COCONUT SHELL AS AGRO-BASED FILTRATION MEDIA FOR STORMWATER MANAGEMENT POLLUTION CONTROL

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ABSTRACT

For the past decade, conventional filter media using River Sand (RS) has been commonly implemented as a stormwater management pollutant control to filter pollutants from runoff rainwater. However, the utilization of organic agro-based materials as biofilter media has yet to be fully explored and its potential in terms of physical properties to promote stormwater pollution filtration is still lacking in literatures. Therefore, this study discusses the potential of providing/shifting to a more organic and efficient filter media specifically Coconut Shell, focusing on filtration efficiency-influenced factors and its comparative filtration performances regarding Conductivity, Total Suspended Solid (TSS) and Turbidity percentage removal. The influence of operating parameters such as porosity and specific gravity of CS was analyzed through experimental method. This work evaluates the effectiveness of using CS as an agro-based filtration media. Additionally, the study also discusses a comparative analysis of three filter media design which are 100% RS, 100% CS and 50% CS + 50% RS filter column configurations to select the most optimum filter efficiency performance. Hence, the study demonstrated a successful application of CS as a potential sustainable adsorbent for the removal of stormwater pollutants (Conductivity, TSS and Turbidity) when operated at a condition of 50% CS + 50% RS filter media.

ABSTRAK

Sejak sedekad lalu, media penapis konvensional menggunakan Pasir Sungai (PS) telah biasa digunakan sebagai bahan penapis dalam pengawalan pengurusan pencemaran air hujan Walau bagaimanapun, penyelidikan mengenai penggunaan bahan asas tani organik sebagai media biopenapis masih belum diterokai sepenuhnya dan potensinya dari segi sifat fizikal untuk menggalakkan penapisan pencemaran air ribut masih kurang dalam penulisan. Oleh itu, ulasan ini secara kritis membincangkan potensi menggunakan Tempurung Kelapa (TK) sebagai media penapis yang lebih efektif serta memfokuskan berkenaan faktor-faktor yang mempengaruhi kecekapan penapisan dan prestasi penyingkiran peratusan dalam menyingkirkan Kekonduksian, Jumlah Pepejal Terampai (JPT) dan Kekeruhan. Parameter yang mempengaruhi operasi dan keberkesanan TK sebagai bahan penapis yang baik seperti keliangan dan graviti tertentu telah dianalisis melalui kaedah eksperimen. Kajian ini menilai keberkesanan penggunaan TK sebagai media penapisan berasaskan pertanian. Selain itu, kajian ini juga membincangkan analisis perbandingan tiga reka bentuk media penapis iaitu konfigurasi lajur 100% PS, 100% TK dan 50% TK + 50% PS untuk memilih prestasi kecekapan penapis yang paling optimum. Demikian itu, kajian ini telah berjaya menunjukkan aplikasi TK sebagai penjerap mampan yang berpotensi untuk menapis bahan pencemar dari air hujan (Konduktiviti, JPT dan Kekeruhan) apabila dikendalikan pada keadaan 50% CS + 50% media penapis PS.

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LIST OF SYMBOLS

L	-	Liter
LPM	-	Liter Per Minute
g	-	gram
%	-	Percentage
mg	-	Milli gram
m^2	-	Meter Square
kg	-	Kilo gram
ml	-	Milli liter
mm	-	Milli meter
NTU	-	Nephelometric Turbidity Units
μS	-	Microsecond
cm^3	-	Centimeter cube

LIST OF ABBREVIATIONS

RS	-	River Sand
CS	-	Coconut Shell
KS	-	Kernel Shell
BMP	-	Best Management Practices
ET	-	Evapotranspiration
SS	-	Suspended Solids
POFA	-	Palm Oil Fuel Ash
TOC	-	Total Organic Carbon
TSS	-	Total Suspended Solid
BFOB	-	Biofiltration over organic bed
OFM	-	Organic Filter Materials
RH	-	Rice Husk
PFF	-	Palm Fruit Fiber
EFB	-	Empty Fruit Brunch
PKO	-	Palm Kernel Oil
NTU	-	Nephelometric Turbidity Units
BOD	-	Biochemical Oxygen Demand
TSS	-	Total Suspended Solid
TIC	-	Total Inorganic Carbon
MWQC	-	Multiparameter Water Quality Checker

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The channelization of streams, the degradation of stream habitat, and the degradation of water quality are just a few of the environmental challenges that have arisen as a result of urban runoff. Urbanization and industrialization have resulted in rapid changes in people's awareness of the need to protect the environment. As a result of a lack of environmental protection technologies and effective environmental governance, problems with the water environment in developing countries have become increasingly severe. Aside from that, ongoing problems with stormwater quality management are jeopardized by rising urbanization, which generates more surface runoff as a result of an increase in impervious surfaces. Unquestionably, urbanization increases stormwater runoff, resulting in an increase in the danger of floods, a decrease in local infiltration, and an increase in sediment, heavy metal, and nutrient pollutants as mentioned by O'Sullivan (2015). Especially problematic in this context is the fact that rainwater is a non-point source pollutant, which creates significant difficulties in controlling rainfall runoff and rainwater pollution. This has also had negative consequences on the water environment, which has resulted in severe economic losses in the long run.

