EFFECTIVENESS OF ALLIUM TUBEROSUM AND ALLIUM FISTULOTUM AS COVER IN IMPROVING GREEN ROOF WATER QUALITY

NORAINI BINTI SHARI

UNIVERSITI SAINS MALAYSIA

2022

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by

NORAINI BINTI SHARI

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

AUGUST 2022

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: Effectiveness Of Allium Tuberosum And Allium Fistulotum As Cover In Improving Green Roof Water Quality

Name of Student: Noraini Binti Shari

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Date : 9/8/2022

Approved by:

(Signature of Supervisor)

Name of Supervisor : DR NURUL HANA MOKHTAR KAMAL
PENSYARAH DS51
PUSAT PENGAJIAN KEJURUTERAAN AWAM
KAMPUS KEJURUTERAAN
UNIVERSITI SAINS MALAYSIA

Date : 10/8/2022

Approved by:

(Signature of Examiner)

Name of Examiner : DR NOOR AIDA SAAD
Lecturer
River Engineering And
Urban Drainage Research Center (REDAC)
Engineering Campus
Universiti Sains Malaysia
14300 Nibong Tebal, Penang.
Tel: 04-599 6538 Fax: 04-599 6926

Date : 11/8/2022

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. All praises to Allah and His blessing for the completion of my final year project. I thank God for all the opportunities, trials and strength that have been showered on me to finish writing the research. I experienced so much during this process, not only from the academic aspect but also from the aspect of personality.

First and foremost, I would like to sincerely thank my supervisor Dr. Nurul Hana Mokhtar Kamal for her guidance, understanding, patience and most importantly, she has provided positive encouragement and a warm spirit to finish this research. It has been a great pleasure and honour to have her as my supervisor.

I would sincerely like to extend my thanks to Dr. Khairul Rahmah Ayub, Research Officer in the River Engineering and Urban Drainage Research Centre (REDAC), Tn. Hj Mohamed Shukri bin Abdullah, Assistant Engineer Department of Drainage & Irrigation Penang for assist and guiding me throughout the data search process and also helping me to get a better understanding of urban water management and hydrology. Furthermore, the appreciation and millions of thank also to all technicians from the Environmental & Fabrication laboratory for helping and guiding in handling the materials and equipment for the testing in this project.

Finally, my deepest gratitude goes to all of my family members and all my colleagues for their motivation, prayers and their sincere help during my studies. It would not be possible to write this research without the support from them.

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LIST OF SYMBOLS

NO^{3}	Nitrate
PO_4^{3}	Phosphate

LIST OF ABBREVIATIONS

ARI	Average Recurrence Interval
BMPs	Best Management Practices
DOE	Department of Environment
DID	Department of Drainage and Irrigation
IDF	Intensity Duration Frequency
GCMs	General Circulation Models
MMD	Malaysian Meteorological Department
MSMA	Urban Stormwater Management Manual of Malaysia
NTU	Nephelometric Turbidity Units
NWQS	National Water Quality Standard for Malaysia
PPKA	Pusat Pengajian Kejuruteraan Awam,
pH	Potential Hydrogen
SUDs	Sustainable Urban Drainage System
TN	Total Nitrogen
TP	Total Phosphorous
WQI	Water Quality Index
USM	Universiti Sains Malaysia

ABSTRAK

Salah satu Sistem Saliran Bandar Mampan (SUDS) ialah bumbung hijau, Ia merupakan konsep yang menyokong kawalan dari punca yang menekankan kuantiti dan kualiti air ribut sebagai strategi bersepadu. Kajian terhadap pengaruh tumbuhan Allium Tuberosum dan Allium Fistulosum sebagai penutup bumbung hijau terhadap kualiti air telah dijalankan di USM, Nibong Tebal. Objektif kajian ini ialah untuk menentukan keberkesanan Allium Tuberosum dan Allium Fistulotum sebagai penutup bumbung hijau dan menentukan samada data larut lesap bumbung hijau mengikuti Standard Kualiti Air Malaysia (NWQS). Kualiti air larian kedua-dua tumbuhan ini dibandingkan dengan kualiti air tumbuhan kawalan. Diantara ujian parameter yang dilakukan ialah Jumlah Fosforus (TP), Jumlah Nitrogen (TN), Keperluan Oksigen Kimia (pH), warna dan kekeruhan. Keputusan menunjukkan tumbuhan Allium Fistulosum mampu mengurangkan bahan cemar tertentu daripada air hujan yang terkumpul dari segi kekeruhan, warna, Jumlah Fosforus (TP) dan Jumlah Nitrogen (TN) iaitu masing-masing 57%, 37%, 15% dan 30%. Manakala tumbuhan Allium Tuberosum menunjukkan bacaan yang lebih baik dalam ujian kekeruhan (78%) dan warna (59%) kecuali Jumlah Fosforus (TP) dan Jumlah Nitrogen (TN). Ujian Nilai Keperluan Oksigen Kimia pula menunjukkan kedua-dua tumbuhan masih berada dalam julat NWQS, iaitu Kelas II manakala lain-lain parameter berada di luar julat NWQS. Secara kesimpulannya, tumbuhan jenis *extensive* tidaklah menunjukkan signifikasi yang jelas bagi rawatan air hujan, namun tumbuhan jenis ini dapat memberi manfaat kepada estetika, iklim bandar dan biodiversiti. Penyelidikan di masa depan disaran untuk mempelbagai jenis tumbuhan dan media bagi mengenalpasti keberkesanan penyingkiran bahan pencemar dalam sistem bumbung hijau.

