# PERFORMANCE OF SANDWICHED KENAF FIBRE AND SUGARCANE HUSK IN TREATING PAVEMENT RUNOFF

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**Nor Azlina Alias[1*], Badronnisa Yusuf[2]**

*[1,2]Department of Civil Engineering, Faculty of Engineering*
*University Putra Malaysia, Selangor, Malaysia*

*[*]Corresponding author: a_norazlina@upm.edu.my*

## *ABSTRACT*

*Rapid urbanisation appears to cause more paved parking areas being provided which contributed into a greater impermeable surface area. Pavement runoff from the impermeable surface area does indeed have a high concentration of contaminants and it has been identified as a major cause of deterioration of nearby recipient water bodies. The more develop the country is, the poorer the water quality they have (Ashantha, et. al 2005). It carries pollutants, sediments, nutrients and heavy metals. An intensifying development in areas with impervious surface leads rainwater with small particles runs rapidly into drainages and rivers that may cause blockage that eventually leads to flash flood problem. Changes in land use increased the degree of soil imperviousness led to the increased of stormwater volume (Kundzewicz, et al., 2007). This study used a potential block system that is equipped with inner storage and expected to give minimal impact to the environment in order to improve the water quality and prevent ponding in the paved and impermeable areas. Figure 1 illustrates the simulation of pavement runoff was conducted to evaluate the performance of kenaf fibre and sugarcane husk that sandwiched in a modular block at a model scale in the hydraulic laboratory. The collected pavement runoff stored lower tank were tested and parameters observed were chemical oxygen demand, biological oxygen demand, amounts of suspended solids and turbidity. Water quality before and after being treated with the filtration media were compared. The performance and effectiveness of the two bio-composite materials as filter media were also assessed in decelerating the rate of runoff. Results show that the two proposed bio-composite materials are capable in reducing surface runoff, storing water, and reducing pollutant concentrations. The kenaf fibre appears to perform better in treating the polluted pavement runoff while sugarcane husk has a better performance in storing runoff and reduce the peak flow of runoff.*

***Keywords: Bio-Composite, Integrated Storage, Pavement Runoff, Wastewater Treatment***

## 1.0 INTRODUCTION

Earlier in 1997, Boller stated that the pollutants from streets and roofs carried by stormwater was the major contributor in surface water pollution. Nowadays, runoff from pavement is one of the main causes of urban water pollution and has become a major concern as it transports large quantities of contaminants to receiving waters in many countries including Malaysia (Lee, *et al.,* 2007). In rapid urban areas, the pavement runoff has proven to be a significant source of contamination that threatens the quality of urban water (Qian *et al.,* 2021) in which the parking areas are a common type of impervious surface that is directly proportionate to rapid urbanisation. The entire presence of contaminants, including heavy metals, organic matter, and petroleum hydrocarbon pollutants, is increasing tremendously due to the growing number of cars, factories, and people (Markiewicz *et al.,* 2017). The roadways serve as depositories for a vehicular where road-deposited sediments (RDS) such as sand, loose gravel, mud or tar from vehicles typically attach to fine-grained particles accumulated on roadway systems between the periods of precipitation. These pavement runoff with particles will be washed out and directly enters the water bodies.

***Figure 1: Lab Scale Simulation of Pavement Runoff using Rainfall Simulator System (RSS)***

Pavement runoff contains a mass of pollutants and known to be a significant contributor to the deterioration of receiving water bodies (Park *et al.,* 2015, Qin *et al.,* 2016, Risch *et al.,* 2018). According to Ma *et al.* (2018), 69.24 percent of the particle pollution is caused by runoff from road surfaces. However, the types and sources of road surface pollutants diverse depends on regional characteristics; thus the quality of pavement runoff varies by regions. Table 1 tabulates the typical pollutant in pavement runoff in the US and Asian. Studies reported that different rainfall events also result to varies greatly (Xue *et al*. 2020).

Capturing and treating urban runoff before it enters the receiving water courses is one of available methods in solving this issue. Hence, the aim of this study is to propose a sustainable media in treating pavement runoff before it enters the drainage system. Thus, the specific objective is to evaluate the performance and the effectiveness of sandwiched bio-composite materials that are kenaf fibre and sugarcane husk as filter media. This study is to also promote sustainability in treating the contaminated water.

