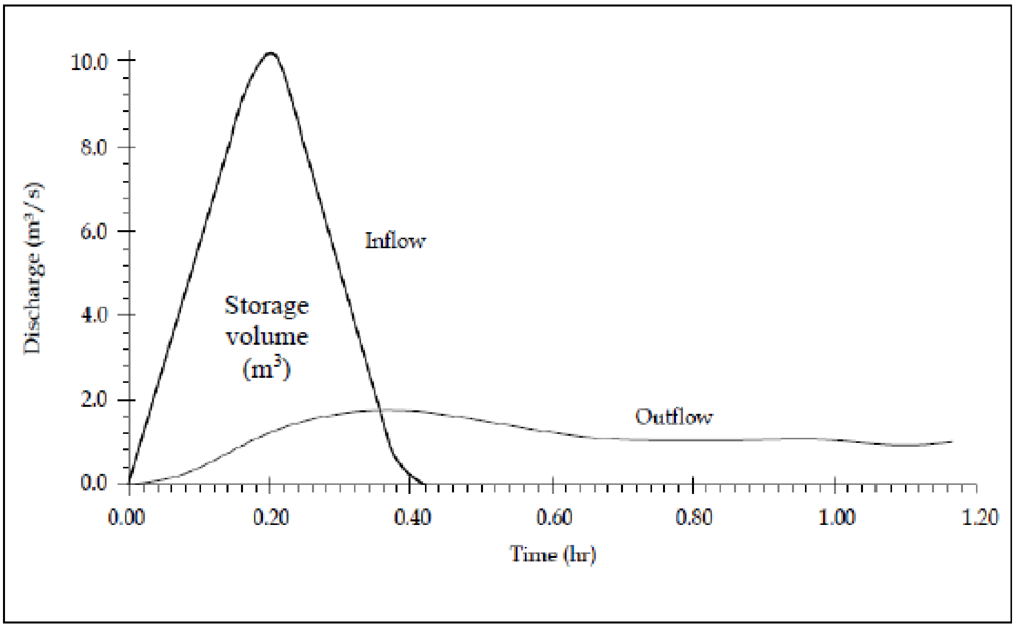


Figure 2.1: Inflow and Outflow for the storage volume by MSMA 2nd Edition

2.2.2 Improve Air Quality

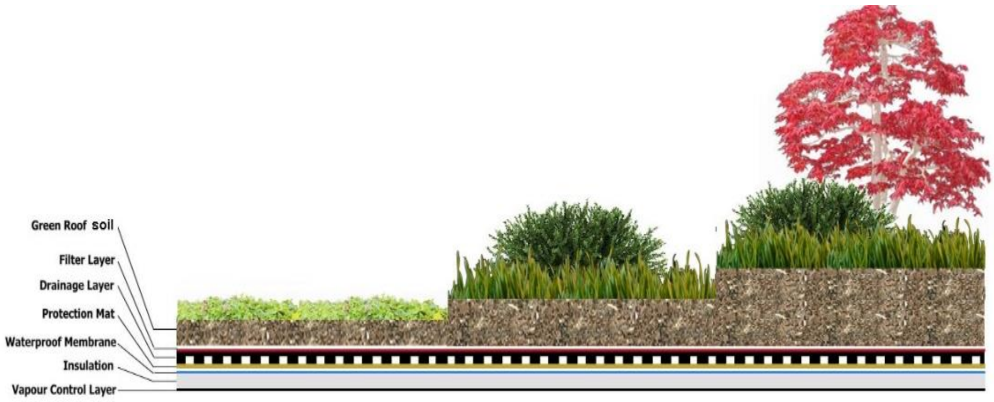
Pollutants can be removed from the air by plants. Due to the fast deterioration of the environment, plants' potential to purify the air has received much interest (J. F. Li et al., 2010). World Health Organization (WHO) recognized particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) as the guideline to gauge air quality. A study by Viecco et al., (2021) concluded that some 50 per cent to 75 per cent of low-rise buildings with green roofs could improve air quality for pedestrians and commuters in the adjacent area.

