Performance analysis of fabricated bio-filtration system for small-scaled greywater treatment: TSS and turbidity removals

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Abstract. River pollution, which is mainly due to excessive drainage of untreated domestic greywater, has becoming a serious concern in both poor and developing areas like Sarawak in the current years. Realizing the vital role of Sarawak rivers, the need to improve the level of pollution, demand for clean freshwater resources, as well as to save cost on household water supply, the greywater generated daily from every household needs to be pretreated for reuse, otherwise, discharged. This further demands for cost-effective pretreatment technology for domestic and residential use. This research, therefore, analyzes the efficiency of a low-cost bio-filtration system which utilizes agricultural wastes, namely rice husk and coconut coir, as bio-filter media to improve the quality of greywater effluent samples in terms of total suspended solids (TSS) and turbidity removals. This paper presents the extended results obtained from the previous research work using the same fabricated pre-treatment system, which consists of six main units i.e. wastewater storage tank, water feed tank, pre-sedimentation tank, bio-filter, post-sedimentation tank and treated water storage tank. The system is operated for six hours to complete several cycles of treatment. At every one-hour interval, both TSS and turbidity levels of the wastewater samples are recorded and the removal performances are evaluated and analyzed. Positive outcomes are attained from this research study such that the rice husk system is able to reduce the TSS and turbidity levels by 49.06% i.e. from 53.00 mg/L to 27.00 mg/L with an average rate of 4.33 mg/L.hr, as well as 57.79% i.e. from 41.70 FNU to about 17.60 FNU, at a rate of 4.02 FNU/hr respectively. Besides, the coconut coir bio-filtration system achieves TSS removal efficiency of 49.70% i.e. from 65.60 mg/L to 33.00 mg/L at mean rate of 5.43 mg/L.hr, and 63.10% turbidity removal i.e. from 48.40 FNU to 17.86 FNU, at 5.09 FNU/hr respectively.

Keywords: bio-filtration, coconut coir, domestic greywater, rice husk

1. Introduction
Sarawak, being one of the developing states in Malaysia, has been experiencing credibly an explosive growth in its population in the recent years and is anticipated to further expand in terms of its technology, sociology and economic status in the near future. This strongly demands for cleaner and safer environment to ensure a more sustainable and promising future. According to Kuok et al. [1], in the past, only 40% of the pollutants, excluding nutrients and bacteria, were able to be removed from the black water through the septic tank treatment whilst the greywater was directly discharged, along with the
stormwater, to the Sarawak tributaries without any pretreatment. The disposal of this untreated wastewater had adversely upset the quality and ecosystem of the Sarawak rivers.

To ensure and offer better access to safe and sustainable water supplies, minimize environmental degradation, as well as, to preserve the public health and the burdening costs associated to it, strenuous efforts must be done [2]. According to Chan et al. [3], rivers contribute to 97% of Malaysia water supply, whilst the remaining 3% are from the sub-grounds aquifers. Realizing this important role of rivers as the main freshwater source and to mitigate river pollution, particularly in Sarawak, domestic greywater needs to be treated before its release to the drains and river bodies [4]. Without prompt preservation actions and proper wastewater management, various roles of Sarawak rivers will be affected and Sarawak’s natural resources and water will continue to scarce [5]. Besides, the high cost of installation and operation of many water pollution treatment technologies introduced has burdened the society, thus the need to propose more cost effective and sustainable schemes.

Many previous studies had been carried out to propose potential alternative treatments and safe wastewater disposal strategies in the face of limited freshwater supply in the future. One of the most suggested and high potential approaches is to recycle and reuse the treated greywater by filtering and recycling miscellaneous drain water then using it for many secondary water applications [6]. Commonly, the treated water is used for non-potable purposes that do not require drinking water quality to be achieved. These include activities like cooling, rinsing and flushing in industries, as well as for outside use and irrigation purposes rather than wastefully discharging the greywater to Sarawak rivers [1]. Mah et al. [7] also convinced that it is a waste to dispose greywater as it is generated about the same volume daily, thus providing a constant resource of water for other secondary purposes. It can also help to lower the cost of water supply since the normal potable water is generally more expensive due to the costly treatment procedures and management.

