COCONUT FIBRE AS STORMWATER FILTERS IN SUSTAINABLE URBAN DRAINAGE SYSTEMS: A SYSTEMATIC REVIEW

SIVERAJ A/L SANKAR

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

COCONUT FIBRE AS STORMWATER FILTERS IN SUSTAINABLE URBAN DRAINAGE SYSTEMS: A SYSTEMATIC REVIEW

by

SIVERAJ A/L SANKAR

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 2021

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: **COCONUT FIBRE AS STORMWATER FILTERS IN SUSTAINABLE URBAN DRAINAGE SYSTEMS: A SYSTEMATIC REVIEW**

Name of Student: Siveraj a/l Sankar

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 : 6/8/2021

Endorsed by:

____
(Signature of Supervisor)

Name of Supervisor:

Dr.Nuridah Sabtu

Date: 6/8/2021

Approved by:

____
(Signature of Examiner)

Name of Examiner:

Dr. Nurul Hana Mokhtar kamal

Date: 6/8/2021

ACKNOWLEDGEMENT

The completion of this undertaking could not have been possible without the participation and assistance of so many people whose names may not all be enumerated. Their contributions are sincerely appreciates and gratefully acknowledged.

Thus is it not hard to conclude how active assistance from senior could passively impact the execution of a project. I am highly thankful to my supervisor, Dr.Nuridah Sabtu for her active guidance throughout the completion of project.

To all relatives, friends and others who in one way or another shared their support, either morally, financially and physically, thank you.

ABSTRAK

Sistem bioretention direka untuk menghilangkan kedua-dua bahan pencemar terlarut dan zarah dari limpasan air ribut. Sistem ini menggunakan fungsi biofilter untuk menahan air. Serat kelapa atau sabut adalah serat semula jadi yang diekstrak dari sekam luar kelapa. Pelbagai unsur pokok kelapa (misalnya sabut, cengkerang, dan lain-lain) telah diperiksa secara meluas sebagai biosorben untuk penyingkiran pelbagai jenis bahan pencemar dari air, menjadikannya salah satu sisa pertanian terpenting yang dikaji sebagai biosorben untuk rawatan air. Serat kelapa adalah bahan yang sesuai sebagai media penapis dalam biofiltrasi atau bioretention air ribut dalam SUDS. Oleh itu, kajian ini akan berusaha untuk mengkaji literatur dan mengumpulkan data eksperimen yang ada dan untuk menyelidiki ciri, kecekapan serat kelapa dalam sistem saliran bandar yang mampan. Penggunaan penapis serat kelapa untuk menghilangkan pelbagai bahan pencemar dari air dan air sisa mempunyai sejumlah kelebihan, termasuk kapasiti penjerapan yang tinggi untuk pelbagai bahan cemar, kapasiti penahan yang baik dan mengurangkan pembuangan puncak.

ABSTRACT

Bioretention systems are designed to remove both dissolved pollutants and particulate matter from stormwater runoff. This system is uses the functions of biofilters to retain water. Coconut fibre or coir is a natural fibre extracted from the outer husk of coconut. Various elements of the coconut tree (e.g. coir, shell, etc.) have been widely examined as biosorbents for the removal of various types of pollutants from water, making it one of the most important agricultural wastes studied as biosorbents for water treatment. Coconut fibre is a suitable material as a filter media in biofiltration or bioretention of stormwater in sustainable urban drainage system (SUDS). Hence, this study will attempt to review literature and gathering available experimental data and to investigate the characteristics, efficiency of coconut fibre in sustainable urban drainage systems. The use of coconut fibre filter for eliminating various pollutants from water and wastewater has a number of advantages, including high adsorption capacity for a variety of contaminants, good retention capacity and reduces peak discharge.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background Study

In past few decades, many countries have experienced increasing population growth and more people are moving to cities for better lifestyle and opportunities. This fast urbanization have caused the imbalance in hydrological cycle due to increase in pervious area and affected the water quality of stormwater runoff. Urban stormwater runoff flows from building roofs, road surfaces, walkways and parking areas that bring a wide variety of pollutants to catchment areas, rivers and other water sources that have a detrimental impact on the environment and ecology. These pollutants affect the oxygen level, eutrophication, species stress and toxicity of the receiving water body (Davis et al., 2001). The stormwater and pollutant characteristics varies on the land use categories such as residential, commercial and industrial and also the rainfall duration and quantity (Liu et al., 2013). Stormwater filtration such as bioretention or biofiltration is one of the commonly used Low Impact Development (LID) practices due to their ability to remove pollutants, reduce peak runoff flow and volume (Skorobogatov et al., 2020).

Studies performed by several researches have shown that urban stormwater is highly polluted with several contaminants. Stormwater is made-up of a complex combination of natural organic and inorganic materials, as well as a limited number of manmade materials originating from transportation, commercial, and industrial practises. As a result, the quantity and quality of stormwater are closely related to the nature and characteristics of both the rainfall and the catchment (Butler & Davies, 2004; Yusoff et al., 2018).

