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A Comparative Study of Coconut Husk, Sugarcane Bagasse, and Durian Shell as Filter Media for River Water Quality Improvement

Rubiaton Maon[1], Janmaizatulriah Jani[1]*, Fathiah Mohamed Zuki[2]

[1] *Faculty of Civil Engineering,*
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA
[2] *Department of Chemical Engineering, Faculty of Engineering,*
Universiti Malaya, 50603 Kuala Lumpur, MALAYSIA

*Corresponding Author: janmaizatulriah@uitm.edu.my
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Abstract

The rapid urbanisation and subsequent increase in impermeable surfaces have significantly exacerbated river water contamination, necessitating sustainable and low-cost treatment solutions. Sungai Chuau, Selangor, was selected as the study site due to its role in supporting the Putrajaya Wetland system and its exposure to urban runoff, making it an ideal location to assess water filtration effectiveness. This study investigates the effectiveness of three agricultural wastes: coconut husk (CH), sugarcane bagasse (SB), and durian shell (DS) as filter media for improving river water quality in Sungai Chuau, Selangor, Malaysia. The filter media were prepared through drying, grinding, and sieving to ensure optimal filtration efficiency before being tested in a system comprising 80% agro-based media and 20% aggregate. The effectiveness of these materials was analysed based on key parameters, including pH, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), and ammoniacal nitrogen (NH_3-N). Results showed high variability in COD and TSS, particularly in Method 2, indicating localised pollution sources. Coconut husk exhibited the highest pollutant removal efficiency, significantly reducing COD, BOD, and NH_3-N levels while maintaining acceptable water quality. Conversely, sugarcane bagasse and durian shell degraded water quality, with DS contributing to increased pH and COD levels due to preparation methods. The statistical analysis confirmed stable BOD and DO values, though a notable drop in DO5 suggested organic pollution. These findings highlight coconut husk as a viable, sustainable filtration alternative, while further optimization of sugarcane bagasse and durian shell is required to enhance their effectiveness. Rapid urbanization has significantly impacted river water quality, necessitating sustainable and cost-effective treatment solutions.

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1. Introduction

Water pollution is the contamination of water bodies, including lakes, rivers, oceans, aquifers, and groundwater, primarily caused by human activities [1]. This contamination adversely impacts ecosystems, human health, and the environment. Pollutants are often discharged into water bodies without sufficient treatment to eliminate harmful compounds, exacerbating the issue. Addressing water pollution effectively requires sustainable, low-cost, and environmentally friendly solutions. The literature review on the use of agro-based filter media for river water treatment, particularly in the context of Sungai Chuau in Selangor, highlights the pressing need for sustainable solutions to urban water quality issues. Urbanisation in Malaysia has led to significant environmental challenges, including pollution in river systems, necessitating innovative approaches to stormwater management and ecosystem protection. Urban rivers in Malaysia face degradation due to rapid development and inadequate ecological considerations [2]. Effective stormwater management is critical, as urbanisation increases runoff and pollution levels [3]. The presence of pollutants such as polychlorinated biphenyls (PCBs) in river systems poses health risks, emphasising the importance of effective filtration methods. Implementing agro-based filters can mitigate these risks by improving water quality and reducing contaminants [4].

Traditional water filtration systems often rely on materials like sand, coal, and activated carbon. Although it is effective, these materials can be costly and environmentally taxing due to resource extraction and processing. Moreover, synthetic materials can contribute to long-term environmental degradation. In regions like Malaysia, agricultural waste is abundant but underutilised, often ending up in landfills or being improperly managed, which can itself contribute to pollution. Malaysia generates approximately 17 million metric tons of agricultural waste annually, including coconut husk, sugarcane bagasse, and durian shells, which are often discarded or burned, causing environmental issues. There is a critical need for innovative approaches to transform this agro-waste into effective, sustainable filter media for water treatment.