ABSTRACT

One of the Sustainable Urban Drainage Systems (SUDS) is a green roof. It have advocated the concept of control at the source in stormwater management. This concept emphasises the quantity and quality of stormwater as an integrated strategy. The influence of extensive Allium Tuberosum and Allium Fistulosum vegetated roofs on water quality was studied and installations located in USM, Nibong Tebal. The objective of the study was to determine the efficacy of Allium Tuberosum and Allium Fistulotum as green roof cover and also verify green roof leachate data follow the NWQS. The runoff quality from vegetated roofs was also compared with the runoff quality from control column. The following parameters were investigated: TP, TN, pH, colour and turbidity. The results shown that Allium Fistulosum able to reduce certain contaminants from collected rainwater in terms of turbidity, colour, TP and TN with 57%, 37%, 15% and 30% respectively. While Allium Tuberosum shown better readings in turbidity (78%) and colour (59%) except TN and TP . pH values shown both vegetations are still within the NWQS range, which is Class II and other parameter are class III and above in NWQS Apart of that the extensive vegetated roofs not obviously significance for rainwater treatment., however they can be beneficial for aesthetics, city climate, and biodiversity. Future research should be conducted on additional types of vegetation and media to identify the removal effectiveness of pollutants in green roof applications.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia's rapid urbanisation has had a detrimental effect on the environment, particularly water quality. Additionally, Malaysia's tropical climate, which produces abundant heavy rainfall over a short period of time, contributed to the increase in runoff. The road is paved, and parking lots prevent water from flowing through it and beyond, thereby increasing surface runoff into the river. All contaminants and silt will be carried away by running water on the surface. Green initiatives, such as the green roof, have emerged as one of the most promising solutions to this problem (Bakar et. al., 2021). A green roof not only manages runoff water it also helps by reducing urban heat islands, balancing building temperatures and increasing biodiversity (Arabi et al. 2014). The green roof concept was developed to encourage the growth of various types of vegetation on the tops of buildings, thereby providing aesthetical, environmental, and economic benefits. (Vijayaraghavan & Raja, 2015).

In other countries, green roofs have been gradually implemented as part of urban stormwater management plans in urban areas. Malaysia is also not left behind in introducing green roofs in line with the recommendations of the Ministry of Energy, Green Technology, and Water as part of the initiative for green technology development in the construction industry. Table 1.1 show the examples of implementation green roofs in Malaysia. There are two types of green roofs that can be classified as extensive or intensive. Extensive green roofs have a substrate depth of 100-250 mm, while intensive roofs have a substrate depth of 300 mm or more. Intensive roofs are heavier than extensive roofs. Another thing that makes the intensive roofs different is that they have shrubs and small trees embedded in their substrate to a depth of more than 20 cm (Jahangir *et al.*, 2020). In general, a green roof system is composed of four major components a vegetation layer, a growing medium, filter sheets, and a drainage layer. The vegetation layer is the plant species that cover the roof, while the growing medium is a solid substance that contains soil, peat, plant parts, bark, humus, or other solid substances. A filter is placed on top of the layer to prevent sludge formation. The drainage layer prevents excessive water stagnation in the substrate, which could harm the vegetation.

Table 1.1: Examples of green roof projects in Malaysia since 1998 (Chow & Abu Bakar, 2016)

Year	Building/ Projects	Type
1998	Rice Garden Museum (Laman Padi), Langkawi	Intensive
2002	Ministry of Finance, Putrajaya	Intensive and Extensive
2003	Putrajaya International Convention Centre (PICC), Putrajaya	Intensive and Extensive
2004	Malaysian Design Technology Centre (MDTC), Cyberjaya	Extensive
2004	Putrajaya City Hall, Putrajaya	Extensive
2005	Serdang Hospital	Intensive
2007	Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia	Retrofit Extensive
2009	KL Sentral Park	Intensive
2009	Sime Darby Oasis, Damansara	Extensive
2011	Newcastle University Medicine Malaysia, Nusajaya	Extensive
2013	Laman PKNS, Shah Alam	Intensive
2014	Heriot-Watt university, Putrajaya	Extensive
2016	Tun Razak Exchange (TRX)	Intensive

1.2 Problem Statement

Despite being considered an effective strategy to reduce environmental problems in Malaysia, the number of green roof projects compared to other Asian countries such as Singapore, Hong Kong, and Japan was considered low (Ismail et al. 2012). In Malaysia, there are no specific guidelines or policies for the implementation of green roofs that were not included in Malaysia's Stormwater Management Manual, specifically the 1st and 2nd editions of the Urban Stormwater Management Manual of Malaysia (MSMA). The process of designing a green roof should be taken into consideration because a poor design can result in the failure of the green roof structure. The government plays a critical role in promoting the establishment of green roofs. Additionally, factors such as the stage at which green roofs are established, technology, expertise, material availability, and awareness among various stakeholders are identified as obstacles (Ismail et al,2018).