Bioretention systems are designed to remove both dissolved pollutants and particulate matter from stormwater runoff. Hence, this study will attempt to review literature and gathering available experimental data and to investigate the characteristics, efficiency of coconut fibre in sustainable urban drainage systems. Coconut fibres are natural fibres extracted from the outer layer of the fruit of the coconut palm, *Cocos nucifera* tree (Siriphanich et al., 2011). Coconut trees are found all over the world in tropical climate countries. Coconut plants are used for foods, fibres and woods. Coconut fibre is a suitable material as a filter media in biofiltration or bioretention of stormwater in sustainable urban drainage system (SUDS). Coconut fibre can be used for filtration in the geotextile field, preventing the mixing of fine soil and coarse material. It has a high lignin content, followed by cellulose, water-soluble matter, pectic substances, and hemicellulose ash content (Tedoldi et al., 2016). Coconut fibres are resistant to the degradation of fungi and bacteria. Coconut fibres are more resistant to tendering and chemical exposure compared to other cellulosic fibres.

1.2 Problem Statement

Urbanization and development of roads, parking lots and buildings on pervious land areas eventually increases the impervious land cover. This scenario leads to an increase in stormwater peak flow rates, total runoff volume, and degradation of runoff water quality. Urban stormwater runoff is a nonpoint source pollution, which may contain a significant amount of pollutant compounds. The pollutants in the stormwater runoff may cause negative impact on the receiving water bodies such as retention ponds and watersheds.

Stormwater management practices such as Sustainable Urban Drainage System (SUDS) focuses on overcoming the stormwater runoff problems in terms of quality and quantity at source. Bioretention or biofiltration is the environmentally friendly solutions for the problem. This system contains various layers of filtration media to improve the quality of the stormwater runoff. Coconut fibre/coir is an environmentally friendly and low-cost agriculture waste that can be used as a filter layer in bioretention or biofiltration.

This study aims to conduct systematic review on coconut fibre/husks as stormwater filters in sustainable urban drainage systems. The study was conducted by identifying the characteristics and efficiency of the coconut fibre/husk to be used as a filter in drainage system. However, this system was still little understood and quite complicated in terms of design and implementation due to many technical considerations. There have not been many reviews produced regarding this issue and the review is conducted to study the suitability of coconut fibre in terms of the characteristics and the hydraulic efficiency of using it in drainage system to filter stormwater.

1.3 Review Objectives

The review objectives of this study are:

- To identify the characteristics of coconut fibres as stormwater filters.
- To examine the efficiency of coconut fibres as stormwater filters quantitatively and qualitatively.
- To identity the limitations of coconuts fibres as stormwater filters.

1.4 Review Questions

The review questions of this study are:

- What are the characteristics of coconut fibres as stormwater filter?
- How well do coconut fibres as stormwater filter functions?
- What are the limitations of using coconut fibres as stormwater filter?

1.5 Scope of study

This study aims to do a systematic literature review (SLR) on coconut fibre as stormwater filter in SUDS. The literature review will include 50 articles related to the title of this topic around the world. The timeline set for this articles are between 2000 to 2021. the review will include an intensive review on the characteristics, quality, and quantity of coconut fibre as stormwater filter.

1.6 Importants and benefits

The primary finding of this literature review is to identify the gap of knowledge in using of coconut fibre as filter layer in SUDS. There are not many experimental studies conducted on this topic. This review paper will identify and highlight the characteristics, efficiency and limitations of coconut fibre as filter layer in SUDS.

1.7 Dissertation Outline

This thesis consists of five chapters namely Introduction, Literature Review, Methodology, Results and Discussions and Conclusion and Recommendations.

Chapter 1: this chapter includes a brief introduction to the study, the problem statement, the objective of the study, the expected outcome and importance of the study. This chapter will be helpful to give brief information and overview about the content of the dissertation.

Chapter 2: this chapter includes past journals/research paper that related to the project title and objectives of the project.

Chapter 3: this chapter provides all the detailed steps included in the SLR process and procedures. Also includes brief explanations to each step involved in this study.

Chapter 4: this chapter SLR results and discussions which includes data analysis and RQ answers.

Chapter 5: this chapter provides the conclusion to this review paper and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Urban stormwater runoff contains contaminants such as sediments, nutrients, organic content, and heavy metals that end at waterways, rivers and other receiving waterbody. Components of urban stormwater management is to control the quality, quantity, erosion, sediment with the operation and maintenance while maintaining the esthetical value (DID, 2011). The importance of urban stormwater management is to avoid flooding by minimising the surface runoff by channeling the runoff into a retention system, detention pond or other methods. As a result, in addition to minimising surface runoff, urban stormwater management strategies have changed to incorporate methods to minimise quantity of the runoff and improves the water quality.