Consequently, to recycle, pretreat and reuse the domestic greywater without incurring high cost of technology to the users, more cost effective and sustainable wastewater recovery technologies are demanded. El Nadi et al. [8] suggested the use of agricultural wastes as the natural packing media in the filtration vessel, as one of the feasible options to reduce the cost of the treatment system and control environment pollution; both river and land pollutions due to the massive accumulated amount of agricultural wastes generated and dumped. Therefore, this research aims to investigate the effectiveness of such wastes, namely rice husk and coconut coir, as the low-cost media installed in a fabricated bio-filtration system for the pretreatment of the domestic greywater effluent. While the previous work by Renang et al. [4] reported positive results of both media in improving the BOD5 and COD quality of the wastewater, this paper presents the extended results to the similar system that is, to evaluate their effectiveness in terms of total suspended solids (TSS) and turbidity removals.

2. Materials and Methods

2.1. Fabricated bio-filtration system

This research is an extension of the previous work which similarly focuses on the treatment of domestic greywater using the same continuous bio-filtration system. The previous results were reported by Renang et al. [4]. The fabricated bio-filtration system basically consists of six main unit operations, as depicted in the schematic diagram in figure 1. The effluent sample was collected from Desa Ilmu, Kota Samarahan, and the system was made to operate for six hours to complete several continuous treatment cycles. The primary treatment occurs in the baffled pre-sedimentation tank in which heavy particulates in the effluent sample settle down at the bottom of the tank.

Secondary treatment follows in the bioreactor which is designed at a capacity of 20L of wastewater and consists of a mesh net compacted with natural filters of local agricultural wastes to trap the available particulates passing through it. Coconut coir and rice husks are identified as the potential packing media for the greywater treatment for this purpose. The packing media also serves as microbial bed and support where microorganisms develop on the surface over the continuous cycles of operation and biodegrade the available organic pollutants in the wastewater. The media is designed to be fully submerged in the
greywater as shown in figure 2. They were collected locally from Saratok in Betong Division, Sarawak and used in the bioreactor system without any chemical pretreatment.

The filtrate proceeds to the tertiary treatment process in the baffled post-sedimentation tank to further separate traces of other impurities in the activated sludge, which will settle at the bottom of the tank and later be disposed as waste sludge.

![Figure 1. PFD of continuous bio-treatment system [4].](image1)

![Figure 2. Design of waste-packed bio-filter unit.](image2)

2.2. Performance analysis
The performance of each type of filter media, i.e. rice husk and coconut coir, in treating the greywater effluent, are analyzed and compared based on the reduction of total suspended solids (TSS) and turbidity levels within six hours of continuous treatment cycles.

2.2.1. Total suspended solids (TSS). The amount of total suspended solids in the wastewater samples are determined based on the methods outlined by the APHA (American Public Health Association) (1992). A volume of effluent sample is stirred and pipetted on dish before dried for at least an hour in a drying oven operating at about 105°C. After cooled in a desiccator, the sample dish is weighed using an analytical balance. The steps of drying, desiccating and weighing are repeated until a constant weight is achieved. Then, the amount of total suspended solids in the sample, measured in mg/L, is determined
using DR 900 multi-parameter portable colorimeter. The TSS values of the wastewater samples are analyzed at every one-hour interval for six hours and the percentage of cumulative removals are evaluated and recorded.

2.2.2. Turbidity. The technique to determine the turbidity level in the wastewater sample is also based on the APHA (American Public Health Association) (1992) standard methods. The sample is thoroughly shaken and poured slowly into the turbidimeter tubes to avoid bubbles formation. The water sample is added until the viewing disk can no longer be seen. The turbidity level is then determined directly from the instrument scale on the side of the turbidimeter tube. In this experiment, the turbidity level is measured in the unit of FNU. The turbidity levels of the wastewater samples are analyzed at every one-hour interval for six hours and the percentage of cumulative removals are evaluated and recorded.

