OPTIMIZATION OF FILTRATION USING AGRO-BASED MEDIA BY RESPONSE SURFACE METHODOLOGY

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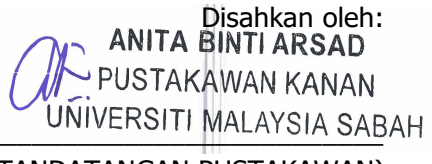

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ABSTRACT

Filtration has been extensively utilized for water quality enhancement. However, urbanization and uncontrollable growth increase the potential for pollutants to enter a water body or river, particularly in stormwater runoff. Numerous studies have reported and demonstrated a continuous improvement in the filtration mechanism's ability by utilizing alternative sources of material as engineered soil media, such as agricultural waste or agro-based medium. Even so, fewer observations have been made about optimizing filtering designs where the findings are still significantly predictive in terms of performance improvement. Hence, this study explores, investigates and optimizes filtration using agro-based media. In this study, the experiment was designed and optimized using Response Surface Methodology (RSM). Numbers of runs had been done with the variation of stormwater concentration (150 mg and 1500 mg) and loading rate (24.88 ml/min, 45.405 ml/min and 65.93 ml/min) as well as different mix-ratio of filter configuration (River Sand 100%, Coconut Shell 100% and River Sand 50% & Coconut Shell 50%) were used to determine TSS and turbidity. The data for all laboratory testing were analyzed and optimized using the Design Expert Version 11.0 software. From the analysis, the selected value of optimization in this study are stormwater concentration of 226.902 mg, loading rate of 49.46 ml/min and selected filter configuration is the River Sand (50%) & Coconut Shell (50%) configuration. Actual stormwater sample were collected from a drainage behind Block C, Engineering Faculty, Universiti Malaysia Sabah and and the stormwater sample were filtrated using the selected optimal configuration. A significant reduction of TSS with 85.31% removal and turbidity with 85.35% removal from the actual stormwater sample were obtained utilizing the selected optimal configuration and there were no clogging or ponding was observed during the run of the experimentation work. Therefore, this indicates that both river sand and coconut shell work well together to provide an efficient and effective stormwater filtering system.

ABSTRAK

PENGOPTIMUM PENAPISAN MENGGUNAKAN MEDIA ASAS TANI OLEH METODOLOGI PERMUKAAN TINDAK BALAS

Penapisan telah digunakan secara meluas untuk peningkatan kualiti air. Walau bagaimanapun, pembandaran dan pertumbuhan yang tidak terkawal meningkatkan potensi bahan pencemar untuk memasuki badan air atau sungai, terutamanya dalam larian air ribut. Banyak kajian telah melaporkan dan menunjukkan peningkatan berterusan dalam keupayaan mekanisme penapisan dengan menggunakan sumber bahan alternatif sebagai media tanah kejuruteraan, seperti sisa pertanian atau medium asas tani. Walaupun begitu, lebih sedikit pemerhatian telah dibuat tentang mengoptimumkan reka bentuk penapisan di mana penemuan masih mempunyai ramalan yang ketara dari segi peningkatan prestasi. Oleh itu, kajian ini meneroka, menyiasat dan mengoptimumkan penapisan menggunakan media asas tani. Dalam kajian ini, eksperimen telah direka bentuk dan dioptimumkan menggunakan Metodologi Permukaan Respons (RSM). Bilangan larian telah dilakukan dengan variasi kepekatan air ribut (150 mg dan 1500 mg) dan kadar pemuatan (24.88 ml/min, 45.405 ml/min dan 65.93 ml/min) serta nisbah campuran berbeza konfigurasi penapis (Sungai). Pasir 100%, Tempurung Kelapa 100% dan Pasir Sungai 50% & Tempurung Kelapa 50%) digunakan untuk menentukan TSS dan kekeruhan. Data untuk semua ujian makmal dianalisis dan dioptimumkan menggunakan perisian Design Expert Versi 11.0. Daripada analisis, nilai pengoptimuman yang dipilih dalam kajian ini ialah kepekatan air ribut sebanyak 226.902 mg, kadar muatan 49.46 ml/min dan konfigurasi penapis terpilih ialah konfigurasi Pasir Sungai (50%) & Tempurung Kelapa (50%). Sampel air ribut sebenar dikutip dari saliran di belakang Blok C, Fakulti Kejuruteraan, Universiti Malaysia Sabah dan dan sampel air ribut telah ditapis menggunakan konfigurasi optimum yang dipilih. Pengurangan TSS yang ketara dengan penyingkiran 85.31% dan kekeruhan dengan penyingkiran 85.35% daripada sampel air ribut sebenar diperoleh menggunakan konfigurasi optimum yang dipilih dan tiada penyumbatan atau genangan diperhatikan semasa menjalankan kerja eksperimen. Oleh itu, ini menunjukkan bahawa kedua-dua pasir sungai dan tempurung kelapa berfungsi dengan baik untuk menyediakan sistem penapisan air ribut yang cekap dan berkesan.