The SUDS applications are a form of technology that is used to minimise runoff by infiltration while also enhancing the quality of stormwater runoff. SUDS applications are sustainable and enhances hydrological cycle by incorporating infiltration, filtration, retention, evapotranspitation and reuse solutions (Srishantha & Rathnayake, 2017).

Stormwater filters, on the other hand, have little impact on the volume or peak flow rate of runoff in urban areas (Lim et al., 2015) . The key advantages of stormwater filters are to remove toxins from the stormwater, reduce their concentrations, and protect downstream water quality (Singhal et al., 2008; Tota-Maharaj & Cheddie, 2015).

This review investigates low-cost solutions for managing urban stormwater runoff more sustainably. Various researches conducted on naturally available materials such as coconut fibre, compost and rice husk as filter media have shown high hydraulic efficiency and are able to remove pollutants found in stormwater such as suspended solids, dissolved solids, heavy metals, biological oxygen demand (BOD) and chemical oxygen demand (COD) (Alias et al., 2020; Lim et al., 2015; Tota-Maharaj & Cheddie, 2015). In this study, coconut fibre as a stormwater filter in bioretention systems is identified and investigated.

2.2 Sustainable Urban Drainage System (SUDS)

SUDS are environmentally friendly drainage systems that create little or no long-term damage to the surrounding ecosystem. SUDS are a collection of management methods, control mechanisms, and policies aimed at draining surface water efficiently and sustainably while reducing emissions and mitigating the effects on local water quality (DID, 2011). New, systematic, and integrated stormwater management policies are currently needed to support the government's efforts to maintain the status of a prosperous developed nation in the early twenty-first century (REDAC, 2000). As a result, a drainage system based solely on SUDS might emerge, with no traditional piped drainage. The benefits of this system are the ability to control the water quality and water quantity. The quality of water in natural waterways will increase when erosion is reduced, and SUDS devices may improve the quality of runoff through filtration and biological action (; Butler & Davies, 2004; Wang & Wang, 2018).

This stormwater management approach can be classified into detention or retention facilities based on its function. A detention system stores excess stormwater runoff in a basin for a certain period and gradually release it to outlet pipe or any type of release mechanism. This helps to reduce the peak flow rate and prevent flooding in post-development areas. A retention system stores water for sedimentation-based water quality control and reduces runoff volume by infiltration into the earth.

2.2.1 Types of SUDS

Sustainable drainage is made up of a number of components, each with its own strategy to controlling flows, volumes, and water quality while also offering amenity and biodiversity advantages. SUDS are a set of components that work together to drain several areas, rather than just conventional soakaways, reservoirs, or wetlands. Following are some examples of SUDS in practice:

2.2.1(a) Green Roof

Green roofs are an addition to an existing roof that allows for the growth of a vegetation layer on top of a growing media layer (substrate) over a waterproofing membrane on the rooftop (Vijayaraghavan, 2016; Zheng et al., 2021). The layers in the green roof are the waterproofing, drainage, filtration, substrate or growth media, and vegetation layers. Three main types of green roof are extensive, semi-intensive and intensive. The selection of green roof type depends on the climate and rainfall intensity of the location. Studies have shown that a green roof has the potential to reducing the volume of runoff, retaining water, and releasing slowly (Kasmin & Musa, 2012; Moran et al., 2004). Using flow restrictors on roof drains, stormwater can be stored on flat roofs, allowing them to fully use their storage capacity. This consists of a cultivated area with substantial storage capacity that also facilitates evapotranspiration and improves water quality as stormwater flows through the soil (Butler & Davies, 2004).

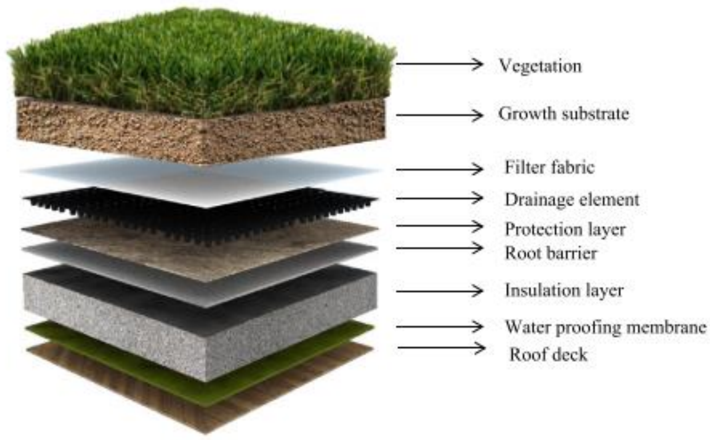

Figure 2. 5: Different layers of green roof components (Vijayaraghavan, 2016)

2.2.1(b) Infiltration Devices

Soakaways, infiltration trenches, infiltration basins and rain garden are examples of infiltration methods in urban stormwater management. These methods are effective for locations where space is limited. A soakaway is an underground structure made of stone, plastic mesh boxes, drywall, or precast concrete ring sections. A filter fabric-lined infiltration trench or basin is a linear excavation that is backfilled with stones and possibly covered with grass or other natural materials. Stormwater runoff channelled to a soakaway or infiltration trench either infiltrates into the ground or evaporates. Rain garden is small depressions in the land that can serve as infiltration area for runoff from roof and low concentration waters. By establishing a surface area of contact, the device provides storage and improves the soil's ability to receive water. Surface water runoff flowing through this devices is stored in the voids of the soil and allowing water to infiltrate slowly into the filtration layer and disperse into the ground.