The growing concern over water pollution has spurred research into sustainable, cost-effective filtration methods, with agro-based materials emerging as a promising alternative to conventional techniques. Agro-based filter media, derived from agricultural or plant-based waste, represent a promising solution due to their abundant oxygenated functional groups, high porosity, and natural adsorption capacity [5], [6]. Agro-waste materials contain functional groups like carboxyl, hydroxyl, and amide, which facilitate the adsorption of pollutants [7]. Agro-waste has emerged as a promising filter medium due to its abundant availability, rich functional groups, and high porosity, making it effective for water treatment applications. Research indicates that various types of agro-waste, such as rice husk, wood chips, and date palm fibre, can significantly enhance pollutant removal in greywater treatment systems [8]. The porous structure of agro-waste increases surface area, promoting better filtration and adsorption of contaminants [7]. Materials such as coconut husk, sugarcane bagasse, and durian shell have been identified as viable options due to their abundance, biodegradability, and cost-effectiveness. In biofilter applications, coconut husk biochar showed enhanced nutrient removal through both adsorption and microbial activity [9]. Activated carbon derived from durian shells, particularly when treated with sulfuric acid, shows enhanced surface area (242.03 m^2/g) and adsorption capacity (92.05% MB removal) [10]. These properties make agro-waste an effective, biodegradable, and cost-efficient alternative to conventional filtration materials. Utilising agro-based materials such as coconut husk, sugarcane bagasse, and durian shell offers a biodegradable and cost-effective solution for water filtration. These materials can enhance pollutant removal efficiency, as demonstrated in various studies on bioretention systems [3].

Utilising such agro-based materials minimises waste generation, promotes a circular economy, and offers a sustainable alternative to conventional filter media [3], [4]. Furthermore, integrating agro-waste into filtration systems reduces reliance on landfills and supports income generation for the agricultural industry. Studies have demonstrated the effectiveness of agro-based materials in removing pollutants from water [5], [11]. For instance, [12] highlighted the potential of agricultural waste in treating water contaminants, while recent advancements have explored the optimisation of these materials for specific applications. However, the effectiveness of each material appears to depend heavily on the targeted pollutant and the characteristics of the water source. Some materials may excel at removing certain contaminants while being less effective or even detrimental for others. Therefore, despite their promise, further research is needed to refine the application of agro-based materials in large-scale filtration systems [6], [13].

This study compares the performance of selected agro-based filter media, including coconut husk, sugarcane bagasse, and durian shell, for stormwater filtration. The filter column setup comprises 80% agro-based media and 20% aggregate. The objectives of this study are to evaluate the effectiveness of these materials in pollutant removal and to explore their potential as sustainable alternatives to sand-based media. Given their availability, affordability, and minimal environmental impact, these agro-waste materials offer significant advantages for sustainable water management in Malaysia. While the use of agro-based filter media presents a promising avenue for improving river water quality, it is essential to consider the broader implications of urbanisation and the need for integrated water management strategies that encompass ecological sustainability and public health.

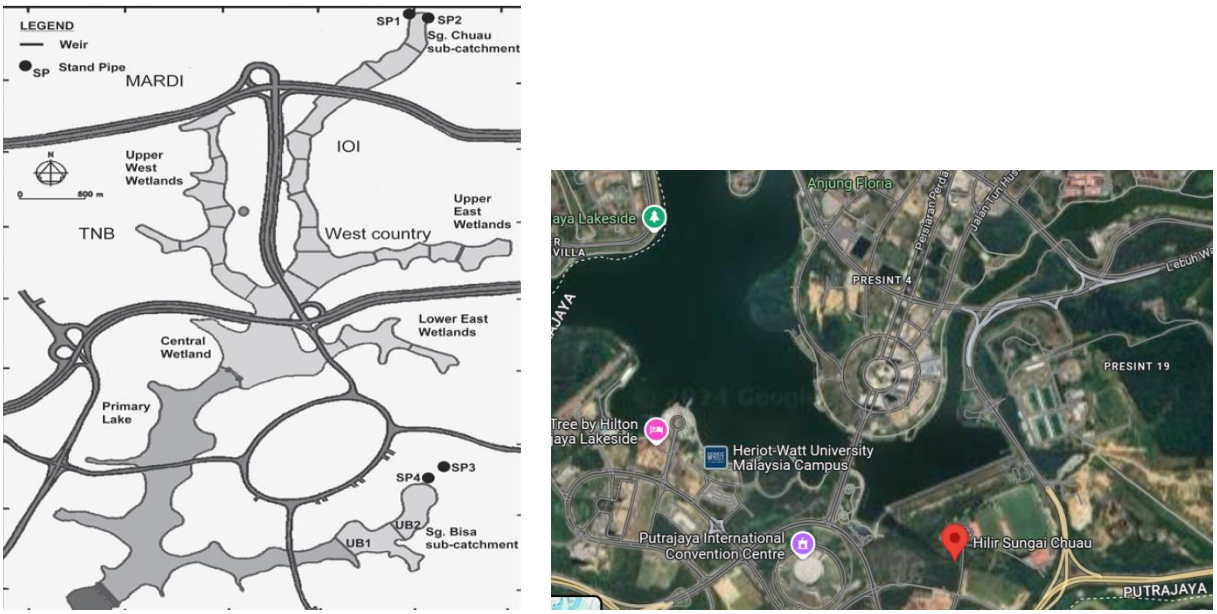
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2. Methodology