2.2.3 Improve Stormwater Quality

Despite rainwater being typically thought to be clean, it may be acidic and contain considerable amounts of nitrates. It may incorporate residues of additional pollutants, such as heavy metals and pesticides, depending on the causes of pollution in urban areas and the direction of the prevailing winds (Czemiel Berndtsson, 2010). The ability of the green roof to naturally treat stormwater is subject to the type of vegetation and substrate, as both have a direct influence on the treatment efficiency (Hashemi et al., 2015). According to Liu et al., (2019), the suitable combination of vegetation and type of substrate has a remarkable effect on the reduction of average TSS (Total Suspended Solids), TN (Total Nitrogen), and TP (Total Phosphorus) concentrations.

2.3 Type of Green Roof System

Typically, green roofs fall into two distinct engineering categories: intensive and extensive. Intensive green roofs are constructed with deep soil layers in which they can support larger plants and bushes and often require pruning, fertilizing, and watering. With thin soil layers, extensive vegetated roofs are established. They are planted with tiny plants that will eventually cover the vegetated roof completely (Czemiel Berndtsson, 2010). However, Landscape Development and Landscaping Research Society e.V. (FLL), (2018) indicates the semi-intensive green roof is an extension of the intensive type.



	Extensive Vegetated Roof	Semi-intensive Vegetated Roof	Intensive Vegetated Roof
Soil Depth:	3-6 in.	6-10 in.	10 in. and more
Weight:	13-30 PSF	24-40 PSF	35- 100+ PSF (up to 150 PSF)
Type of Plants:	Mosses, sedums, and grasses	Grasses, herbs, and shrubs	Lawn, perennials, shrub, and small trees.
Cost:	Low initial cost $10-$20/SF	Medium to High initial cost $15-$20/SF	Hight initial cost $15-$25/SF
Maintenance:	Low	Periodically	Regularly
Irrigation	No	Periodically	Regularly
Function:	-Ecological protection layer -More suitable for large area -More suitable for retrofit projects	-Designed green roof -More suitable for plant diversity -More suitable for design-oriented layout	-Park-like garden -Best insulation properties and water runoff/retention. -Suitable for accessible rooftop -Larger range of plant diversity

Figure 2.2: Type of Green Roof. Source by Medium

2.3.1 Extensive Green Roof

Extensive greening reflects self-sustaining and evolving natural kinds of vegetation. We use plants that have a high capacity for regeneration and have a specific adaptation to harsh site circumstances Landscape Development and Landscaping Research Society e.V. (FLL), (2018). The planting media depth on extensive green roofs varies between 1.6 and 6 inches. A study to compare ranges of media depth conducted by Olly et al., (2011) found that the 6 inches deep provide significant benefits to the plantation with greater access to water in the soil profile. According to German requirements for green roofs, FFL 2018, the substrate for extensive green roofs should include just 4–8% organic materials. In general, extensive green roofs present a greater cost-benefit ratio than intensive green roofs, with an average benefit of 2.4 times greater than the cost of the green roof (Azis & Zulkifli, 2021).