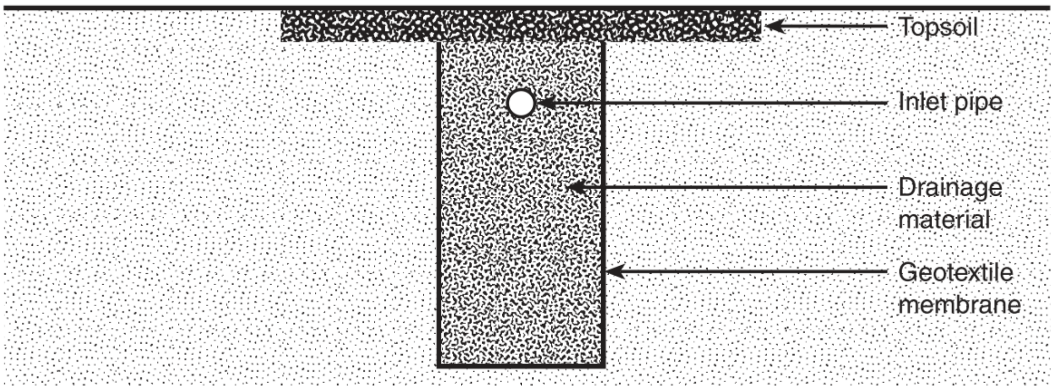

Figure 2. 6: Infiltration trench (Butler & Davies, 2004)

2.2.1(c) Swales

Swales are grass-lined channels that are used to transport, store, infiltrate, and handle stormwater (Butler & Davies, 2004).. Runoff reaches directly from impermeable surfaces such as adjacent houses. The runoff is kept either until it is infiltrated or until the treated runoff is transported to the sewage system. The design of grassed swales encourages storm water conveyance at a slower, more controlled rate and works as a filter medium, eliminating contaminants and permitting stormwater infiltration. They are frequently used in conjunction with other control measures as a pre-treatment. Sedimentation, infiltration through grass and adsorption onto it, and penetration into the soil are all methods for removing pollutant, reduce the runoff volume and flow rate. Swales are commonly seen next to roadways, where they replace traditional gullies and drainage pipe systems, but they can also be found in landscaped areas, next to parking lots, alongside fields, and in other open spaces. They are suitable for use as industrial drainage systems since any pollution is apparent and can be handled with before it causes damage to the receiving stream.

2.2.1(d) Pervious Pavement

Pervious pavements are commonly used in car parks, walkways, and other little or no traffic areas. For the surface layer, there are numerous options available. It could be made up of a range of different sorts of blocks or a layer of porous asphalt. Water can seep through porous blocks via pores in the material, or water can pass through permeable blocks when the material is not porous but the blocks are arranged in such a way that water can move between them. Permeable blocks can be laid with a pattern of bigger voids filled with soil and grass, or gravel, or with a tight fit with water moving through narrow slots between blocks (Hu et al., 2020).

A pervious car park structure's storage capacity can also be increased by receiving additional runoff from roof surfaces or other impermeable surfaces. This additional inflow should be evenly distributed on pervious pavement, and the water should be introduced to the pavement structure either by being released so that it flows through the surface layer, or by using a silt trap to avoid clogging the sub-surface layers. Rainwater stored in the sub-base could potentially be used for toilet flushing and garden/landscape irrigation (Hu et al., 2020).

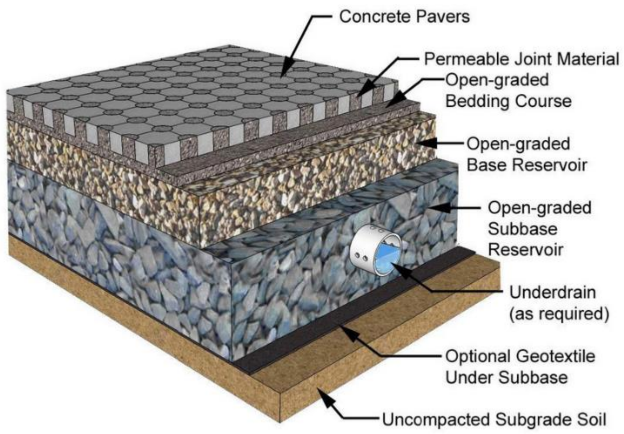

Figure 2. 7: Layers in a pervious pavement

2.2.1(e) Ponds

Ponds are suitable for use with flows that are relatively uncontaminated. Depending on whether or not a permanent pool of water is maintained, they are categorised as wet or dry. A constant volume of water is incorporated into the construction of wet ponds. In addition to flood management, this sort of pond generally has aesthetic, recreational (e.g., sailing, fishing), and environmental benefits (e.g., reintroducing wildlife habitats to urban areas). Wet ponds can help with pollution control by improving the water quality of the outflow through sedimentation and biological processes. Because many contaminants are connected to suspended particles, which are captured by sedimentation, this is the case. The depth of the pond is usually limited to 1.5–3.0 m to avoid thermal stratification (Butler & Davies, 2004).