The methodology began with a desk study of the topic, which involved reviewing previous studies to gain insights and establish a foundation for the study. Once the study's objectives and focus were determined, a suitable study area was selected for river water collection, with Sungai Chuau chosen as the site. Water samples were then collected from the designated locations, followed by the preparation of agro-based materials, including coconut husk, sugarcane bagasse, and durian shell. Laboratory analyses were subsequently conducted to evaluate water quality parameters, including ammoniacal nitrogen (NH3-N), chemical oxygen demand (COD), pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and total suspended solids (TSS). The results of these parameters were compared against the Water Quality Index (WQI) to assess the effectiveness of the agro-based materials.

2.1 Study Area

Sungai Chuau is a river located in the Hulu Langat District of Selangor, Malaysia, as shown in Fig. 1. This river plays a significant role in supporting the Putrajaya Wetland system, one of its primary water sources [9]. The wetlands were developed to improve water quality and provide ecological benefits, making Sungai Chuau a vital component of environmental management and urban planning in the Putrajaya region. The river contributes significantly to the health of the wetland ecosystem and the broader environmental conservation efforts in the area.



(a) **(b)**

Fig. 1 *Study area (a) Map of Putrajaya Wetland [15]; and (b) Plan view from Google map*

Water samples were collected from three points along Sungai Chuau: upstream, midstream, and downstream. A total of 5 litres of water was collected at each sampling point using standard grab sampling techniques. However, because the worst quality was observed downstream, only the downstream water sample was used for further treatment. Sampling was carried out during a single-day field study to ensure consistency. Additionally, in situ measurements were conducted using a Horiba Water Quality Monitor, as illustrated in Fig. 2(b).

2.2 Agro-Based Filter Media

The agro-based materials, including coconut husk, durian shell, and sugarcane bagasse, were prepared using two distinct methods before being utilised in the experiment, as outlined in Table 1. Coconut husk (HS), sugarcane bagasse (SB), and durian shell (DS) were chosen for their availability, cost-effectiveness, and adsorption properties. Coconut husk's lignocellulosic content aids in pollutant removal, sugarcane bagasse's cellulose enhances filtration, and durian shell's porous structure supports adsorption. These agro-wastes provide a sustainable alternative to conventional filtration while reducing agricultural waste. However, the challenges of using this agro-based media stem from material degradation, inconsistent performance, and scalability issues.

In the first method, the materials were collected from local markets and cut into small, random pieces. They were then rinsed with tap water and immersed in distilled water until the pH stabilised at approximately ±2.

Following this, the materials were sun-dried for 24 hours and then oven-dried at 103-105°C for a minimum of 24 hours. For the durian shell, an additional step of carbonisation was carried out at 200°C (to ensure partial pyrolysis) for 2 hours (as adopted from Abdul Taha et al. [11]). After cooling to room temperature, the materials were ground and sieved to obtain granules sized between 2.0 mm and 0.6 mm. In the second method, the durian shell was oven-dried for 24 hours, as in the first method. However, it was then subjected to chemical activation by soaking it overnight in lemon juice acid to enhance pore enlargement. Citric acid in lemon juice can effectively break down lignocellulosic structures in durian shells, enhancing porosity, surface area, and interactions with cellulose, hemicellulose, and lignin, and introducing carboxyl (-COOH) and hydroxyl (-OH) functional groups that improve reactivity and adsorption capacity. The chemically treated material was thoroughly rinsed with distilled water and oven-dried again for 5 hours at 105°C. These preparation processes ensured that the materials were adequately processed and optimised for their use in the experiment.