3. Results and discussion
The performance of both rice husk and coconut coir, as natural filters of the bio-filtration system, on the TSS and turbidity levels of the sample effluents are analyzed in this section.

3.1. Total suspended solids (TSS) removal
Figure 3 illustrates the trends of the measured mean values of TSS in the sample effluents over the six-hours treatment. The difference in the TSS performances between the rice husk and coconut coir systems are comparatively insignificant whereby the prior resulted in an overall TSS removal efficiency of 49.06% with an average rate of 4.33 mg/L.hr, from 53.00 mg/L to 27.00 mg/L, whilst the latter similarly showed about the same TSS reduction rates of 49.70% and 5.43 mg/L.hr, from 65.60 mg/L to 33.00 mg/L.

The trends in figure 3 also portray that the rate of reduction of TSS are relatively higher at the early hours of treatment, before it generally decreases over time as tabulated in table 1. It is shown that the highest TSS removal rates for rice husk and coconut coir systems are obtained only within the first hour of treatment, which are at rates of 11.00 mg/L.hr with 20.75% TSS reduction from its initial value, and 14.60 mg/L.hr with 22.26% reduction, respectively. These results indicate that both rice husk and coconut coir can well behave as effective mediums for the physical filtration of suspended solids in the greywater samples, by which, the coconut coir system provides a minimally better performance than the other.

The performance of coconut coir packing media for TSS removal in this research is compared with that reported by Vinod & Mahalingegowda [9]. Significantly lower overall removal efficiency is obtained in this work, which is at 49.70%, as compared to that achieved by Vinod & Mahalingegowda [9] at 89.82%. This happens due to higher initial TSS values of the sample effluent and longer retention and operating period of six days performed by the authors which allowed higher efficiency, twice as much obtained in the current investigation. Hence, this shows that the removal efficiency will increase as the retention time in the reactor increases.
### Table 1. Rate of total suspended solids (TSS) removal.

| Time (hr) | Mean TSS (mg/L) | Hourly Rate of TSS Removal (mg/L.hr) | Rate of Cumulative TSS Removal (mg/L.hr) |
|-----------|-----------------|-------------------------------------|----------------------------------------|
|           | Rice Husk       | Coconut Coir                        | Rice Husk | Coconut Coir |
| 0         | 53.00           | 65.60                               | -         | -            |
| 1         | 42.00           | 51.00                               | 11.00     | 14.60        |
| 2         | 31.90           | 46.70                               | 4.90      | 4.30         |
| 3         | 31.10           | 38.00                               | 0.80      | 6.00         |
| 4         | 27.80           | 36.70                               | 3.30      | 1.30         |
| 5         | 27.00           | 33.00                               | 0.80      | 3.70         |
| 6         | 27.00           | 33.00                               | 0.80      | 3.70         |

### Table 2. Deviation of total suspended solids (TSS) from standard A and standard B limits.

| Time (hr) | Deviation from Standard A DOE (%) | Deviation from Standard B DOE (%) |
|-----------|-----------------------------------|----------------------------------|
|           | Rice Husk<sup>b</sup>             | Coconut Coir<sup>b</sup>         |
| 0         | 6.00                              | 31.20                            | -47.00 | -34.40 |
| 1         | -16.00                            | 2.00                             | -58.00 | -49.00 |
| 2         | -25.80                            | -6.60                            | -62.90 | -53.30 |
| 3         | -36.20                            | -12.00                           | -68.10 | -56.00 |
| 4         | -37.80                            | -24.00                           | -68.90 | -62.00 |
| 5         | -44.40                            | -26.60                           | -72.20 | -63.30 |
| 6         | -46.00                            | -34.00                           | -73.00 | -67.00 |

<sup>a</sup> TSS values for Standard A and Standard B are 50mg/L and 100mg/L respectively (based on the 8<sup>th</sup> Schedule of EQA 1974 by Department of Environment (DOE) Malaysia).

<sup>b</sup> Negative percentage reflects lower TSS values from the standard limits, and vice versa.