Between storm events, dry ponds do not have a persistent pool of water to store. Excavated, berm-encased or dished areas with grass or porous paving line them. Water meadows are the naturally created variants. It can be used as retention basins (with no permanent exit and only infiltration for drainage) or detention basins (with some sort of outflow mechanism back into the drainage system) (i.e., fixed or mechanical hydraulic controls). Dry ponds are generally overlooked by the general public because they are multi-functional, serving as recreation places and only filling during severe storms. Because of the re-erosion of previously deposited particles during filling, dry ponds have lower pollutant removal efficiency and are smaller than wet ponds. Wet/dry ponds are a hybrid of the two pond kinds mentioned previously. Part of the storage area is always full with water, while the other only fills during periods of high flow. For example, ‘extended' detention basins frequently include a permanent pool for aesthetic purposes (Butler & Davies, 2004).

Figure 2. 8: Detention pond

2.3 Infiltration systems

Typically, stormwater infiltration's function is to eliminate pollutants from stormwater by passing it through a layer of porous material such as sand, gravel or soil above the ground table (GWT) (DID, 2011). The solids that are removed from the water are kept by the filter medium during filtration process. However, some filters employ organic materials like peat or leaf compost, or a combination of sand and an organic component (Shukla & Shukla, 2013; Singh et al., 2016). Adsorption criteria and chemical precipitation reactions inside the filter media can help to retain dissolved pollutants such dissolved metals and hydrocarbons. Stormwater flows into a collection pipe or empties into an open-channel drainage system after flowing through the media or infiltrate into the ground.

2.3.1 Types of filtration

As filtration is popular in SUDS implementation and management, there are number of variants in the design and systems used for suitability of the scale and condition of the locations. For example, sand filters and vegetative filters or biofilters.

2.3.1(a) Sand filtration

Sand filtration systems consists of different designs such as surface sand filter, underground sand filter and perimeter sand filter. A surface sand filter is a designed chamber with sand filter bed and a temporary runoff retention above the bed. Pollutants are caught or strained out of the filter bed's surface. The underground sand filter is housed in a three-chamber underground vault that may be accessed via manholes or grate openings in this configuration. In the storm drain system, the vault might be on-line or off-line. The perimeter sand filter is made up of two parallel trench-like chambers that are commonly put along the roadside or parking lot's perimeter. As shown in figure 2.5 the first chamber, which features a shallow permanent pool of water, receives stormwater runoff before the runoff spills into the second trench, which has a sand layer, the contaminants will settle at the bottom.

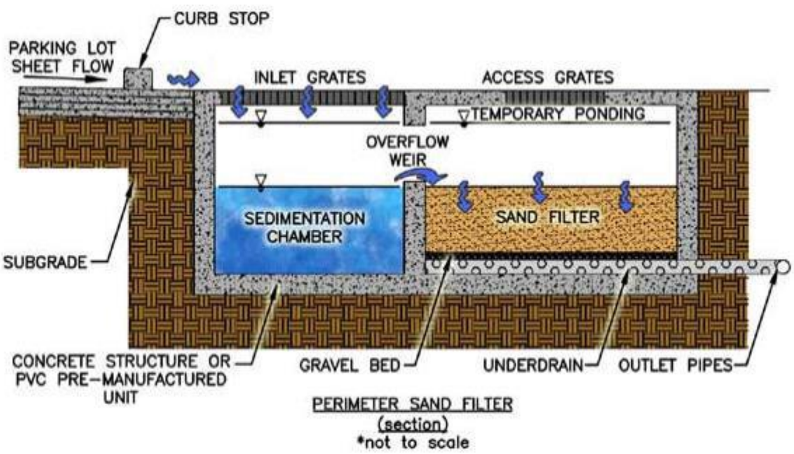

Figure 2.5: Typical perimeter sand filtration design

2.3.1(b) Biofiltration

Areas of existing or planted vegetation along grasslands, storm drains, streams, or other bodies of water are known as biofilters in the biofiltration process. They are typically utilised to minimise pollution from both point and non-point sources. Types of biofilters are grass channels, dry or wet swales, and filter strips. Permanent grasses or wood are commonly used in these zones. They remove nitrogen and phosphorus from water, as well as sediments, pesticides, organic debris, pathogens, and other pollutants. The rate at which biofilters remove total suspended solids (TSS) is determined by the type and depth of vegetation in the filter strip. Deposition, infiltration, biological and chemical processes all help to remove pollutants from runoff water by dispersing the water evenly to the covered area of the biofilter. Figure 2.6 shows the swale biofiltration drainage.