(a) **(b)**

Fig. 2 *On-site water quality measurement (a) Water quality measurement using Horiba; and (b) Value of water quality at the downstream of Sg. Chuau*

Table 1 *Types of agro-based media and filter media setup*

Type of agro-based	Before Drying	After Drying
Coconut Husk (CH)		
Sugarcane Bagasse (SB)		
Durian Shell (DS)		

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Type of agro-based	Before Drying	After Drying
Filter media set up		

As shown in Table 1, a filtration system was set up using 9 bottles sample were used, which is 2 bottles sample for durian shell (labelled as D1& D2), 3 bottles sample for coconut husk (label as CH1, CH2 & CH3), 3 bottles sample for sugarcane bagasse (label as BS1, BS2 & BS3), and one bottle sample for initial value. The filtration setup used half of a 1.5L mineral water bottle (approximately 750mL) as the filtration unit, and the system operated under gravity-driven flow. Each bottle was filled to 80% capacity with the respective agro-based material and 20% with 20mm aggregate (adopted from Abdul Taha et al., 2022 [7]). After filtration, water samples were analysed for ammoniacal nitrogen (NH3-N), chemical oxygen demand (COD), pH, dissolved oxygen demand (DO), biochemical oxygen demand (BOD), and total suspended solids (TSS) following standard HACH procedures. The analyses were conducted using the HACH standard method with a spectrophotometer and reagent kits, following the manufacturer's guidelines. pH was measured with a digital pH meter, and DO was measured with a HACH HQ40d multi-parameter probe. COD and BOD were analysed using the HACH DR6000 UV-Vis spectrophotometer, with BOD assessed through a 5-day incubation method at 20°C. TSS and NH_3-N concentrations were determined using gravimetric and colourimetric methods, respectively. The experimental results were statistically analysed to compare the pollutant removal efficiency of each agro-based medium and to evaluate their potential as sustainable filtration alternatives for river water treatment.

3. Results and Discussions

Table 2 shows the initial COD value of Sungai Chua water at 29 mg/L, indicating relatively clean water. After treatment, the lowest COD value of 11 mg/L was achieved using coconut husk (CH3), highlighting its effectiveness as a natural filter. Sugarcane bagasse (BS) had a moderate COD of 150 mg/L, whereas durian shell (DS1) had the highest COD of 206 mg/L, indicating greater pollution. The high COD levels in durian shells are likely due to their preparation method, in which the chemical activation with lemon juice and incomplete washing may have introduced organic contaminants. These findings underscore the potential of coconut husk for water treatment and the limitations of durian shell in this context. Regression analysis was performed to assess the correlation between initial pollutant concentrations and removal efficiency, yielding an R^2 of 0.85, indicating a strong relationship between filtration performance and initial contamination levels.

Table 2 *Initial water quality of Sg. Chuau vs DOE water quality index classification*

Parameters (%)	Initial Water Quality	DOE Water Quality Index Classification [16]				
		Class I	Class II	Class III	Class IV	Class V
COD (mg/l)	29	<10	10-25	25-50	50-100	>100
pH	6.02	>7	6-7	5-6	<5	>5
DO (mg/l)	9.66 -DO0 5.36- DO5	>7	5-7	3-5	1-3	<1
AN (mg/l)	0.23	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
TSS (mg/l)	19	<25	25-50	50-150	150-300	>300
Water Quality Index (WQI)		<92.7	76.5-92.7	51.9-76.5	3.0-51.9	<31.0

As shown in Fig. 3, after treatment with agro-based media, the lowest COD value was 11 mg/L (coconut husk), while the highest was 206 mg/L (durian shell). The second method was used for SB1 and DS1. Coconut husk

showed high efficiency in reducing oxidizable particles, making it a promising natural filter. Sugarcane bagasse (150 mg/L COD) showed moderate effectiveness, whereas durian shell significantly increased COD, likely due to contaminants introduced during its preparation. As for the initial dissolved oxygen (DO), DO0 is 9.66 mg/l, while DO5 is 5.36 mg/l. The result shows that CH2 yields the highest DO0 value, at 9.9 mg/l. Meanwhile, the lowest value is 6.63mg/l (SB2). The higher DO5 value is CH2 (5.47 mg/l), with the lowest being DS2 (0.49 mg/l). The amount of organic matter in water is shown by BOD. A high BOD value indicates a large amount of biodegradable organic matter in the water. This could come from sewage, agricultural runoff, or industrial effluents. Microorganisms require a large amount of oxygen to break down organic waste when the BOD is high [11]. This can cause the water to lose oxygen, which is bad for marine life. Low or no oxygen levels can be caused by high BOD.