Unlike conventional roofing, a green roof is not only concerned with quantity control, which refers to runoff control, but it also serves as quality control. In urban areas with limited space for conventional stormwater management practices, a green roof may be the most effective possible option for managing stormwater Cristiano et al. (2021). Various forms of phosphorus and nitrogen, as well as heavy metals, petroleum hydrocarbons, pesticides, suspended solids, nutrients, and pathogenic microorganisms, are the most common contaminants found in urban stormwater runoff (Berndtsson, J. C. (2010). However, the effectiveness of green roofs in treating stormwater requires additional research.

One of the primary components in the installation of a green roof is vegetation. Due to the diversity of plant species found in each region, selecting a suitable plant for green roofs can be challenging. Each green roof should be able to withstand the regional climate as well as its own microclimate, solar radiation tolerance, plant cooling ability, wind speed, and rainfall distribution. Drought resistance is critical because it enables growth medium systems to integrate a high number of irradiance and low soil moisture characteristics (Rowe et al., 2012). The depth and composition of the media also have a significant impact on the plant selection for roofscapes. Therefore plant species must be selected in a way that is compatible with both the green roof ecosystem and the requirements for runoff water quality in order to achieve the desired results (Hashemi et al, 2015). Based on industry experience and long-term research, experts recommend extensive green roof vegetation with succulent leaves, shallow spreading roots, and rapid reproduction (MacIvor & Lundholm, 2011). In this study, an extensive green roof system was selected with a focus more on the vegetation to improve water quality runoff using Allium Tuberosum (chives) and Allium Fistulotum (spring onion).

1.3 Objectives

1.3.1 Objectives 1

To determine the effectiveness of Allium Tuberosum and Allium Fistulotum as a cover of green roof.

1.3.2 Objectives 2

To determine the compliance of the green roof leachate quality data based on the National Water Quality Standard for Malaysia.

1.4 Scope of the Study

This study is more focused on identifying Allium Tuberosum (chives) and

Allium Fistulotum (spring onion) that can be used as vegetation for a green roof to improve runoff quality. Vegetation plants of a green roof can be divided into different parts of the plant, which are the root, stem and leaf. Green roof plants are usually selected based on their drought tolerance, ground covering ability and aesthetics. The identified selected plant also can be compared in terms of their performance on water quality. The plant selection factors are based on low-growing perennials that thrive in full sun and well-drained soil, grow easily in a bright, sunny location, and require little care.

Other than that, this study also incorporated actual rainfall data and converted it into a rainfall simulator. The rainfall station, referred to as Kolam Bukit Pancor Station, is located closest to the green roof model that was built in the greenhouse of Pusat Pengajian Kejuruteraan Awam, Universiti Sains Malaysia. Then the water quality of the raw stormwater and harvested stormwater from the green roof will be tested in the laboratory and classified based on Water Quality Index (DOE-WQI). Classifying water quality based on WQI will involve five parameters: pH, turbidity, colour, Total Nitrogen and Total Phosphorus. All these parameters above will be evaluated based on a laboratory test.

1.5 Limitation of the Study

The researcher faced several obstacles in completing this study. The first challenge was to use a physical green roof model for the experiment. The model construction cost and space constraints were major challenges. A column study using real green roof design components was used because it is cheaper and takes up little space. The sample size also limited the study's time frame. Because this study involves stormwater treatment, the experiments can only be conducted after a rainy day. In addition, this research study is about vegetation that requires sufficient light to survive. Therefore, in future research, ensure that the plant receives adequate lighting.

1.6 Disertation Outline

The dissertation for this study is divided into five chapters. The first chapter introduces green roofs and the importance of green roofs in urban areas and the problem statement, objectives, scope of the study, and research limitations. The second chapter is a review of the previous research paper on green roofs. The vegetation for green roofs and the quality of the harvested rainwater from green roofs will be the focus of this literature review. The third chapter is the methodology of this research, which explains in detail how the researcher will conduct this study. The fourth chapter is an explanation and discussion of the results of the experiment for the vegetation sample and the quality of the harvested rainwater from the green roof. This research comes to an end in chapter five, which is the goal was met and that there are suggestions for future research on this study

CHAPTER 2

LITERATURE REVIEW

2.1 General Overview

This chapter will review the literature on green roofs and their efficiency in removing pollutants from rainwater. There are three types of green roofs extensive, semi-intensive, and intensive. This chapter will also review the types of green roofs, benefits of green roofs, considerations for plant selection, hydrological pattern, design of rainfall intensity and the characteristics and quality of rainwater. Finally, a literature study of Allium Tuberosum and Allium Fistulosum efficacy in water treatment will be done.

2.2 Introduction

Best Management Practices (BMPs) in stormwater management are methods or processes aimed at minimising the volume and improving the quality of stormwater runoff at a reasonable cost. Depending on their design, locally implemented best management practices (BMPs) can bring various social, environmental, and economic benefits to those who live near or downstream of the BMPs that have been formed by mimicking natural processes. The best location to reduce pollution is right where it starts at the source. Green roofs are part of best management practices. They involve the cultivation of plants on rooftops and do so by providing several advantages that can help mitigate the detrimental effects of pollution, particularly in urban areas. They can help with stormwater management by reducing runoff and improving water quality, conserving energy, mitigating the urban heat island, extending the life of roofing membranes, reducing noise and air pollution, sequestering carbon, providing a more aesthetically pleasing work and living environment, and providing a higher return on investment when compared to traditional roofs (Czerniel Berndtsson, 2010; Rowe and Getter, 2010)..