***Table 1: Typical Concentration of Pollutants in Pavement Runoff (Kang et, al. 2019)***

| Parameter | Locations | | | |
|---|---|---|---|---|
| | United States of America | Australia | China | Korea |
| Total Suspended Solid (mg/l) | 12-129 | 60-1350 | 439 | 536 |
| COD (mg/l) | 37-130 | | 373 | 468 |

## 2.0 FILTRATION USING BIO-COMPOSITE MEDIA

A variety of filtration systems have been developed and proved to be useful for alleviating the pavement runoff pollution. These systems mainly include filtration facilities such as filtration trenches, gutter systems and basins storage systems such as constructed eco-wetlands/lagoons, vegetated retention ponds (Eriksson *et al.,* 2007) which requires large areas and restrict the application. As Fuerhacker *et al.,* 2011 in his studies mentioned that filtration systems for parking areas have been developed and showed effective results for treating the polluted urban road runoff. Thus, a modular integrated storage brick for urban drainage system is proposed.

It is widely known that the kenaf fibre is mostly used as reinforcement in concrete and less studies on the performance of kenaf fibre and sugarcane husk in treating contaminated water were discussed. Researchers discussed more on the potential of Kenaf as reinforcement (Kumar and Velmurugan, 2022). Shirvani *et.al,* (2019) concluded that reinforcement of structural elements and construction materials this natural fiber has gained popularity among researchers and industries due to environmental concerns. Thus, this paper focused on the performance on these two bio-composite raw materials in treating the polluted water. Since the primary goal of employing biological wastes is to filter tiny particles in pavement runoff, both were washed with tap water, rinsed thoroughly and dried. No chemical treatment was done to the bio-composite materials used. Both fibres were then compacted and sandwiched in the brick opening. For sustainability, the bio-composite wastes are selected to promote greeneries in parking areas besides minimizing the impervious areas. Figure 2 shows the types of bio-composite materials used in this study.

*Kenaf fiber* *Sugarcane husk*

***Figure 2: Bio-Composite Materials as Filter Media***

Since a system that equipped with layered filter media can reduce the pollution by adsorption, absorption, ion exchange, or complexation reactions (Pitcher *et al.,* 2004; Fuerhacker *et al.,* 2011), therefore, selecting and configuring the filter media are essential issues for a runoff treatment system.

## 3.0 FILTRATION TEST EQUIPMENT

A modular mortar brick with an inner opening is designed to store and elongate the surface runoff time. The opening section in the centre of brick is the area where bio-composite materials are to be placed at the same time to reduce individual's brick weight. The brick was casted in halved for easy handling with average weight of 1.85 kg. The contaminated pavement runoff will be filtrated by the sandwiched bio-composite materials before entering the water bodies. A single brick is design to have 200 m x 75 mm x 80 mm (length x width x thick) with 30 mm x 30 mm x 80mm (length x width x thick) opening in the middle.

A 2.0 m long and 1.0 m wide Rainfall Simulator System (RSS) that is equipped with storage tank was used to simulate rainfall. The storage tank was filled up with 100L pavement runoff that was collected at parking area nearby UPM Hydraulic Laboratory prior to the experiment. While columns of modular brick were placed inside the catchment area. Figure 3 illustrates the arrangement of modular brick and its opening where kenaf and sugarcane husk were placed.

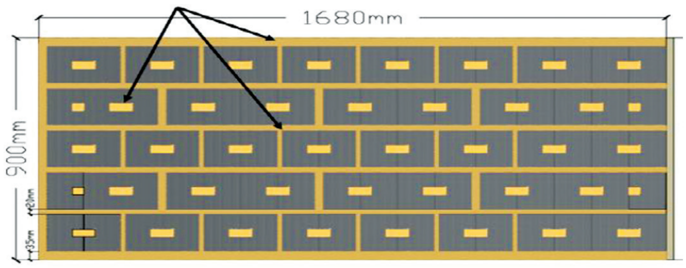


***Figure 3: Plan View of Modular Brick in RSS Catchment Area***

Altogether, about 82 bricks were placed in the RSS catchment area. As mentioned earlier, the opening sections were filled with the bio-composite materials; kenaf fibre and sugarcane husk as shown in Figure 4. Half of the bricks' height was filled with the bio-composite. Based on the density of kenaf fiber and sugarcane husk (Hazrol *et al.,* 2023 and Sharzad *et al.,* 2022), each brick carries about 50 gram and 43 gram of kenaf and sugar cane husk respectively.

The gaps between bricks were also filled with a bio-composite medium. This is to ensure that all contaminated pavement runoff is filtered. The pavement runoff was collected during the monsoon season between November to January. The amount of runoff collected from each rainfall event was tested three times for its quality once been filtrated by Kenaf fibre.