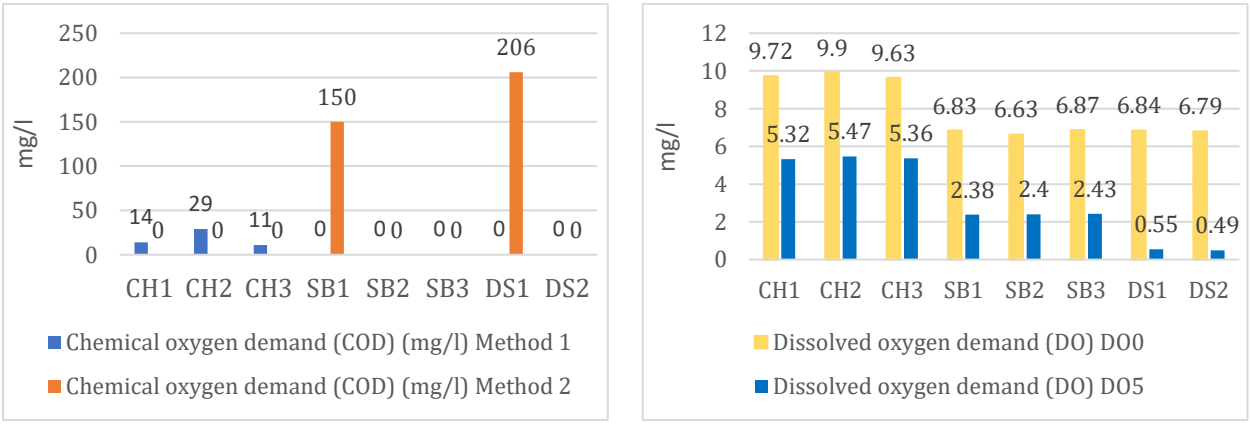


Fig. 3 *Chemical oxygen demand (COD) and dissolved oxygen (DO)*

Based on the results, the greatest reduction in BOD is in SB2 at 4.23 mg/l, while the highest is in DS2 at 6.3 mg/l. Then, pH is a quantitative measurement of the concentration of hydrogen ions in water. The pH scale ranges from 0 to 14 and is logarithmic. Acidic circumstances are indicated by a pH of 0 to 6.9, neutral conditions by a pH of 7, and alkaline (basic) conditions by a pH of 7.1 to 14(pH control, n.d.). Aquatic organisms often thrive within a specific pH range, typically 6.5 to 8.5. Extreme pH levels can negatively affect or even be harmful to numerous species. For instance, fish and invertebrates may experience physiological stress or perish when exposed to pH levels below 5 or above 9. The pH level significantly affects the overall chemical composition of water, particularly the equilibrium between carbonate and bicarbonate ions. Maintaining this equilibrium is vital to mitigating significant fluctuations in the water's pH. The results obtained clearly show that DS has the highest alkalinity.