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LIST OF ABBREVIATION

BMPs	-	Best Management Practices
RSM	-	Response Surface Methodology
COD	-	Chemical Oxygen Demand
BOD	-	Biochemical Oxygen Demand
AC	-	Activated Carbon
CSAC	-	Coconut Shell Activate Carbon
CS	-	Coconut Shell
DoE	-	Design of Experiments
TSS	-	Total Suspended Solid

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The filtration method has been utilized in many water quality improvement applications. It is typically used to remove particles from a suspension of fluid, including liquid, gas, or supercritical fluid. Isolation may be achieved by separating one or both components, depending on the application. When it comes to stormwater management, the need for filtration has been stressed, particularly in enhancing water quality.

Generally, stormwater is rainfall that contains additional contaminants and may seep into the earth, be kept on the surface, or runoff. Since stormwater carries various pollutants from the impervious surface (roadways and building roofs) such as debris, litter, suspended solids, nutrients from fertilizer, heavy metal, oil, and surfactants from the industrial sector before discharging into the river, pond, and lakes, urban stormwater runoff may have a significant impact on the water quality of nearby water bodies (Chang et al., 2018). This is mostly due to increased urbanization, which resulted in the clearance of trees and ground paving, reducing the area's infiltration rate. Due to the high imperviousness of the urban environment, rainwater cannot simply seep into the ground as it does in a natural landscape, resulting in impacts such as floods and water pollution. Clogging and other unexpected events, such as overflows, might occur as a result of this untreated stormwater, which could impact the water characteristics of the water bodies (Nasrizal et al., 2021). Correspondingly, stormwater quality varies significantly according to local temperature and rainfall occurrences (Wong T. et al., 2011). If it is properly managed and gathered, it has the potential to become the most significant source of non-potable water. In addition, stormwater management

comprises regulating the quality and quantity of stormwater runoff via structural and operational methods. An integrated water management system is an integral component of the urban environment's water management system. In the past, stormwater management has mostly concentrated on developing best management practices (BMPs), with progressively larger drains being created to lessen the effects of stormwater runoff without considering the environmental consequences of such practices (Kandel et al., 2017). The use of green infrastructure in stormwater management in Malaysia has increased in recent years, with more emphasis being placed on managing the quantity and quality of stormwater according to the guidelines provided in the MSMA 2nd Edition 2012 (USMM, 2012), including detention and retention ponds, rainwater harvesting, inlet catch basins, and roof gardens, among other things. The approaches used in this stormwater runoff management are low development (LID) strategies. They are designed to treat a certain volume of water quality at or near the source of runoff (Goh et al., 2019). This system exemplifies the definitive filtering approach, with sand, planting soil, and compost serving as the primary components for preserving the vegetative environment necessary for nutrient absorption and vertical and horizontal infiltration of stormwater runoff to remove pollutants.

Formerly, conventional media filtering was used extensively for stormwater management purposes. Media filtration is a procedure that removes suspended particles from stormwater as it passes through granular media (Erickson, A.J. et al., 2013). The media filtration design for stormwater purification is easy and well-defined, and additionally, the upkeep and maintenance of these filters have been well researched and recorded (Erickson, A.J. et al., 2013). However, there is a need to revamp the present filtering system to adapt to a more sustainable approach by using agro-based media. Agro-based media or Agro-waste material is described as a waste generated due to different agricultural processes. Plants stalks, hulls, manures, leaves, and veggie squander are examples of agricultural waste. It is common for farmers to generate agro-waste due to their operations. Agricultural waste is often deemed unusable and usually dumped in agricultural environments (Harris, P.J.C., 2001). The buildup of agro-waste may constitute a threat to a person’s health and safety and even the surroundings aesthetics. Hence, such matter indicates a problem that demands appropriate resolution. Because it is both

inexpensive and easy to be obtained, reusing agricultural waste materials for stormwater filtering is preferable rather than throwing them away or disposing of them completely.

Therefore, the design experiments and statistical approaches based on Response Surface Methodology will be utilized to improve system effectiveness in removing pollutants from stormwater. The ultimate goal is to create a sustainable and cost-effective filter media mixture using coconut shell CS. Common one-factor experimental designs are ineffective in predicting and optimizing filtering performance due to the large number of factors that influence filtering performance.

Hence, Design Expert v11 is used to conduct RSM with quadratic design to achieve the highest possible design factor level. Agro-waste as a filter media composition will be evaluated in its hydraulic conductivity or permeability, among other characteristics. As a result of this research, the environmental protection-driven community, along with the MSMA, will be encouraged to consider the employment of agro-waste as a possible course of action to low-cost construction materials since it has the potential to remove pollutants from stormwater and might as well be able to achieve the national zero waste goal in the most efficient and effective way possible.