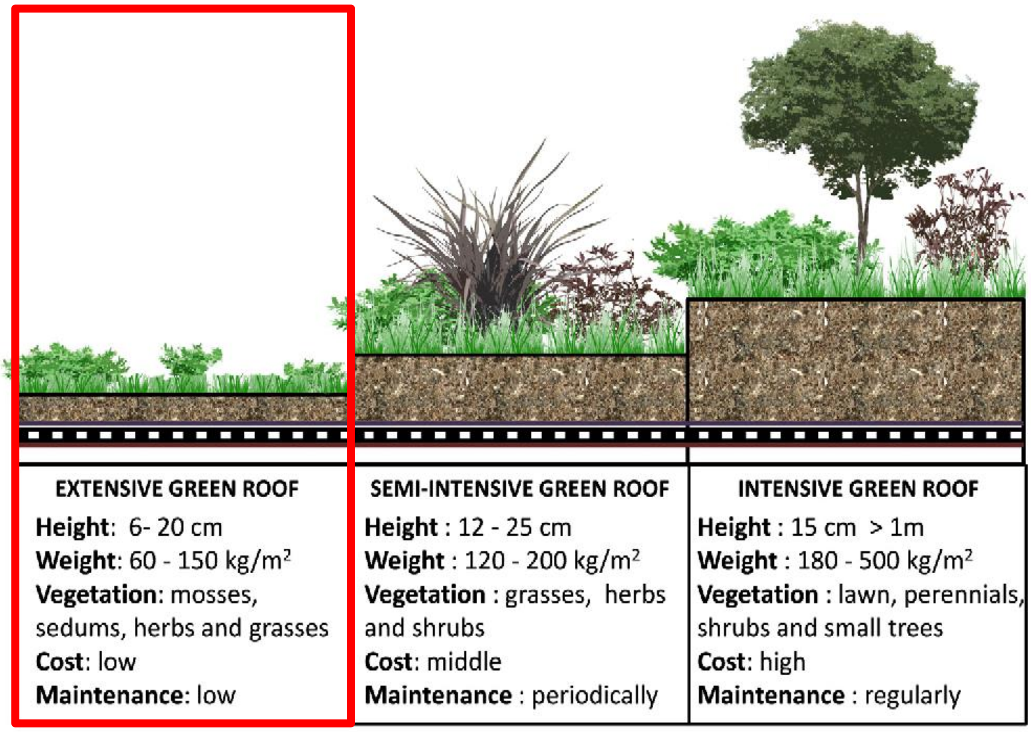


Figure 2.3: Extensive Green Roof (Fernandez-Cañero et al., 2013)

2.3.2 Intensive Green Roof

Intensive green roofs are defined by a thick substrate of greater than 12 inches, a diverse plant/vegetation community that resembles ground-level landscapes, a high-water holding capacity, increased investment and operational expenditures, and a heavier weight (Shafique et al., 2018). An intensive green roof with increasing vegetal coverage has significantly reduced indoor heat stress and lowered indoor substrate temperature by 2.5 to 3.5 degrees Celsius (Chowdhury et al., 2017). In terms of cost, van der Meulen, (2019) highlighted for intensive roofs, the load-carrying capacity of the structure must be carefully examined and, if necessary, reinforced, which is considerably more expensive. The rate of return on investment is ambiguous or negative.

Figure 2.4: Illustration of intensive green roof components (Bronz, 2017)

2.3.3 Semi- Intensive Green Roof

'Semi-extensive' roof gardens employ the same low-input materials and layers as the extensive design but with slightly greater depths of growing material (up to 20 cm depth) (Dunnett & Nolan, 2004). This intensive and extensive green roof combination has a thick substrate typically covered in tiny plants, bushes, and Grass. These roofs require constant care and have a significant initial investment due to their superior performance (Shafique et al., 2018). Semi-intensive green roofs are more cost-effective to build than intensive green roofs and require less care. Certain invasive species of vegetation, such as ground cover plants, herbaceous plants, and moss, maybe tolerated based on the semi-intensive green roofs' greening objectives (Landscape Development and Landscaping Research Society e.V. (FLL), 2018).

Figure 2.5: Illustration of intensive green roof components (Bronz, 2017)

2.4 Design Consideration of Growing Media in Green Roof

Substrates for green roof growth are typically a mixture of natural and synthetic minerals, recycled or waste materials, and organic matter. Sand, clay, gravel, and lava (scoria) pumice are all-natural minerals used as growing substrates for green roofs (Ampim et al., 2010). A research by Cascone,(2019) recorded there were two distinct sets of factors that define the substrate. Firstly, density, grain size, water permeability, maximum water volume, and air volume in saturated conditions are all physical factors during chemical characteristics, including pH, electrical conductivity, and organic matter concentration. A suitable substrate selection should provide permanent physical support for plants and strike a delicate balance between enough plant accessible water and nutrient retention and free drainage. The proportions of components vary between substrates depending on the desired plants, the type of green roof, and other factors, including the permeability of water, water storage capacity, air content, and pH value, among others (P. a Y. Ampim et al., 2010).

The Landscape Development and Landscaping Research Society e.V. (FLL), (2018) highlighted the requirement varies according to the material type and must take into account the following attributes: material compatibility, environmental friendliness, plant suitability, fire characteristics, particle distribution, durability, structure and layer stability, compression behaviour patterns, water permeability, water-storage capacity, pH–value, and salt content. The particle size distribution depends on the course depth, and the diameter of 0.063mm particles can not surpass 10% by mass. In associated with water permeability, the media should have a high water 21 permeability to allow excess rainwater to be quickly removed into the roof drains. Water infiltration rate mod can be used to evaluate the permeability of the media, and the coefficient of permeability Kf must be more than 0.3cm/s or 180mm/min. Additionally, the pH of the media should be close to that of the vegetation layer and not exceed 1.5 units. Both extensive and intense irrigation systems should have a pH of between 6.0 and 8.5.