Currently, there is no indication that the increasing trend of urbanization will come to an end. Instead, future predictions foresee sustained population growth, with urban populations likely to account for more than two-thirds of the total in 30 years, according to the United Nations Population Division. United Nations (2019) states that while urbanization has the potential to spur economic growth, it has also increased the responsibility of those who are accountable for recognizing and managing its environmental implications to limit environmental damage.

Anthropogenic impacts on the environment increase dramatically with population growth, owing to the improvement of roads, the construction of buildings, and the provision of other comforts, as well as the increase in energy use. In densely populated urban areas, the amount of anthropogenic emissions exceeds the area's ability to absorb those pollutants. Pathogens, organic matter, nutrients, sediments, and poisons are all forms of pollutants. Switching from previously green regions to impermeable surfaces such as asphalt and roofs, for example, increases stormwater runoff. As a result, the quality of runoff is affected by anthropogenic activity. Whenever stormwater flows over impermeable surfaces, it washes away a wide range of pollutants and transports them to receiving bodies of water. It was indicated in the study by Wood Ballard et al. (2015) that contaminated stormwater discharges can cause damage to recipient water bodies in various different ways, resulting in both public and environmental impact.

It has been stated by Li et al. (2016) that the combination of increased contaminant load owing to urbanization and climate change generating heavy precipitation and increased stormwater runoff necessitated the establishment of a functional stormwater infrastructure system. Stormwater management facilities that are environmentally friendly must be implemented more aggressively on a global scale in order to control both the quantity and the quality of stormwater. To provide a sustainable solution, these so-called blue-green facilities take use of the restoration of naturally occurring processes that have been disturbed as a result of urbanization.

The term "bioretention" refers to a method of treating and retaining rainwater from both local and large catchment areas before the water is discharged to a receiving water body. According to Larm & Blecken (2019) , "bioretention" is a term used to describe a method of treating and retaining rainwater from both local and large catchment areas before the water is discharged to a receiving water body. As explained by Kratky et al. (2017), when untreated stormwater inflow reaches the biofilter, the water flows through the plants and then percolates through the filter material, therefore removing contaminants. Not to mention that through an underground drainage system as well as a sewage system, the treated water is dumped into the receiving water body.

Bioretention has become more adaptable as a stormwater management practice all across the world, including Malaysia, as it has gained in popularity. This strategy is commonly utilized to limit negative impact of non-point source pollutants largely from urban stormwater runoff connected with impermeable areas as mentioned by Brown & Hunt (2011). This method gives good function in flow management and also stormwater treatment across literatures. As part of their research, Browne et. al (2013) compared the effectiveness of bioretention systems to other Best Management Practices (BMPs) such as detention ponds and infiltration.

The majority of bioretention sites are constructed from a diverse range of different types of vegetation and fillers, as well as storage and maybe underground drainage infrastructure. Plants, fillers, and buildings for the bioretention area are selected prior the design of the bioretention area can be completed. Initially, the notion of bioretention areas included the combined impacts of soil, plants, and microorganisms; soil, plants, and microorganisms are the primary elements influencing the treatment that may be achieved through bioretention areas, as are soil and plants. The concept of bioretention areas has evolved to include the concept of combined impacts of soil, plants, and microorganisms, as well as the concept of soil and plants (Roy-Poirier et al., 2010).

The successful design of bioretention zones, as well as the prediction of the treatment impact for different pollutants and the rainwater retention capacity during operation, are still ongoing research projects that need to be studied and improved. The success of bioretention in treating stormwater pollution is primarily determined by three factors: the type of filter used for the retention of stormwater runoff, the number of pollutants removed by bioretention, and the type of plants utilized in the bioretention system.

According to Soberg et al., (2019) the selection of the filter is the most important design parameter for bioretention in a composite. It is possible to retain a portion of the rainwater, which causes contaminants in the rainwater to migrate to the surface of the filter's surface. According to Hsieh and Davis (2005), the hydraulic conductivity of the filter has the greatest influence on the volume of retained rainfall, while the removal of contaminants such as heavy metals has the greatest influence on the adsorption and interception capacity of the filler. The evapotranspiration (ET) of plants contributes to the reduction of stormwater runoff, while the absorption of pollutants by plant roots aids in the removal of pollutants from rainwater. As a result, the choice of filler is determined by the permeability of the water and the ability of the filler to absorb impurities.

The types of stormwater filter media can be classified into three main categories, agro-based materials, industrial by-products, and artificial materials. Based on the differences in filter hydraulic conductivities and particular pollutant absorption capacities, Davis et al. (2009) research suggests that the type of filter to use has an impact on the selection process. The features of the filler, such as porosity, effective nutrient content, permeability, and particle size distribution all of which have an impact on the quality of the rainwater discharge, determine how well the system performs and how long it lasts as states by Carpenter and Hallam (2010). In regard to the last aspect, adjusting the bioretention design dimensions can reduce the impact towards the retention and treatment impact of rainwater. According to Payne et al. (2014), the dimensions cover aspects such as the surface depression volume, the filling depth, and the interior water storage (IWS) capacity of the structure. In this study, the choice for the type of filler will emphasize on agro-based filtration media.