*Kenaf fiber* *Sugarcane husk*

***Figure 4: Openings and Gaps were filled up with Bio-Composite Materials***

Pump and a flow meter attached to the RSS to control the discharge at 2.5L/m imitating the moderate rainfall intensity at 26.5 mm/hr. The test was run immediately after the runoff was stored into the storage tank to ensure the pavement runoff properties remain unchanged. The duration for each rain simulation was about 40 minutes until the storage tank is emptied. Those procedures were repeated for Sugarcane husk. Once the pavement runoff run and infiltrated through the media, it was then collected at the outlet and tested for its quality. The treated pavement runoff filtrated by kenaf and sugarcane husk were compared with untreated pavement runoff.

## 4.0 COMPARATIVE STUDY: PERFORMANCE OF BIO-COMPOSITE MEDIA

Following Li, H *et. al.,* (2017), a column experiment to study pollutants form urban storm-runoff was conducted and the concentrations of total suspended solids (TSS) and chemical oxygen demand (COD) were among the parameter observed in the influent and effluent thus, in order to evaluate the performance of bio-composite media used in treating the contaminated pavement runoff, the effluent were tested for its turbidity, bio-chemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS).

The average readings on pavement runoff quality before and after treated by bio-composite materials are as in Table 2. The results obtained after the pavement runoff being treated (effluent) by both bio-composite materials were compared with the untreated pavement runoff referred as influent. Figure 5 summarized the results obtained.

From Table 2 above, pavement runoff that has been filtered through both materials were improved. Most of the parameters tested on the effluent gave better readings compared to the influent. The ability of kenaf fibre and sugarcane husk to lowered COD level may lead to positive environmental where both bio-composites were found effective in treating the chemical oxygen demand (COD). Kenaf fibre and sugarcane husk record 75% and 58% COD reduction respectively. Comparing the results with the Department of Environment quality index, the COD value treated by kenaf fibre had improved from Class V to Class IV but the one treated by sugarcane husk remained in Class V.

It is well known that lower BOD value indicates less polluted or cleaner water. The BOD of untreated pavement runoff was less than 20 mg/L which can be considered nearly contaminated. Introducing the bio-composite materials to reduce the BOD seems like a good approach. From analysis, the percentage of BOD removal rate by kenaf fibre and sugarcane husk were around 20%. The filtered runoff was about 80% lesser before being classified as contaminated and nearly to fall in Class IV.

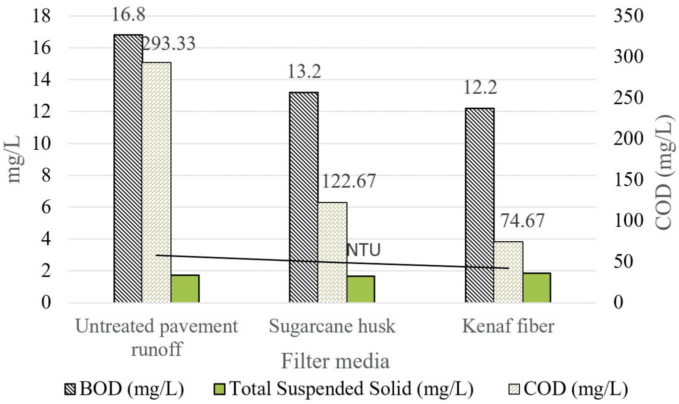


***Figure 5: Comparison between Treated and Untreated Pavement Runoff***

Referring to Figure 5, it clearly shows that the readings of COD, BOD and turbidity improved except for TSS. It is known that TSS often related to turbidity. If the TSS is high, turbidity is expected to increase proportionately. This is approved by tests conducted where the turbidity increased when TSS increased as in Table 2. The ratio between turbidity to TSS of untreated pavement runoff was 1.73 while 1.17 and 1.52 were the ratio obtained for the pavement runoff filtered by kenaf and sugarcane husk respectively. From the turbidity test conducted, kenaf and sugarcane filtered and reduced the percentage of turbidity. Around 28% and 14% turbidity in pavement runoff were reduced by kenaf fibre and sugarcane husk respectively.

***Table 2: Pavement Runoff Quality***

| Parameter | Untreated Pavement Runoff | Treated with Bio-Composite Materials Sandwiched in Modular Block System | | DOE Water Index Class IV |
|---|---|---|---|---|
| | | Kenaf Fibre | Sugarcane Husk | |
| COD (mg/L) | 293.33 | 74.67 | 122.67 | 50-100 |
| BOD (mg/L) | 16.8 | 12.2 | 13.2 | 6-12 |
| Total Suspended Solid (mg/L) | 1.72 | 1.84 | 1.68 | 150-300 |
| Turbidity (NTU) | 2.98 | 2.16 | 2.55 | |

A significance improvement in water quality between 20% to 75% were observed. Overall, the turbidity improved from 2.98 NTU to 2.16 NTU and 2.55NTU, turbidity compared to TSS in pavement runoff that was filtered by kenaf was better. Higher turbidity at minimum TSS observed in sugarcane husk could be due to its texture that dusty. Hence, it is agreed that the bio-composite materials used were able to treat the turbidity.