The depth and weight of the growing media are determined by the vegetation, the roof design, climatic factors, and the drainage method. The importance of the increasing media differs by kind of green roof, ranging between 12–14 kg/m2 with an 8 cm thickness for extensive green roofs. Hydraulic efficiency, water retention, and permeability must be considered while developing green roof growing material. Extensive green roofs should have a porosity of at least 58 per cent (Cascone, 2019).

2.4.1 Residuals Coffee Grounds

Coffee is a beverage appreciated by millions around the world, and more studies are being conducted to validate its advantages. However, this drink generates huge waste, precisely coffee grounds (Cruz-Lopes et al., 2017). Being one of the high demand beverages, the coffee industry produced a staggering 6 Mt/yr. of by-products (Anastopoulos et al., 2017). The current study found that using coffee grounds, a common food waste, to remove lead ions from the water supply was feasible (Tokimoto et al., 2005).

Coffee ground compositing studies have revealed pH levels ranging from slightly acidic to slightly alkaline. pH changes will occur only near the coffee grounds, not the whole of the soil profile (Cruz et al., 2012). In addition, Ballesteros et al., (2014) found in the research that Coffee grounds will help to control soil temperature and preserve moisture in the soil.

2.5 Green Roof Implementation in Malaysia

Despite the lack of architectural rules in Malaysia, the interest in building or implementing the green roof system is growing. Research on the effectiveness and enhancement of green roofs for Malaysia's weather conditions has garnered much interest from Malaysian researchers (Rahmah, 2020). In Kuala Lumpur alone, there are 150,000 square meters of unused rooftops that can be tapped to implement green roofs, which leads to increasing green space (Akbari et al., 2016). In Malaysia, the implementation of a green roof is concentrated within residential buildings, mostly made up of intensive types (Rahman et al., 2013). Based on a survey by Ismail et al., (2018), the residential buildings have the highest percentage of green roof implementation at 46.7%, followed by commercial buildings at 34.4%, while institutional buildings stood at 10%. A study by Rahman et al., (2013) has compiled thirty green roof projects successfully applied in Malaysia, where ten are shown in Table 2.1.

Table 2.1: The past Green Roof projects in Malaysia (Rahman et al., 2013)

Green roof Project	Location	Type of green roof	Type of building	Level	Accessibility	Completion Year
Islamic Art Museum	Tasik Perdana, Kuala Lumpur.	Extensive	Museum	One	Public access	1998
Secret Garden	Bandar Utama, Kuala Lumpur.	Intensive	Shopping mall	Seventh	Public access (but on weekend only)	2007
Menara Mesiniaga	Subang Jaya, Selangor.	Extensive	Office	First level of the extended roof area.	Non-accessible	1992
Oasis Ara Aquare	Damansara, Selangor.	Extensive	Retail shop	Second	Accessible	2009
Kiara 9	Mont Kiara, Kuala Lumpur.	Intensive	Condominium	Three and a half (consist of 16 gardens)	Private access	2011
Casa Desa Condominium	Taman Desa, Kuala Lumpur.	Intensive	Condominium	Third	Private access	2008
The Saffron	Sentul East, Kuala Lumpur.	Intensive	Condominium	Fourth	Private access	2008
Riana Green East	Wangsa Maju, Kuala Lumpur.	Intensive	Condominium	Fourth	Private access	2009
The Tamarind	Sentul East, Kuala Lumpur	Intensive	Condominium	Fourth	Private access	2006
Menara Binjai	Ampang, Kuala Lumpur.	Intensive	Office	Every third floor has access to garden terraces, Sky garden at thirty two floors.	Private access	2011

2.6 Hydrological Pattern in Malaysia and Area of Study

According to study by Ying & Abdul Ghani, (2019)) Malaysia is situated in the Asian region, which does have a climate that is distinct from other areas that utilise green roofs. Malaysia is renowned for having a tropical rainforest climate which is typically hot, humid, and rainy. The same study byYing & Abdul Ghani, (2019) stated that rainfall and flooding are inextricably linked, as increased rainfall intensity results in increased runoff. A historical trend of rainfall study by Syafrina et al., (2015) recorded that between 1975 and 2010, the number of hourly extreme rainfall events in Peninsular Malaysia increased significantly. The Rainfall Intensity-Duration-

Frequency (IDF) curve is widely used in hydrology and water supplies for planning, designing, and operating hydraulic facilities. Climate change's predicted increase in rainfall intensity and frequency may affect the IDF curves (Noor et al., 2018; Simonovic et al., 2017).