2.3 Type and Structure of Green Roof

They are generally categorized as either intensive or extensive. Intensive green roofs are frequently designed as public places and may include trees, shrubs, and hardscapes similar to landscaping found at ground level. Generally require substrate depths greater than 15 cm and require intense maintenance (Snodgrass and McIntyre, 2010). Intensive roofs also tend to be more expensive than extensive roofs. In contrast, extensive green roofs are generally built with substrate depths less than 15 cm. Green roof layers consist of a structural support system, insulation, waterproof membrane, root barrier, drainage layer and drainage filter, and substrate with vegetation.

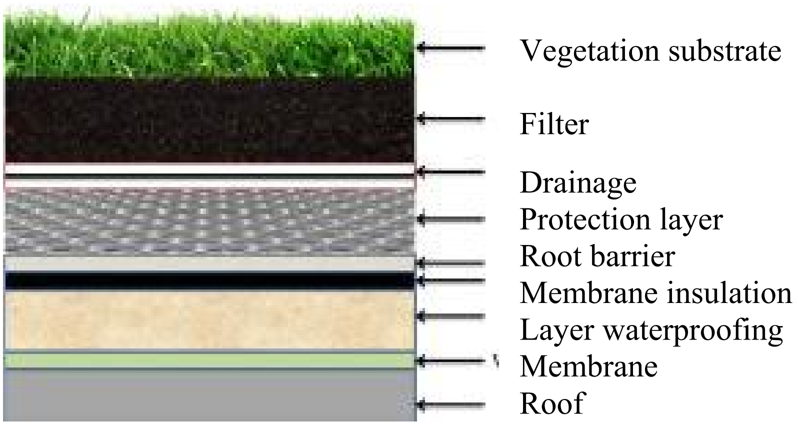
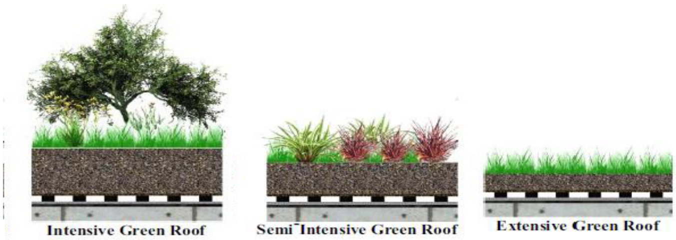


Figure 2.1 : Typical component of green roof (Shafique et al., 2018)



	Intensive Green Roof	Semi-Intensive Green Roof	Extensive Green Roof
Maintenance	High	Periodically	Low
Irrigation	Regularly	Periodically	No
Plant communities	Lawn or Perennials, Shrubs and Trees	Grass-Herbs and Shrubs	Moss-Sedum-Herbs and Grasses
System build-up height	150 - 400 mm on underground garages > 1000 mm	120 - 250 mm	60 - 200 mm
Weight	180 - 500 kg/m^2	120 - 200 kg/m^2	60 - 150 kg/m^2
Costs	High	Middle	Low
Use	Park like garden	Designed Green Roof	Ecological protection layer

Figure 2.2 : Types of Green roof and criteria (Raji et al., 2015)

2.4 Benefits of Green Roof

The importance and advantages of urban green space cannot be overstated. The use of a green roof has several advantages for social, economic, and environmental well-being. Many researchers discovered that the benefits of a green roof could include reduced peak flow and runoff, improved the environment and reduced energy costs, the reduction of noise, the improvement of water quality and many other benefits. The following is a list of the advantages that a green roof may provide.

2.4.1 Reduce Peak Flow And Runoff

Green roofs are the best stormwater management practices in urban areas because the vegetation and substrate layers have abilities to store a large amount of water (Chen X-P et al., 2015). Vegetation increases evapotranspiration, and the growing medium absorbs a large amount of rainwater. This causes a reduction in peak flow and runoff. The runoff reduction depends on many factors, which include the type of vegetation, thickness of the growing medium, type of drainage material, rainfall intensity and slope of the green roof. The most important part is the substrate of the green roof, and it should have a high moisture-holding capacity to store more rainwater. (Stovin V et al., 2012).

2.4.2 Water quality enhancement

Green roofs are also the best strategies for reducing stormwater runoff and water quality (Nagase A, Dunnett N, 2012). Green roof substrates and vegetation layers are critical for runoff reduction and pollution absorption from rainwater. The substrate adsorbs contaminants and heavy metals from rainwater, so improving the water quality. Berndtsson et al. (2006) conducted a water quality analysis on the extensive green roof. Teemusk and Mander, (2011) performed experiments on extensive green roof performance in Estonia, and the result revealed that the green roof reduced the nitrogen as compared to runoff.

2.4.3 Improve The Environment And Reduce Energy Costs

In urban locations, the green roof's two primary functions are reducing surface temperature and providing thermal comfort. Green roofs increase the thermal resistance of the building, which cools it in the summer and also saves energy expenditures (Getter KL et al., 2011). Green roof vegetation and substrate also absorb fewer solar radiations than the other types of roofs, hence also saving the money used for cooling (Wong NH et al., 2003). A study from Japan revealed that green roofs could reduce the surface temperature from 30 °C to 60°C (Yang et al., 2015). Reduction of surface temperature and thermal comfort are the two important functions of the green (Yan et al, 2021).