Figure 2.6: Grass swale drainage system

2.4 Bioretention system

Biorentention system is a popular best management practices (BMP) which uses biological absorption and porous media infiltration processes to remove pollutants from stormwater runoff (DID, 2011). Small rainy runoff is captured, temporarily detained, and treated before being released back into the receiving waters by these structural controls. Pretreated runoff will be channelled into systems that can be built from a shallow dug site along a proposed drainage channel or swale. This system is uses the functions of biofilters to retain water. This system can be designed to be permeable or impermeable to let water infiltrate to the ground. Impermeable systems uses a layer of geotextile lining to prevent water to infiltrate.

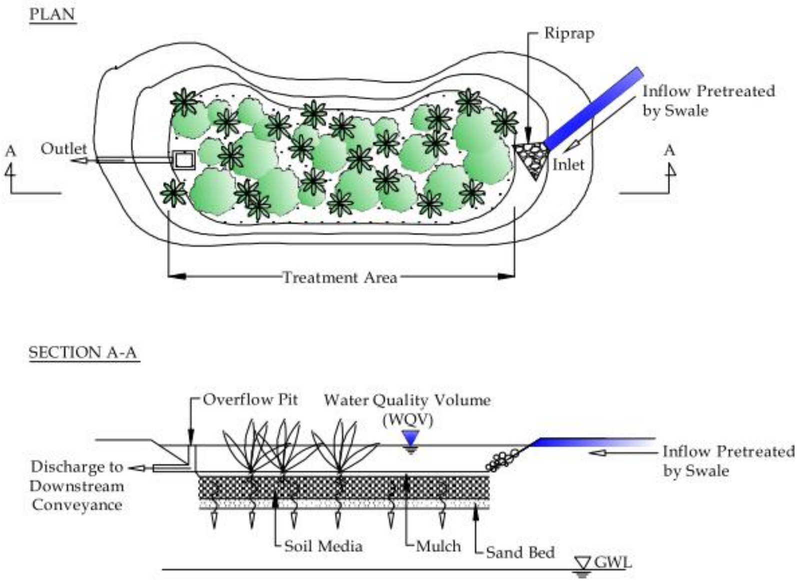

Figure 2.7: Typical bioretention design

2.5 Design criteria for biofiltration and bioretention systems

The storage volume, depth, slope, soil and permeability rate of the planting soil bed, and either the hydraulic capacity of the underdrain or the permeability of the subsoil are the basic design parameters for bioretention systems. The system must have enough storage space above the bed's surface to contain the storm runoff volume without overflowing. The bed's thickness and character must be enough for pollution elimination, and its permeability rate must be high enough to drain the stored runoff within 72 hours (NJDEP, 2009).

2.5.1 Siting

Space availability for straightforward installation considering setback regulations on residential subdivision lots and commercial lots • Site with land surface that allows for reasonably uniform dispersion of flows The systems should not be placed near building areas, well heads, or septic systems (unless the design includes suitable waterproofing measures and is certified by a geotechnical engineer). Table 9.2 shows the minimum setback lengths from structures and property lines for various soil types. Retrofit and redevelopment prospects for stormwater management, particularly in regions where total stormwater management control is not possible.

2.5.2 Drainage area

Small catchments with less than 1.0 ha of impervious surface should typically use an individual bioretention system to capture and treat runoff. When used to treat bigger regions, the systems are more likely to clog faster. Furthermore, transporting flow from a broad area to a bioretention system is complicated. Generally, commercial or residential drainage areas larger than 0.5-1.0 ha will discharge flows greater than the ARI storm event every five years. When flows rise over this point, the designer must consider the risk of erosion to stabilised regions.

2.5.3 Slope

On relatively small slopes, bioretention methods work well (usually less than 5 percent). The site must have a sufficient gradient so that runoff from a bioretention system can be connected to the storm drain system. However, it's worth noting that bioretention systems are frequently found next to parking lots or residential landscaped areas, which have gentle slopes.

2.5.4 In-Situ Soils

The permeable bioretention systems should be located in an area where the in situ soil is sandy and well drained. Impermeable systems should be employed on clayey and poorly drained soils. It is advised that permeable bioretention systems be installed on in situ soils with saturated hydraulic conductivities greater than 13 mm/hr. When a permeable bioretention system is utilised with a saturated hydraulic conductivity of less than 13mm/hr, the bioretention area becomes prohibitively huge. Furthermore, soils with poorer hydraulic conductivities will be more prone to clogging, necessitating additional pretreatment.