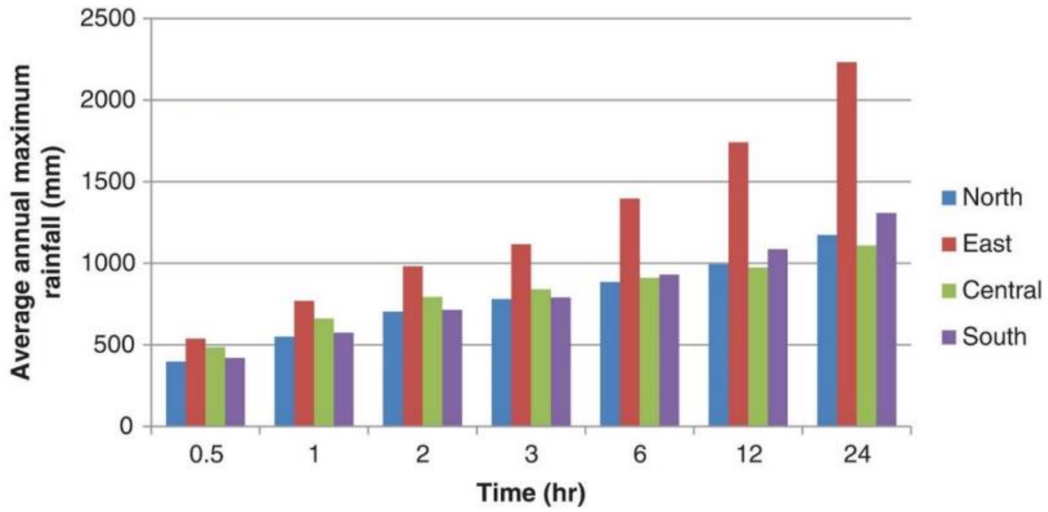


Figure 2.6: Analysis of rainfall in Peninsular Malaysia (Chin et al., 2016)

2.7 Design of Rainfall Intensity

To design the rainfall intensity (mm/hr), the duration (minute) and ARI (months/years) should be considered. The intensity of varies ARI and rainfall duration can be computed based on intensity-duration-frequency (IDF) curves (*Green Wall for Retention of Stormwater UPM*, n.d.). The same study also mentioned the actual data of rainfall observed in 24-hour precipitation data are crucial in determining the rainfall intensity. The paper concluded that the one-year ARI and 5 minutes of storm duration provide the best result for best performance. The estimated future intensity of design rainfall differs based on the climate model used (Kim et al., 2020). For this study, the inflow rate for rainfall simulation is 8 litres per hour (l/hr) with 5 minutes storm duration. Meanwhile, the rainfall intensity is 191.25 mm/hr. According to the standard by DID, the classification of rainfall is very heavy or severe.

Table 2.2: Rainfall Intensity classification according to the Department of Irrigation and Drainage (DID)

Rainfall Intensity (mm/hr)	Classification
1 - 10	Low
11 - 30	Moderate
31 - 60	Heavy
>60	Very heavy or severe

2.8 Rainwater Characteristics and Compositions

As the scope of the study focuses on the stormwater quality from the green roof, therefore the characteristics and compositions are noteworthy explored. Research by Fazillah Abdullah et al., (2021) revealed that the design of rainwater in the studied area was influenced by local human activity such as agricultural and industrial. In an urban area, the most significant factor determining the organic content of rainwater is anthropogenic sources, including home and industrial wastewater effluents, urban and agricultural runoff, and the combustion of fossil fuels (Chon et al., 2015). A research by Mendez et al., (2011) found that the quality of rainwater harvested from the green roof directly influences the selection of growing media.

Essentially, Norman et al., (2019) underscored the presence and quantities of organic, inorganic, physical, and biological impurities are affected by various elements, including roof characteristics, meteorological factors, roof location, hydrological factors, material chemical qualities, and storage medium.