### 3.2. Turbidity removal

Figure 4 shows the effects of rice husk and coconut coir bio-filtration systems on the turbidity of the effluent samples over the six hours of continuous treatment. The turbidity levels are observed to decrease...
over time for both packing systems. For instance, the rice husk packing media system is able to reduce the initial average turbidity of sample from 41.70 FNU to about 17.60 FNU with a total removal of 24.10 FNU (57.79% efficiency) and an average rate of 4.02 FNU/hr throughout the six hours of treatment. On the other hand, over the same period of treatment, the coconut coir filtration system reduces the sample mean turbidity by 63.10%, from 48.40 FNU to 17.86 FNU with an average rate of 5.09 FNU/hr. It is hence, observed that the overall removal efficiency of effluent turbidity by the coconut coir bio-filtration system is insignificantly better than that achieved by the rice husk system.

As viewed in figure 4 and table 3, the turbidity of the domestic greywater sample decreases significantly for the first four hours of operation before attaining steady removal rates towards the end of the cyclic treatment. The highest rate is achieved at the first hour of treatment for both systems whereby the rice husk system records a rate of 7.40 FNU/hr which is 17.75% reduction from the initial average turbidity, whilst the coconut coir media records a significantly higher rate of 19.83 FNU/hr with 40.97% turbidity reduction. These rates gradually reduce over time as more substances are trapped on the packing media and the media become more spent. Similar to the performance on TSS removal, the results depict that both rice husk and coconut coir bio-filtration systems can effectively improve the turbidity of the greywater samples, in which the latter performs slightly better than the prior.

![Figure 4. Performance analysis on turbidity.](image)

**Table 3. Rate of turbidity removal.**

| Time (hr) | Mean Turbidity (FNU) | Hourly Rate of Turbidity Removal (FNU/hr) | Rate of Cumulative Turbidity Removal (FNU/hr) |
|-----------|----------------------|------------------------------------------|-----------------------------------------------|
|           | Rice Husk | Coconut Coir | Rice Husk | Coconut Coir | Rice Husk | Coconut Coir |
| 0         | 41.70     | 48.40        | -         | -            | -         | -            |
| 1         | 34.30     | 28.57        | 7.40      | 19.83        | 7.40      | 19.83        |
| 2         | 28.80     | 24.80        | 5.50      | 3.77         | 6.45      | 11.80        |
| 3         | 25.20     | 22.87        | 3.60      | 1.93         | 5.50      | 8.51         |
| 4         | 19.10     | 20.60        | 6.10      | 2.27         | 5.65      | 6.95         |
| 5         | 18.50     | 18.00        | 0.60      | 2.60         | 4.64      | 6.08         |
| 6         | 17.60     | 17.86        | 0.90      | 0.14         | 4.02      | 5.09         |
4. Conclusion
The rice husk packing filters have been found to reduce the TSS and turbidity levels by 49.06% from 53.00 mg/L to 27.00 mg/L (average rate of 4.33 mg/L.hr) and 57.79% from 41.70 FNU to about 17.60 FNU (average rate of 4.02 FNU/hr) respectively, whilst, the coconut coir media packs have reduced both levels by 49.70% from 65.60 mg/L to 33.00 mg/L (mean rate of 5.43 mg/L.hr) and 63.10% from 48.40 FNU to 17.86 FNU (mean rate of 5.09 FNU/hr) respectively. These outcomes also depict that both rice husk and coconut coir systems demonstrate almost similar removal efficiencies in reducing the TSS and turbidity levels from the effluent, with the latter achieving just slightly higher removal percentage. In conclusion, both rice husk and coconut coir bio-filtration systems can perform well as effective mediums and have shown positive outcomes in improving the quality of the greywater samples, in terms of the amount of Total Suspended Solids (TSS) and turbidity level. Nevertheless, the performance of the system could be more obvious when the sample effluent has higher initial TSS values or when longer retention time is employed. The findings of this research, hence, suggest that the biofiltration pre-treatment system using natural packing filters i.e. rice husk and coconut coir can be employed for greywater pretreatment especially for use in the rural areas.

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