2.4.4 Ecological, Social And Economic Benefits

Green roofs can benefit both the aesthetics and wildlife of a region (Niu H et al., 2010). Various studies Francis RA et al. (2011) have demonstrated that green roofs are quite beneficial in reducing habitat loss in the urban area. Green roofs also stimulate recreational activities in the urban area. It benefits wildlife by allowing them to assemble in green spaces. It aims to convert impermeable surfaces into natural green spaces, which provide significant environmental benefits in the urban area.

Green roofs provide relief from the concrete construction by introducing green space in urban areas. Green open spaces attracted to eyes and tried to connect people together for roof gardening. Green roofs also enhance property values (Liu K and Minor J, 2005). Green roofs can additionally create opportunities for urban agriculture. They can produce the different vegetables and make the society self-resilient for the food production. In Michigan, USA, people irrigated tomatoes, green beans, cucumbers, peppers, basil, and chives for food production from green roofs (Whittinghill et al., 2013).

Several studies have discussed that green roofs have multiple cost benefits. However, the cost benefits of green roofs are determined by various factors such as the selection of green roof systems and by the plant types (Niu H et al, 2010). The waterproofing membrane of a normal green roof is almost 10–20 years, and a green roof could have a life of more than 50 years (Tsang SW and Jim CY, 2011). Bianchini and Hewage, (2012) used a probabilistic approach to measure the benefits of green roofs, and the results indicated that the green roofs with correct design are usually economically feasible. Green roofs increase the property values as well as the aesthetic appearance of the building (Liu K and Minor J, 2009)

2.4.5 Noise reduction

Another benefit of the green roof is the reduction of the noise level. A green roof can reduce the noise compared to without green roofs. Connelly and Hodgson, 2013 investigated green roofs and non-vegetated roofs in the field to check the noise level reduction. It has been proved that vegetated roofs reduced noise frequency by 10 and 20 dB. Green roofs have the ability to absorb the sound waves and reduce the sound level as compared to the non-vegetated roof.

2.5 Considerations For Plant Selection

The aim of the project and the desired roof aesthetic are critical variables in the plant selection procedure. If the project's goal is to create a more natural environment, indigenous species may be chosen. Irrigation, on the other hand, is often necessary not only for the roof's native plants but also for the long-term survival of individual plants and the plant community as a whole (Durhman et al, 2006), leading to the need for further maintenance (Leigh Jane Whittinghill, 2012).

Another factor influencing the process of plant selection is the canopy structure of the plant species. To minimize solar radiation transmission, plants with a predominantly horizontal leaf distribution and/or substantial foliage development should be chosen. It should be emphasized that the canopy's primary function in green roofs is to provide shade (Barrio, 1998). Growing a range of plant species in complicated mixes is possible with an appropriate green roof structure and sufficient depth of growing media (with increased water supply, nutrients, and root penetration volume). The utilisation of a variety of plant species, such as herbs, grasses, perennials, and trees, contributes to the roofscape's natural appearance.

The rate at which plants grow, their nutrient requirements, and their vulnerability to pollutants. The type of plant species and their location on roofs are also determined by the geographical location, the rate of air pollution, the rooftop height, shade, the depth and composition of the growing medium, the accessibility of the roof, the purpose of runoff water management, the irrigation method, the purpose of thermal insulation, installation techniques, and maintenance.

Additionally, installation practices may have an effect on plant selection. They can be established on the ground as plugs or on a mat, tray, or blanket and then directly placed on the roof - or by seed, plugs, or cuttings seed on the roof growing medium. The availability of plants in each of these forms may influence the species selection process. Additionally, the long-term requirement for irrigation is a critical aspect of the plant selection process. Additionally, the long-term irrigation requirements of individual species will factor into plant choices (Getter & Rowe, 2008).

Although extensive roofs typically require little maintenance, the shallow media depth limits plant species to herbs, grasses, mosses, and drought-tolerant succulents such as Sedum. In places with high precipitation, choosing a porous aggregate such as light-weight aggregate or pumice is critical, as slower moisture penetration rates result in increased weight loads on roofs when compared to faster moisture infiltration rates. Due to excessive nutrient loss, it can be difficult to sustain plant development in certain settings. However, when fertilizers are used to promote plant development, nutrient leaching and runoff may occur, especially if no water runoff capture and reuse measures are used (Snodgrass 2010).

Additionally, other research indicates that growing vegetables such as bean (Phaseolus vulgaris), cucumber (Cucumis sativus), pepper (Capsicum annuum), basil

(Ocimum basilicum), and chive (Allium schoenoprasum) on a large green roof with low irrigation and fertiliser inputs is possible. Vegetable production on retrofitted green roofs with shallow growing substrate depths and heavy seasonal care is a viable option in metropolitan settings (Whittinghill et al.,2013)

2.6 Hydrological Pattern

Rainfall is the driving factor behind all stormwater studies and plans. Understanding rainfall processes and the value of rainfall design data is a prerequisite for developing successful drainage or stormwater control systems. Malaysia has substantially higher rainfall frequency and severity than most other nations, particularly those with temperate climates. As Figure 2.3 shows, rainfall in northern peninsular Malaysia, including Penang, has increased in recent years compared to the base years. This is potentially due to climate change. In Penang, the annual rainfall per hour has increased from an average of 31 mm in the 1990s to 180 mm currently, representing a six-fold increase (Othman et al., 2021). Penang experienced an increasing trend in maximum rainfall from 2014 to 2017 (Figure. 2.4), and as Penang became more exposed and vulnerable to increasing rainfall extremes (Syafrina et al., 2015).