2.8.1 Important Parameters of Rainfall

Precipitation's nature – alkaline or acidic – is determined by the concentration of leading water-soluble inorganic gases and soil generated particles. When cations outnumber anions, the precipitate becomes alkaline, and vice versa. pH is the primary indicator of precipitation type (Shaheed et al., 2017). Meanwhile Norman et al., (2019) found that the rising CO2 levels influence climate change and a corresponding fall in rainwater pH. Moreover, the temperature of rainwater has an influence on the pH as Bogan et al., (2009) recorded the decrease in rainwater temperature, and the pH is found to be decreased as well.

During rain events, heavy metals may be discharged from soils. Mean rainfall intensity has the most considerable influence on heavy metal discharge concentration, followed by peak rainfall intensity and rainfall amount (Xue et al., 2020). Heavy metals such as iron (II) (Fe2+) and zinc (Zn2+) are commonly found in rainfall. The iron concentration in rainwater ranges between 0.01mg/L and 0.38mg/L (Asrah Bin Muhamad & Abidin, 2016).

2.9 Summary

From various past studies, the application of green roof has many benefits particularly in reducing the urban heat island, reduce the stormwater runoff, reduce the air quality and stormwater quality. The scale of development of green roof can be classified into three types which are intensive, extensive and semi-extensive, each has its design and suitability. Until this research is completed, Malaysia has no standard guideline on the design and application of green roof system despite recorded numbers of green roof projects. Moreover, from past research, the coffee residual has potential in improving the stormwater quality as research shown the ability of coffee residual to remove heavy metals.

CHAPTER 3

METHODOLOGY

3.1 Introduction

To commence this research, the literature review is first prepared to provide a better understanding of the research proposal based on the previous studies. Among the topics discussed are the benefit of green roofs, the type of green roof, design considerations and the effectiveness of residual coffee grounds in water treatment. Specifically for this research, the residual coffee grounds will be used to test its effectiveness and therefore, some laboratory tests on the grounds and harvested stormwater will be executed.

In order to obtain the permeability coefficient of a mixture of media (sand and residual coffee grounds), the constant head test will be carried out to study the drainage performance. The quality index of the harvested rainwater will then be measured for each of the parameters in the Environmental Laboratory as listed in Figure 3.1.