2.5.5 Groundwater

Bioretention systems should be built above the groundwater table to guarantee that groundwater never comes into contact with the system's bottom, preventing groundwater pollution and system failure. A minimum vertical gap of 0.6m should be maintained between the seasonal high water table and the bottom of the bioretention system. Sites with shallow groundwater should be avoided since infiltration will be ineffective. Similarly, whether bedrock or the impermeable layer is shallow, the organic absorption penetration layer of a bioretention system is effective in pollutant removal.

2.6 Coconut fibre as amendment in filtration and bioretention systems

Coconut fibre or coir is a natural fibre extracted from the outer husk of coconut. Various elements of the coconut tree (e.g. coir, shell, etc.) have been widely examined as biosorbents for the removal of various types of pollutants from water, making it one of the most important agricultural wastes studied as biosorbents for water treatment (Mukkulath & Thampi, 2012). The coconut palm (Cocos nucifera) belongs to the Arecaceae family (palm family). Coconut palms can be found all across the tropical world. Millions of people in tropical coastal regions rely on it for their livelihood. Because of the wide range of uses, coconut palms have been dubbed the "tree of life" (Hwang et al., 2016). Aside from the precious contents of the nuts, the coconut palm is noteworthy because the husks, shells, leaves, and stem of this tree have numerous uses. Coconut fibres come from the husk of the tree that surrounds the coconut. Copra production produces coir as a by-product, while the husks are considered trash and are often utilised as mulch or fertiliser due to their high potash content (Bhatnagar et al., 2010).

. It has the best tear strength of all natural fibres and is resistant to extreme wet environments, chemical and microbiological attacks. The principal elements are cellulose (36–43%), hemicellulose (18–20%), and lignin (41–45%), with pectin (2–3%) being a minor constituent. These are known to contain groups that are responsible for metal ion adsorption in aqueous solutions (Bhatnagar et al., 2010).

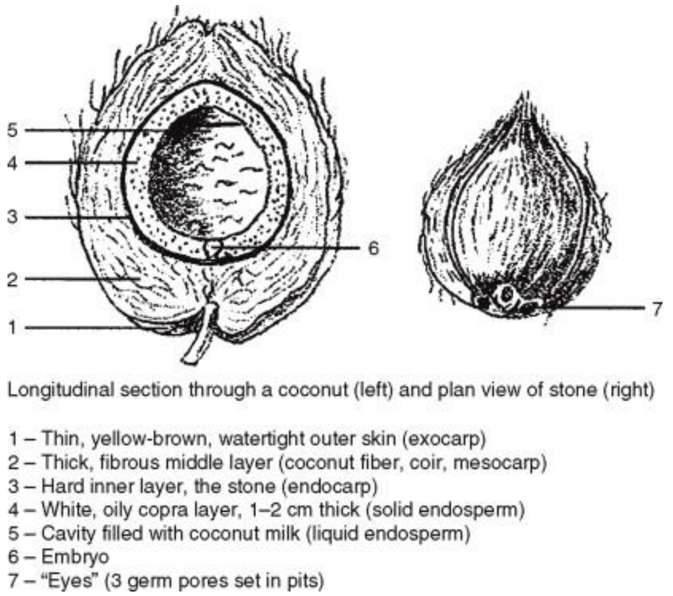

Figure 2.5 Coconut fruit and its parts (Hutten, 2007)


Figure 2.6 coconut husk and fibre

The filter was made up of an organic filter medium made up of coconut fibres. Shredded coconut fibres and gravel were used as the media. The size of the ponding region in the filter was determined by the amount of stormwater dosing. Shredded coconut husk/fibres, matted to form a sheet-like layer, is the principal media in this filter. Smaller particles that pass through the husk fibres will not be able to enter the filtrate (with a gravel bedding layer), hence the filter fabric was designed to create a suspended solids deterrent (Jurczak et al., 2018).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the formulation of review questions, SLR protocol conducted, systematic searching strategy, the data extraction and data synthesis, as well as reporting the SLR.

3.2 Planning of SLR

3.2.1 Formulation of Review Questions

The formulation of the review is based on the three objectives of this study. Each objective of the study have one review question to it. The review questions are derived to answer the objective of the study with the findings from the study. The review questions were "What are the characteristics of coconut husks/fibres/coir as stormwater filters", "How well do coconut husks/fibres/coir as stormwater filters functions" and "What are the limitations of using coconut husks/fibres/coir as stormwater filter". These review questions were used in the formulating of SLR protocol and creating searching strings.

3.2.2 Review Protocol

The review protocol for this study was created to identifying the steps involved in this study. The protocol has three steps and sub-steps to it. Based on Figure 3.1, the steps for this study were planning, conducting and reporting. The first stage is planning stage which was divided into two parts development of review protocol and formation of review questions. Three review questions for the study are formed based on the three objectives of the study. These review questions were created to answer the characteristics, efficiency and limitations of coconut fibre as filter media in stormwater management system. The second stage was conducting, searching strategy is formed to select the papers to be reviewed. The searching database is divided into two primary database and secondary database. In the searching strategy, the inclusion and exclusion criteria are set to select the most relevant and latest papers to be reviewed. The inclusion and exclusion criteria for this study is set as time frame of publications, type of publications and language of publication. In the eligibility stage, the title and abstract of the papers are read and performed inclusion and exclusion. The full-body read for some articles for further clarifications. The final stage is reporting the data extracted from screening. Data related to the study were extracted out and presented in a table or graphical presentation. The data includes the comparison of the results of the experiment from different authors, Summary of qualitative and quantitative measurement of the research and more. In the end, a discussion and conclusion of the qualitative synthesis has written.