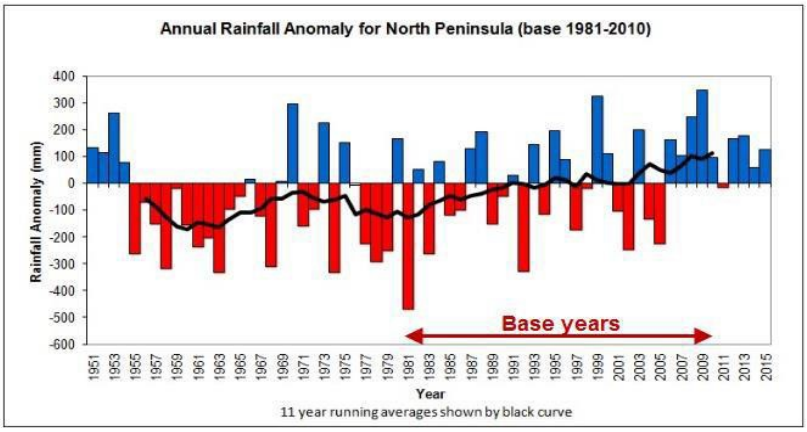


Figure 2.3 : Annual Rainfall Anomaly For North Peninsula (2010–2017)
Source: (Chacko, 2019)

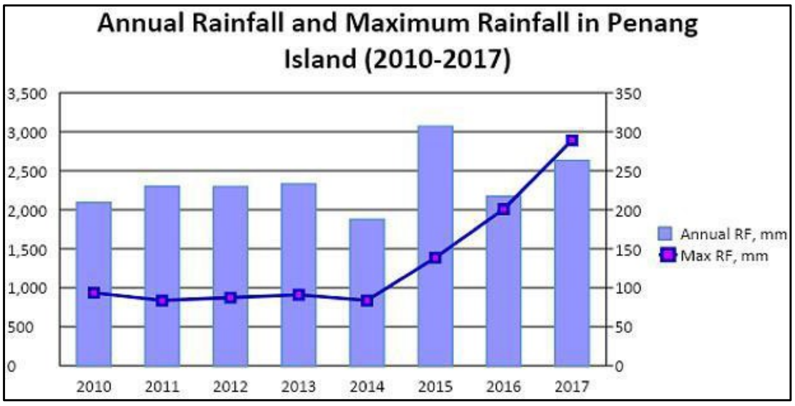


Figure 2.4 : Annual rainfall and maximum rainfall for Penang Island (2010–2017)
Source: (Chacko, 2019)

2.7 Design of rainfall intensity

The design rainfall intensity is defined as the intensity of a constant intensity design storm with a specified design return period and duration equal to the time of concentration for the drainage region and which has the given design return period and duration. Once the design return period and duration values are known, the design rainfall intensity will be calculated using an appropriate intensity-duration-frequency graph or equation for the drainage area's location and using the design rainfall intensity.

This study was conducted at the physical laboratory of Universiti Sains

Malaysia (USM); thus, rainfall data was taken at Kolam Takungan Bukit Panchor, Nibong Tebal stations as reference rainfall stations to obtain rainfall intensity. The total storm rainfall depth at a site is a function of the local climate for a particular rainfall duration and ARI. Rainfall depths can be analysed further and transformed to rainfall intensities (intensity = depth/duration).

Lau et al, (2018) studied showed that it was acceptable to use 5 minutes as the critical storm duration in order to enhance the performance of the green wall system where four simulation models according to different conditions and precipitation input are tested. The conditions include investigation of different soil types, average recurrence interval (ARI) and storm duration with design and observed rainfall. The results reveal that synthesis precipitation data decreased runoff by more than half, at 55% on condition of one- year ARI and 5 minutes of storm duration.

Based on Noor et al. (2018) studied, rainfall intensity duration frequency curves for Peninsular Malaysia have been looked at by when the climate changes. The projection of the rain showed that the average amount of rain fell each year has risen over the last century. They used general circulation models (GCMs) to look at IDF curves for the period 2006-2099 and the period 1971-2005 as a base. The model saw an increase in rainfall intensity for short periods of time and a decrease for longer periods.

2.8 Characteristics and Quality of Rainwater

Rainwater is often thought to be unpolluted, yet it can be acidic and contain significant levels of nitrates. Berndtsson et al. (2009) previously reviewed a comparison study conducted by researchers from Japan and Sweden on the efficacy of green roofs in treating heavy metals in rainfall.

However, a green roof may also be a source of various pollutants, including nitrogen, potassium, phosphate, and various heavy metals. Vijayaraghavan et al. (2012) detected considerable levels of nitrate (NO3-) and phosphate (PO43-) in four different real rains.

Razzaghmanesh et al. (2014) found comparable results when comparing intense and extensive green roof outflow. Their research revealed that the pH, turbidity, nitrate, phosphate, and potassium levels in intensive green roofs were higher than in the outflows from the extensive green roofs.

2.9 Plants For Extensive Green Roofs

There are a lot of different kinds of plants in each region, which makes it hard to choose the right one for green roofs. Each green roof should be able to live in the climate of the area as well as its own microclimate. With these restrictions, it is important to get information from different places and climates to find the best plant species for the green roof. Plant species on extensive green roofs must endure drought, intense wind exposure, solar radiation, insufficient nutrient supply, extreme temperatures, and a restricted root zone (MacIvor & Lundholm, 2011).