1.2 Problem Statement

Stormwater quality degrades as a result of untreated surface runoff that runs straight into drainage systems. Additionally, stormwater accumulates potentially dangerous contaminants such as dust, metals, and nutrients, which can result in blockage and silt transport, affecting aquatic bodies. Controlling contaminants in stormwater runoff is vital for preventing the influx of non-point source pollutants into near water bodies, which is especially critical in densely populated urban areas. Pollutants of natural and anthropogenic origin are carried away from the air and surface by stormwater runoff and deposited in bodies of water such as bodies of water, rivers, wetlands, coastal waterways, and groundwater. Along with suspended solids (SS), stormwater runoff contaminants include organic materials in both dissolved and particulate forms, heavy metals, and phosphorus (in both dissolved and particulate forms) (Hwang et al., 2021). As a result, stormwater treatment technologies such as filtration, infiltration, and constructed wetlands have been developed and applied to assist in the reduction of nonpoint source pollution.

Furthermore, according to Hwang et al., (2021), the use of sand as a general media for granular filtration media has been widely adopted for runoff treatment processes over the years due to its abundance and suitability in urbanized areas, as well as its high removal efficiencies of SS, phosphorus, and heavy metals through a variety of mechanisms, including filtration and adsorption. The simplicity of a sand filter is one of its most significant advantages, as it frequently results in significant yields. A variety of processes throughout the water management process, including pretreatment, side-stream filtering, and polishing, make use of this technology. A sand filter frequently produces effluent that can be recycled.

Although additives can increase the surface area of the media and improve its adsorption, according to Wang et al. (2009), there are still limitations to the effectiveness of a single sand media in terms of efficiency. When it comes to increasing the production of the sand filter, it is occasionally necessary to use chemicals. The use of sand filtration has its drawbacks, one of which is the rinse water generated during the cleaning process. Extremely contaminated water must be treated and disposed of in a proper manner. The use of anthracite and coal to supplement sand media is both expensive and environmentally unsound (M. Dan et al, 2017). Aside from that, redesigning the stormwater system filter is extremely expensive due to the difficulties in overcoming these limits. The use of agricultural-based filter media will thereby eliminate the need for other following treatment systems, which were previously required when using conventional filter media.

Apart from that, one of the ongoing issues in Malaysia, notably in the oil palm industry, is the growing volume of agricultural waste. Each year, agricultural waste totals 998 million tons worldwide, with 1.2 million tons being disposed of in landfills in Malaysia, owing to the agricultural sector's critical role in supporting human needs and producing a livelihood. According to the Malaysian Department of Statistics (2019), the palm oil sector contributes to one of the country's largest agro-industries, producing vast amounts of trash in the form of empty fruit bunches, fiber, and kernels. This is in compliance with the Agricultural Waste Management System (AWMS). According to Yusoff S. (2006), the amount of waste created in Malaysia continues to grow year after year as a result of the country's rapid expansion. Malaysia is a major producer of Palm Oil Fuel Ash (POFA), a byproduct of palm oil that is used to generate energy. With 200 palm oil mills operating, this equates to 1,000 tons of POFA produced each year. As a result, the concept of sustainable management practices has gained prominence during the last several years. Solid waste management is crucial for environmentally acceptable agricultural waste disposal.

1.3 Objectives of Study

The objectives of this study are as below:

1. To characterize the properties of the selected agro-based material; Coconut Shell (CS) in three different particle size distributions with respect to its porosity and specific gravity.
2. To characterize the stormwater samples in regard to its Turbidity, Conductivity and Total Suspended Solid (TSS) before and after column filtration.
3. To evaluate the effectiveness of using Coconut Shell (C2) in terms of its pollutant removal percentage under selected optimum column filter media configuration.

1.4 Scope of Work

This study will evaluate the design factors of Coconut Shell (CS) of three different particle sizes respectively in terms of its specific gravity and porosity properties that will be affecting the performance of utilizing agro-based media to reduce the pollutants from stormwater through infiltration process before discharging it into a nearby body of water such as lake, pond, and rivers. The most optimum particle size will be selected to be further assessed in conducting objective (2) and (3) respectively.

The particle size distribution of CS is categorized into three sizes mainly C1, C2, C3 for Coconut Shell. The particle size range of each sample can be referred in Table 1. Meanwhile, river sand (RS) will be used as a control variable for this study.

Table 1: Particle Size Distribution of Sample

Sample	**Particle Size Distribution (mm)**		
	> 4.75 mm	1.4 – 4.75mm	<1.0 mm
Coconut Shell (CS)	C1	C2	C3
River Sand (RS)	0.06 – 2.0 mm		

Furthermore, the stormwater properties in respect to the sample's turbidity, conductivity and total suspended solid (TSS) will be further analyzed to determine its impact on the filter performance prior and after the filtration process. The effectiveness of using agro-based as a filtration media will be assessed in terms of the interrelationships among the variation of particle size, density, porosity of Coconut Shell respectively.

The summarized work scope involved in this study is shown in Table 2.