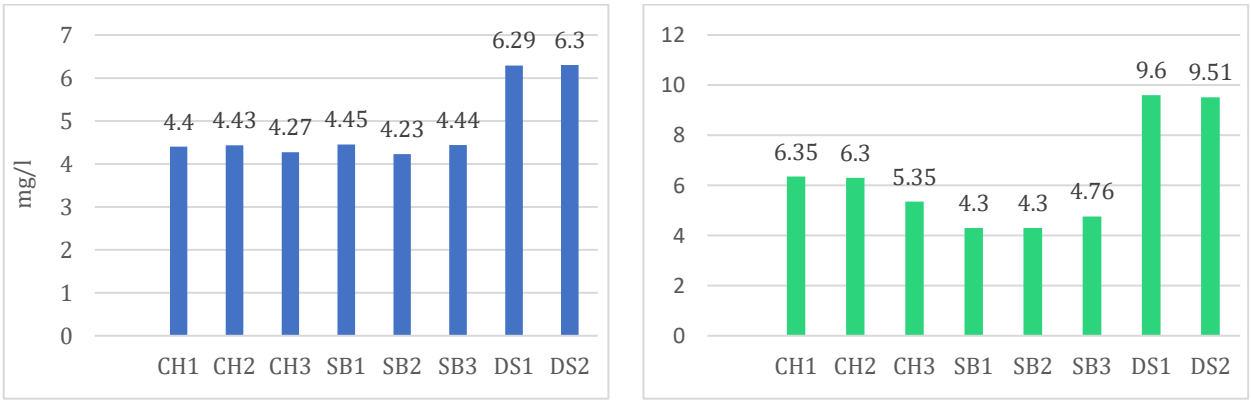


Fig. 4 *Biochemical oxygen demand (BOD) and pH*

As shown in Fig. 5, high TSS levels can indicate pollution from multiple sources, such as farm runoff, urban stormwater, industrial waste, and sewage effluent. From the results, the highest TSS value is CH3 at 24 mg/l, and the lowest is DS1 in the second method at 7 mg/l. Ammoniacal nitrogen (NH3-N) is a very important sign of how clean the water is, especially in rivers and other areas of fresh water. Ammonium is more common in acidic conditions, and ammonia in alkaline conditions. Nitrogen is released when plants and animals die and can be changed into ammoniacal nitrogen. Ammonia (NH3) is dangerous for fish and other animals, even in small amounts. It can put aquatic creatures' bodies under stress, slow their growth, and increase their likelihood of dying. Higher temperatures and pH levels make ammonia more dangerous. Based on the results, CH3 gives the

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greatest reduction in NH3N at 0.35 mg/l. Meanwhile, the worst is SB1, at 6.01 mg/l in the second experimental method.

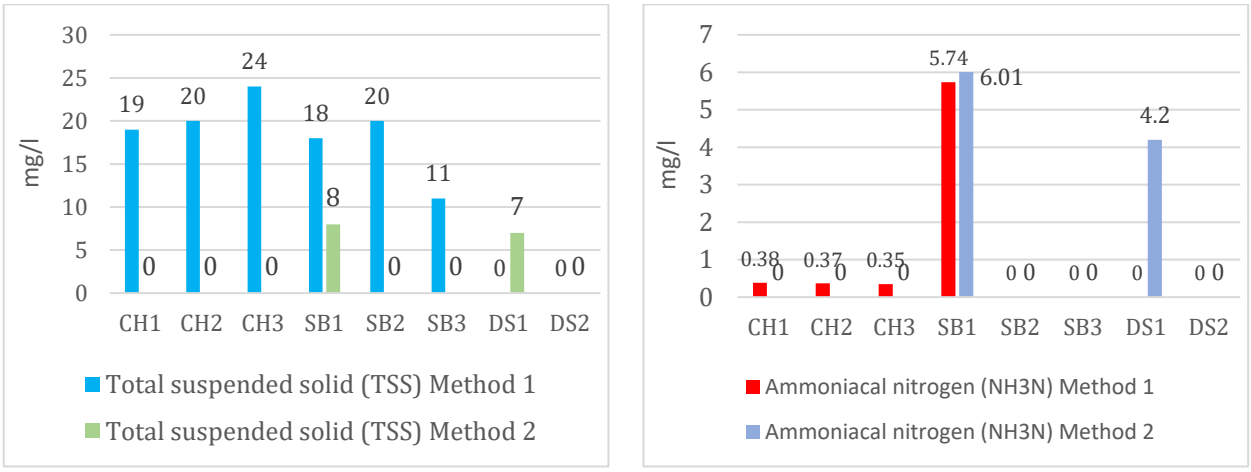


Fig. 5 *Total suspended solids (TSS) and ammoniacal nitrogen (NH3-N)*

Experimental results of water filtration at Sungai Chuau, as shown in Fig. 3 to Fig. 5, use various agro-based media. Among the tested media, coconut husk (CH) demonstrated the most significant improvement in water quality parameters, notably reducing COD, BOD, and NH3-N. However, it also increased TSS, potentially impacting water clarity. The increase in TSS, despite coconut husk-mediated pollutant removal, is due to fibre degradation, insufficient pre-treatment, and mechanical breakdown. Lignocellulosic material releases fine particles, unwashed husk introduces residual debris, and prolonged use causes disintegration. Sugarcane bagasse (SB) effectively reduced BOD, while durian shell (DS) exhibited the highest pH, indicating alkaline conditions. Compared with previous studies, these findings align with the general trend that agro-based materials improve water quality. However, the specific performance of each media can vary depending on factors such as the initial water quality, media characteristics, and experimental conditions. For instance, while coconut husk has shown promise in numerous studies, its effectiveness in reducing TSS can be influenced by factors like particle size and filtration time. To further optimise the filtration process, future research could explore combinations of different media or the development of hybrid materials. Additionally, investigating the long-term performance of these filters and their potential for scaling up to larger-scale applications would be valuable.