2.9.1 Characteristics of Allium Tuberosum and Allium Fistulosum

Allium Tuberosum is among the easiest herbs to cultivate. They thrive best when planted in full sun in a rich, well-drained soil, but will tolerate a little shade (flowering may be diminished) and most soil types. They are simple to propagate from seed or divisions. Once planted, chives are drought-tolerant, but they will thrive with constant hydration. Due to their minimal nutrient needs, they do not require regular fertilization (Plantura Magazine, 2022). There are no serious pest or disease issues with Allium Tuberosum. While Allium Fistulosum is a bulb that grows to be 0.6 m by 0.2 m in size (Plantura Magazine, 2022). It tolerates sandy, loamy, and clayey soils and prefers well-drained soil. Mildly acidic, neutral, and basic (mildly alkaline) soils are optimal. It may thrive in partial shade, and its leaves have a tendency to bend over. The plant thrives in locations with yearly daytime temperatures of between 12 and 25 degrees Celsius, but can tolerate temperatures of between 6 and 30 degrees Celsius and favours a mean annual precipitation range of 850-1,600 mm, but may withstand 700-2,500 mm (Larkcom J, 2013). Easy-to grow plant, it prefers a pH between 6.5 and 7.5, but can tolerate a pH between 4.9 and 8.5 (Larkcom J, 2013). They are able to grow without the use of fertilizers, pesticides, or other chemicals.

2.10 Summary

In this paper, the Allium Tuberosum and Allium Fistulosum was selected for cover of green roof due to various reasons. One of the main reasons is Allium Tuberosum and Allium Fistulosum very common in Malaysia. Besides, they are low-growing perennials that have shallow roots, thrive in full sun and well-drained soil, are easy to cultivate in a bright, sunny position, and require little maintenance.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter describes the procedure for developing this project. The methodology for this project is divided into several sections, including model experiment design, water sampling, laboratory analysis, and data analysis. Additionally, vegetation plays a critical role in removing pollutants from runoff by naturally degrading the pollutant. Allium Tuberosum (chives) and Allium Fistulosum (spring onions) were chosen for this project to determine if they could be used to remove contaminants from rainwater. pH, turbidity, colour, Total Nitrogen, and Total Phosphorus are some of these parameters. These are just a few of the parameters examined in this study. Although the NWQS lists numerous parameters, the selection of parameters should be appropriate to the study being conducted. Particularly, the parameters pH, turbidity, colour, Total Nitrogen, and Total Phosphorus are suitable for the use of rainwater and give this study significance. In this research paper, the experiment was carried out four times (Day 1, Day 3, Day 5 and Day 8) to measure the removal efficiency of the plants. Moreover, each of the data obtained was taken three times to calculate the average to get a more accurate result. Figure 3.2 illustrates of the study's methodology.

3.2 Description of Study Area

The study took place at Universiti Sains Malaysia's Engineering Campus in Seberang Perai Selatan, Penang (Figure 3.1). Penang is a state on Peninsular Malaysia's northwest coast. Penang is made up of an island and a mainland. Seberang Perai has an average annual rainfall of 2241mm, a relative humidity of 79.1%, a mean minimum temperature of 24°C, and a mean maximum temperature of 32°C (MetMalaysia, 2014).