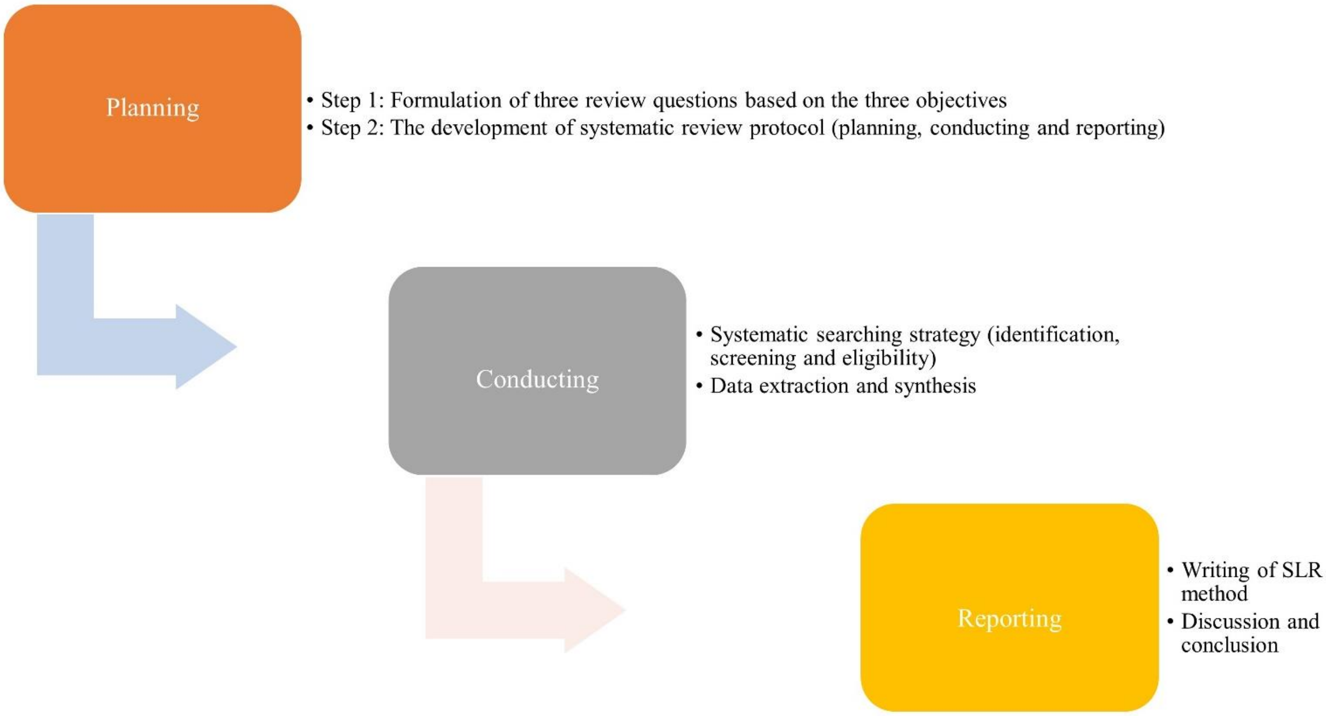

Figure 3.1: SLR protocol

3.3 Conducting the SLR

3.3.1 Systematic Searching Strategies

After the formulation of the protocol, review objectives, and review questions the systematic searching strategy can be performed. It also has a few steps to it including searching strategy, screening, and eligibility.

3.3.1(a) Searching strategy

In order to develop an effective searching strategy to present findings publications from various country is reviewed. The database was categorized into primary database (Science Direct) and secondary database (Scopus).

Firstly, searching strings are formulated based on the keywords generated from the review objectives and questions. Table 3.1 shows the searching strings developed for each database for article searching. Multiple searching strings are used for each database due to usage of many keywords such as stormwater, bioretention, filtration, coconut fibre/husk/coir and many more. This searching strings gives the selected database more options for searching for more related papers for the study. The searching process was run on selected primary and secondary databases based on the main enriched keywords either by using advanced searching techniques which is by using Boolean operator, phrase searching, truncation, wild card, and field code functions separately or by combining these searching techniques into a full searching string as shown in Table 3.1. The searching strings developed are then 'paste' in selected databases to search related articles. Manual searching techniques such as handpicking, snowballing, and emailing the corresponding authors are performed to screen the eligible articles.