The comparison between [17] and this study reveals significant differences in water quality parameters, likely due to variations in media preparation, experimental conditions, and measurement techniques. This study reports higher COD and NH3-N levels for sugarcane bagasse (SB) and durian shell (DS), indicating contamination, whereas [11] showed better performance for these media. Coconut husk (CH) performed consistently well in both studies, but discrepancies in BOD, DO, and pH suggest differences in pollutant removal efficiency and water sample characteristics. These variations underscore the need for standardised methods and further research to optimise media preparation and treatment processes to achieve consistent, reliable results.

As shown in Table 3, the results indicate high variability in COD and TSS (Method 2), with broad confidence intervals suggesting inconsistent pollution levels likely due to localised sources. BOD and DO values remain stable, but a notable drop in DO5 may indicate organic pollution. pH variability (4.3–9.6) suggests acidic conditions at some sites, potentially affecting aquatic life, as reflected by a high standard deviation (2.07). NH_3N and TSS (Method 1) remain within acceptable limits, with low mean values and narrower confidence intervals, indicating manageable pollution levels.

The Water Quality Index (WQI) and corresponding classifications provide insight into the effectiveness of agro-based media for water treatment. As shown in Table 4, the initial WQI of 90.27 places the untreated water in Class II, indicating good quality suitable for recreational use, with some treatment required for potable purposes. After treatment with coconut husk, the WQI dropped to 76.68, maintaining Class II. This indicates that coconut husk effectively reduced pollutants while preserving the water's suitability for recreational use. The results confirm its potential as a viable natural filter for improving water quality. However, as shown in Table 4, the WQI for water treated with sugarcane bagasse increased to 216.4, which is classified as over-range and far beyond acceptable water quality limits. This significant degradation suggests that sugarcane bagasse introduced pollutants into the water, rendering it unfit for any practical use. It implies inefficiency in the treatment method or contamination from the material itself. Treatment with durian shell resulted in the highest WQI, at 463.4, which was also above the range, indicating severe pollution. This dramatic increase likely stems from the preparation

method, where incomplete washing or the activation process introduced additional contaminants. The results highlight that the durian shell is unsuitable for water treatment in its current form.

Table 3 *Statistical analysis*

Parameter	Mean	Standard Deviation	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
COD (mg/L) Method 1	6.75	10.45	0.00	16.58
COD (mg/L) Method 2	44.00	91.88	0.00	124.18
pH	6.18	2.07	4.08	8.28
TSS (mg/L) Method 1	11.50	9.57	2.42	20.58
TSS (mg/L) Method 2	1.88	3.25	0.00	4.70
NH_3N (mg/L) Method 1	0.86	1.99	0.00	2.72
NH_3N (mg/L) Method 2	1.52	2.85	0.00	4.27

Table 4 *WQI at Sungai Chuau*

Agro-based media	WQI	Class
Initial	90.27	Class II
Coconut Husk (CH)	76.68	Class II
Sugarcane Bagasse (SB)	216.4	Over-range
Durian Shell (DS)	463.4	Over range

4. Conclusion

In conclusion, the results highlight spatial variability in water quality across sampling sites, with localised pollution concerns for COD, TSS, and NH_3N, particularly in Method 2. The findings highlight coconut husk as the most effective agro-based media, maintaining water quality within acceptable limits. In contrast, sugarcane bagasse and durian shell significantly degrade water quality, emphasising the need for improved preparation or alternative methods for their use. However, the overall trends suggest manageable pollution levels, with stable oxygen demand and moderate pH fluctuations. Further investigation into site-specific pollution sources, particularly for COD and TSS, is recommended to improve water quality management. To enhance their potential, further research could focus on optimising the pre-treatment processes for sugarcane bagasse and durian shell to improve their filtration properties and sustainability for various applications. Another recommendation is to explore combining coconut husk with sugarcane bagasse or durian shells, as this combination could yield synergistic effects and improve overall filtration performance. Future studies should also investigate the optimal proportions of these materials, as their ratios directly impact filtration efficiency.

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Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***Study conception and design:*** *Rubiaton Maon, Janmaizatulriah Jani;* ***Data collection:*** *Rubiaton Maon;* ***Analysis and interpretation of results:*** *Rubiaton Maon, Janmaizatulriah Jani;* ***Draft manuscript preparation:*** *Janmaizatulriah Jani & Fathiah Mohamed Zuki. All authors reviewed the results and approved the final version of the manuscript.*

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