Referring to Figure 6, both bio-composite materials were capable and performing well in filtering and improving the quality of pavement runoff except for the total suspended solid. The only parameter seems unable to be directly improved the pavement runoff was total suspended solid (TSS). Sugarcane husk recorded 2% improvement of TSS however the kenaf fibre found to be downgrading the quality on pavement runoff in the beginning. Although TSS is worsened, the turbidity improved much. In detail comparison between two types of bio-composite materials used in this study, kenaf fibre was found better in treating the pavement runoff where three out of four parameters tested improved the water quality immediately. The percentage of removal in Figure 6 is supported by several studies on the performance of additive materials particularly the kenaf and coconut husk in treating the polluted water. (S. Nimesha *et. al.,* 2021, U.O. Benjamin, at. al., 2021, Dilaeliyana *et. al.,* 2022). Studies revealed the percentage of removal efficiencies using kenaf and coconut husk ranges from 43 to 90% and 66-69% respectively.

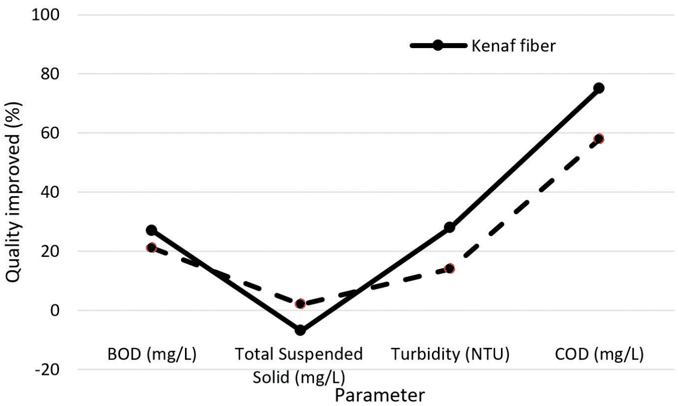


***Figure 6: Percentage of Improvement***

## 5.0 CONCLUSION

Results and analysis conducted show that the kenaf fibre and sugarcane husk that sandwiched in the brick opening area were efficient and can be used in preliminary stage of in treating the pavement runoff. From laboratory work conducted, the quality of contaminated pavement runoff filtrated by the sandwiched bio-composite materials were improved before released into the water bodies. It can be concluded that the research objectives have been achieved where the proposed bio-composite material sandwiched in the designed brick were able to enhance the pavement runoff quality. A better brick and bio-composite arrangement are expected to improve the pavement runoff quality which can escalate the water quality from Class V to IV. Between two types of bio-composite materials proposed, kenaf fibre performed better in all aspects and has potential in treating pavement runoff.

Since the pollutants in pavement runoff are closely related to rainfall volume, rainfall intensity, traffic condition and other factors (Dos Santos *et al*. 2019; Du *et al*. 2019) thus, there is still room for improvement. It is suggested that this research to be extended with the used of different types of brick surfaces as the pavement runoff quality also influenced by the chemical reaction between brick surfaces and contaminant transported.

## 6.0 ACKNOWLEDGEMENTS

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## PROFILES

**TS. DR NOR AZLINA BINTI ALIAS** is a senior lecturer at Civil Engineering Department, Ts. Dr Nor Azlina binti Alias has joined Universiti Putra Malaysia in 2018. She had previously served at the Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, for 12 years. Her doctorate thesis discussed on the development of hydrodynamic flow model; thus her research interest includes water resources engineering and is not limited to hydraulics and hydrodynamics, flood forecasting, numerical modelling and grey water treatment. Her recent works related to grey water treatment using waste materials, floating treatment wetland, integrated handwash facility with sustainable treatment system. Her interest in extensive waste materials drags her to explore on the diverse uses of waste materials that can lead to improvement in the quality of the environment.
Email address: a_norazlina@upm.edu.my

**ASSOC. PROF. DR BADRONNISA BINTI YUSUF** has over 25 years of experience teaching and research. First joined as a lecturer in 1997, Dr Badronnisa is now appointed an Associate Professor at Civil Engineering Department, Faculty of Engineering UPM. Experienced in supervising more than 30 local and international students at both Master and PhD levels, Dr Badronnisa expertise in multiple areas related to Water Resources. She is currently fully enthusiastic in her research on hydraulic structures modelling and is deeply interested in research related to phytoremediation, sedimentation, flow modelling and many more.
Email address: nisa@upm.edu.my