Figure 3.1 : Study site located in the state of Penang, Malaysia

3.3 Research Methodology

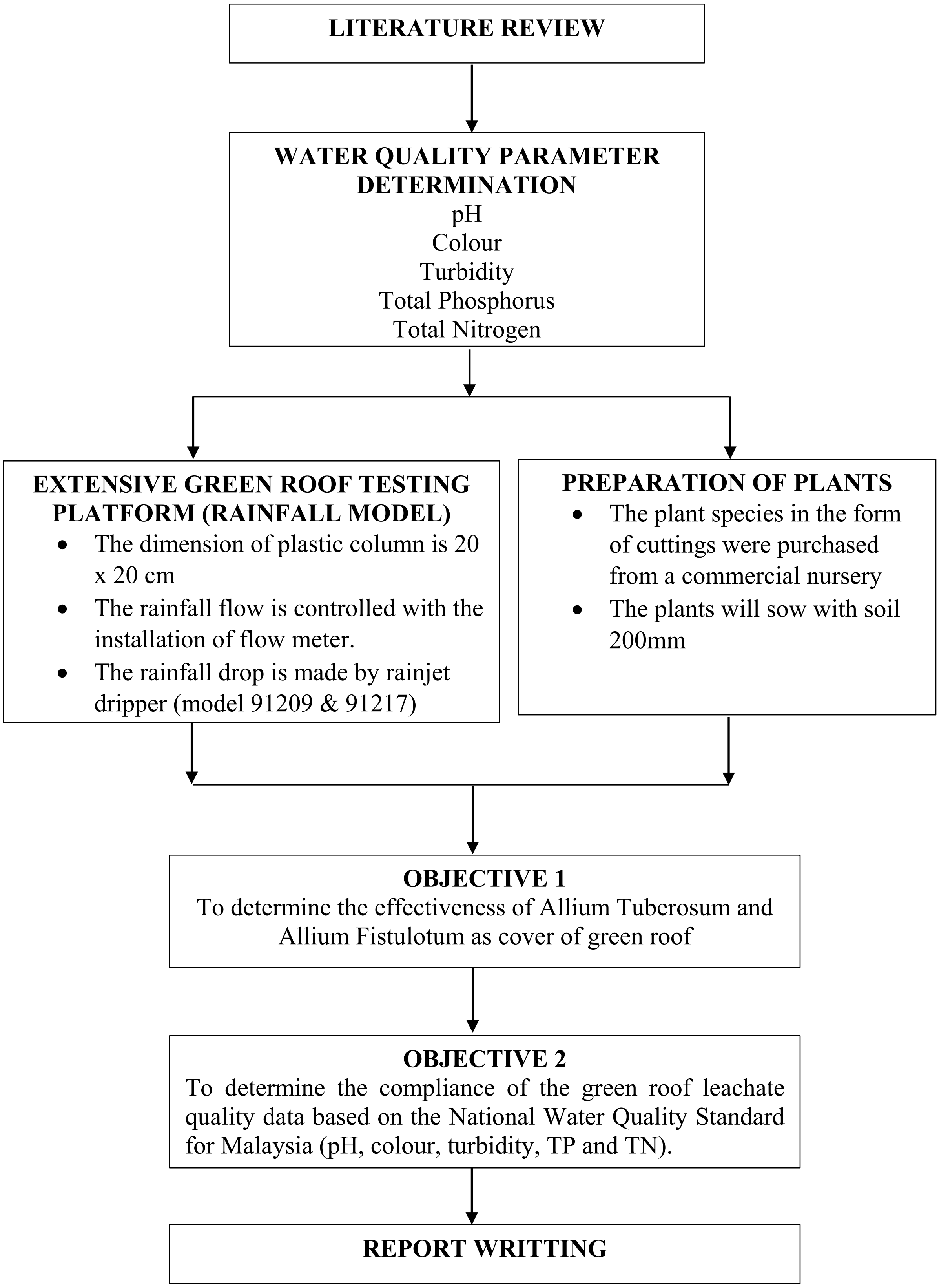


Figure 3.2 : Overview of research methodology

3.4 Design of Physical Green Roofs Model

Column study was chosen to be used as the basis for the green roof model. The dimensions of this model were 20cm x 20cm x 45cm, with the substrate and vegetation being 20cm and 15cm, respectively, as shown in Figure 3.3. The column model is made entirely of clear Perspex. Substrate was created using a mixture of organic planting materials Four-in-one soil (Figure 3.4) and sand. The substrate and plant species were obtained from a commercial nursery and were planted for two month in a poly bag. Once the model was constructed, the vegetation and substrate were transferred into it. Additionally, the flow rate of the rainwater sample used in the model was determined using a specific calculation based on the nearest station ID and MSMA guidelines. The flow rate was determined by flow meter with a fixed volume using a stopwatch. Additionally, the rainwater sample was poured into the model using a dripper to ensure an even distribution of the rainwater sample.

Figure 3.3 : Green roof model

Figure 3.4 : The organic planting soil used

3.5 Hydrologic Data

Artificial rainfall was generated and the outflow was measured. For each test bed, the outflow runoff created by simulated rainfall was compared. The Drainage and Irrigation Department provides 365 days of rainfall data, and the peak rainfall value is utilised to compute the rainfall intensity. The peak rainfall data is determined to be 191.25 mm/h, which DID defines as heavy rainfall, based on the given data (in one hour). The green roof model column is 0.04m^2, which is smaller than the actual coverage of a telemetric station with a 20 kilometer radius. For the simulation of rainfall, an inflow of 8.0 l/hour was used continuously for five minutes, yielding an intensity of 8.0 l/hour for the green roof model.

Table 3.1 : Rainfall intensity

Station Id	Peak rainfall (mm)	Duration (hr)	Intensity (mm/hr)	Area column (m^2)	Flowrate (l/hr)
Stesten Hujan Bukit Panchor	51	3.75	191.25	0.04	8.0

3.6 Laboratory Analysis

3.6.1 pH

The pH of the collected rainwater was measured. First, the pH meter was calibrated with buffer solutions of pH 4, 7, and 10. The electrode was then rinsed with distilled water and dried with a tissue. Then the electrode was immersed in the water sample and the pH was measured with a pH meter. The test was repeated three times with an average value.

3.6.2 Colour

The experiment for sample colour was apparent colour with a wavelength of 465nm. The spectrophotometer DR2800 was used to measure the apparent colour test. First, 10ml blank sample of distilled water was prepared. Then, for calibration purposes, the zeroing button was pressed. Following that, 10ml of sample was placed in a spectrophotometer to determine the colour value. The colour unit was in mg/L PtCo.

3.6.3 Turbidity

This turbidity test is used to determine the relative clarity of a liquid. It is possible to quantify the amount of light scattered by materials in water. Turbidity increased as scattered light intensity increased. Turbidity was determined using a Turbidimeter model HACH 2100P instrument calibrated in Nephelometric Turbidity Units (NTU). To begin, the turbidimeter was calibrated with a blank (distilled water) to eliminate data errors. Following that, the tested samples were placed in a turbidimeter to obtain a reading.

3.6.4 Total Phosphorus

The total phosphorus test measures the amount of phosphorus in water samples. It was determined using HACH equipment and method 10127 in this study. The COD