3.2 Research Methodology

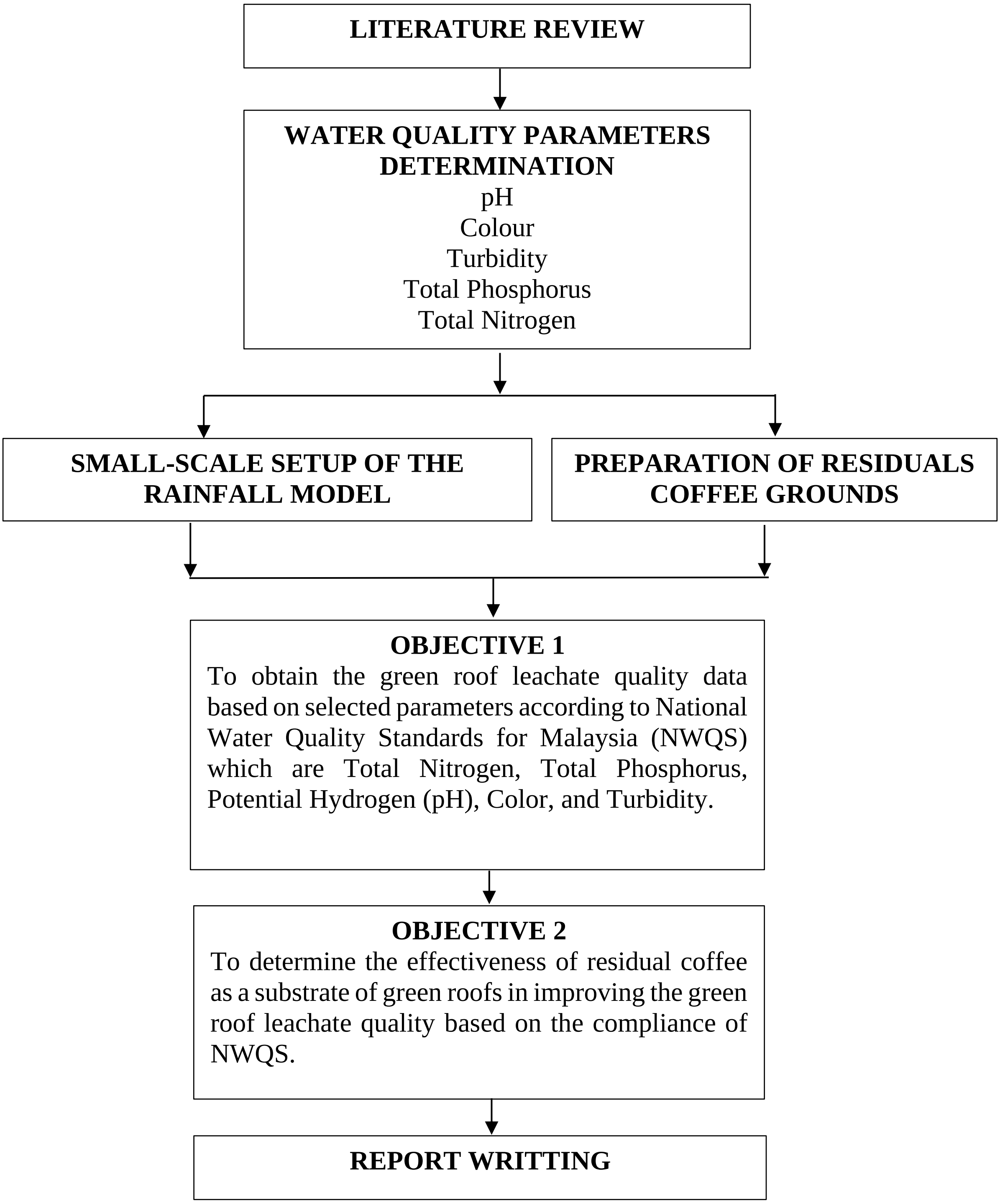


Figure 3.1: The chart of summary of the research methodology

3.3 Set up of Green Roof Model for Experiment

To execute the study, a column study was made with clear perspex with dimensions of 20cm x 20cm x 45cm. This model has 15cm of room for vegetation growth, 20cm of depth for the substrate layer, and 10cm of the drainage layer. In addition, the model will be equipped with a flow meter to regulate the stormwater flow into the model. This will help to replicate the total rainfall of the Nibong Tebal area as part of the variables control. The Japanese Grass will be used as the vegetation layer. As for the irrigation system, rain jet drippers from Claber with model 91217 is connected to the piping system.

A total of 365 days of rainfall data is gathered from Department of Irrigation and Drainage (DID) with a peak rainfall value is selected from Bukit Panchor telemetry station to calculate the rainfall intensity. From the available data, the peak intensity is stood at 191.25 mm/hr which is categorized as very heavy rainfall (in one hour) according to DID. The duration of the rainfall is recorded at 3.75 hours. Noting that the size of the green roof model column is 0.04 m^2 which relatively smaller than the actual coverage of telemetry station of up to 20km radius. Therefore, the replication of rainfall intensity for the green roof model is 8 l/hr.

Table 3.1: Rainfall intensity computation

Peak rainfall at Bukit Panchor telemetry station	191.25 mm/hr
	191.25 $l/m^2.hr$
Rainfall duration	3.75 hours
Area of green roof column model	0.04 m^2
Rainfall intensity for green roof column model	8 l/hr

During the experiment, the harvested rainwater will be pump into the piping system with a submersible pump. The flowrate of rainwater is maintained at 8 litres per by using the flowrate meter.

The experiment will be conducted with 5 minutes rainfall duration. The selection of 5 minutes duration is based on past study by Lau & Mah, (2018) stated that the design parameter of 5 minutes of storm duration would give optimum performance in terms of the water holding capacity and maintaining the condition of vegetation used