1.2 Problem Statement

Clean water is in short supply these days on account of the instant escalation in the population, climate change, and water quality degradation. The situation has gotten so serious that groundwater in several areas is contaminated, forcing people to rely on other water sources. Urbanization is one of the reasons behind this. Urbanization has profoundly affected hydrologic processes, due mostly to the development of impermeable surfaces. Subsequently, it has caused hydrologic changes such as increased surface runoff, decreased stormwater infiltration, and evapotranspiration resulting in increased stormflow, decreased baseflow and increased flow magnitude variation. Weather-related stormwater quality deteriorates because surface runoff is typically conveyed into drainage systems without being treated, assembling potentially risky pollutants such as metals, nutrients and dirt generating silt and clogs before ultimately transporting them and affecting water bodies.

Stormwater flooding is a significant issue in several cities due to growing impermeable urban centres and severe rain events. The effect is exacerbated during periods of high precipitation (P. J. McLachlan et al., 2017), which slows groundwater recharging and causes suspended particles to accumulate. As a result, the ecological system is affected.

Pollutants carried by stormwater into receiving rivers have been a significant cause of worry during the last several decades. Heavy metals stand out the most due to their severe toxicity, lack of biodegradability, and bioaccumulation. Certain metals are hazardous in very low quantities, whereas others are required for human health at extremely low concentrations (Mohammed, A.S. et al., 2011).

Due to the massive demand for sand driven by the construction industry, the globe is edging closer to a sand depletion crisis. Sand from rivers and lakes is a limited resource, and the construction industry is already beginning to experience a sand shortage. Hence, the need for an alternative resource is necessary to prevent the depletion of sand and to develop long-term stormwater treatment strategies is needed in order to enhance stormwater's water quality.

1.3 Objectives of Study

a) To characterize the properties of river sand and coconut shell in terms of its permeability.
b) To characterize the properties of stormwater samples in terms of Total Suspended Solids and Turbidity.
c) To evaluate and assess the pollutant removal effectiveness of Agro-Based Media filtration for stormwater management strategies.
d) To establish the optimum value of filtering the stormwater by Response Surface Methodology.

1.4 Significance of the Study

i. Preserve water quality for future generations

Stormwater filtration utilizing agro-based media is essential for the maintenance of water quality. Various substances, such as grease, oil, insecticides, metals, plastic, and pesticides, collect on surfaces due to gardening and routine everyday usage. Stormwater runoff may transport pollutants to water sources such as streams, lakes, seas, and even groundwater if the runoff is not properly controlled. Furthermore, pollution levels are high in urban areas, where pavement erosion, tyre and brake pad wear, and vehicle emissions and spills can quickly reach drinking water sources. Stormwater filtration systems have the possibilities to draw out a number of these pollutants from water before they reach the rivers and streams that carry them.

ii. Reduce the possibility of floods.

Floods are less likely to occur in areas that have adopted and used effective stormwater agro-based media filtration. As a result, these areas are less likely to be affected by the detrimental consequences of floods. Big downpours are likely to result in flooding in urban areas and areas with little vegetation unless effective flood management technologies are established.

iii. Prevent undesirable stream erosion

Stormwater management helps minimize excessive erosion by limiting the speed and volume of water flowing into streams. If stormwater is not properly managed, it can create severe erosion, preventing the stream from performing its intended role of transporting water and sediment. Furthermore, without proper stormwater management, runoff can cause streams and rivers to overflow, posing a threat to residents' livelihoods. A flooded stream will burst its banks, spilling excess water onto nearby farms and destroying crops. It can also alter the shape and size of streams, causing changes in the distribution of streambed sediments and meander patterns. Plant and animal diversity may suffer the consequences of stream changes.

iv. Readers get to acknowledge the benefits of implementing stormwater filtration using Agro-Based Media material.
v. Help to expose and provide awareness among the community on the importance of preserving and conserving stormwater through Agro-Based Media filtration.
vi. Response surface methodology software can be adopted in this research to determine the filtration efficiency based on the optimum value obtained.

1.5 Scope of Study

In this study, river sand and coconut shell were utilized having sizes of 0.06 - 2.0 mm and 1.4 - 4.75 mm, respectively. These materials were prepared in the Environment Laboratory 1 of Universiti Malaysia Sabah and was further analyzed through constant head and falling head permeability test to determine the permeability of the river sand and coconut shell. Besides that, two types of stormwater sample is prepared that consists of synthetic stormwater sample and actual stormwater sample. The synthetic stormwater sample is prepared by using kaolin powder and measured to two different weight that consists of 150 mg and 1500 mg. While, the actual stormwater sample were collected from a drainage behind Block C building, Engineering Faculty, UMS. The properties and