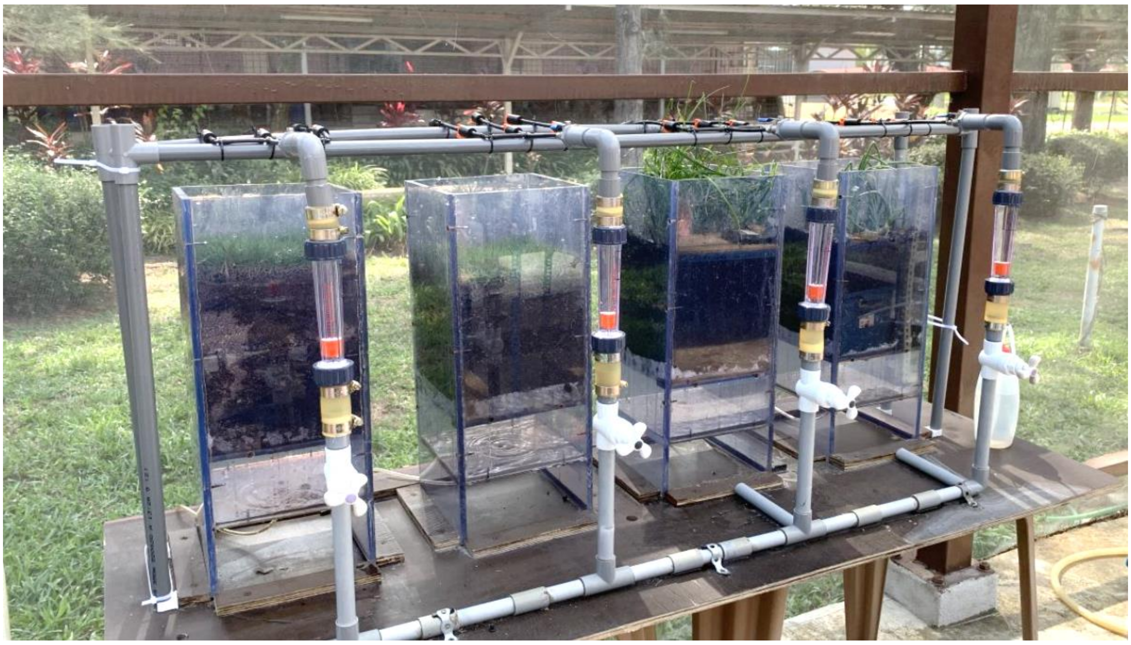


Figure 3.2: The model that will need some modifications

3.4 Constant Head Permeability

The constant head permeability test is a scientific procedure used to measure a soil's permeability. Sand and gravel soils are suited for these experiments. The coefficient of permeability, k, is measured as the rate of water flow through a porous media with a unit cross-section under laminar flow situations. To begin, the ancillary apparatus was constructed. The sample (WW) was then weighed to 0.01g inside the permeameter, and the internal diameter of the permeameter cell was recorded as D. The specimen's length was determined, and readings were made at 120° intervals to determine the average reading. The dry cylinder was then weighed, and the weight was recorded as Wb. After attaching the permeameter to the test equipment, the water valve was opened. Following that, water flow was permitted to continue for many minutes to exhaust all air from the permeameter. Meanwhile, a measuring cylinder was positioned beneath the outflow, and the timer was started. Additionally, the water levels in the manometer tubes were recorded. H1 and H2 were used to denote the readings from both tubes. The volume of water gathered in the measuring cylinder is then determined

Figure 3.3: The apparatus setup for permeability test

during a specified time interval, t, and the water temperature, T°C, is determined. Finally, the cylinder's exterior portion is dried and weighed to 0.01g, Wbw.

3.5 Total Phosphorus

In order to identify the concentration of phosphorus in a water sample, the total phosphorus test is sought to be conducted. The method to be used is Molybdovanadate with Acid Persulfate Digestion Method. It was determined in this research investigation utilising HACH equipment based on procedure 10127. For 30 minutes, the heated reactor is being used to warm the vial at 150 degrees Celsius. The potassium persulfate powder for phosphonate and 1.54N sodium hydroxide standard solution was used in this total phosphorus test.

3.6 Colour

The sample's colour characteristics were determined using a DR 2800 spectrophotometer. The visible colour was determined using a 465nm wavelength. To begin, a blank sample of distilled water was created. Then, for calibration purposes, the zeroing button was pressed. Following that, 10ml of the sample is placed in a spectrophotometer, and the colour value was determined. The colour unit was specified as mg/L PtCo.

3.7 Turbidity

The turbidity of captured rainwater was determined using a Turbidimeter TB 400 and expressed in Nephelometric Turbidity Units (NTU). This turbidity test is used to determine the relative clarity of a liquid. It is essential to measure the quantity of light dispersed by materials in water. Turbidity increased as 0distributed light intensity increased.