A Column Study on The Efficiency and Reusability of Kapok Fibre as Car Wash Wastewater Treatment

N H Hashim1*, W C Chen1, M S S Ibrahim1, N M Abdullah1, Z Abdullah1

1 Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
* Corresponding author: haslina@uthm.edu.my

Abstract. The car washing industry which consumes large amount of water produces Car Wash Wastewater (CWW) which were likely to exceed the standard set in both Malaysia’s and Singapore’s regulation. Kapok Fibre (KF) is a natural adsorbing material which have large lumen and low density is believed to be able to act as an adsorbent to manage the CWW. This study was done to determine the characteristic of KF and CWW and investigate the efficiency of KF in treating CWW along with the reusability of KF through a column study with Organic Loading Rate (OLR) of 12.41g COD/L.day. The CWW contains a certain concentration of Chemical Oxygen Demand (COD, Oil and Grease (O&G), and Anionic Surfactant (AS) though the interaction between KF and AS is novel. KF found out to has the capability in removing COD, O&G, and AS up to 88.37%, 100%, and 83.8% respectively. However, in reusability experiment there is limitation to KF in which by exceeding the operation time to 600 minutes of treatment, the efficiency in removing COD, O&G, and AS were found to drop to 62.02%, 75%, and 55% respectively. This shows that KF could be an avant-garde, low-cost sustainable treatment to treat CWW instead of the conventional high cost and complex operating system.

1. Introduction
The car wash industry is one of industries that uses large volumes of clean water which resulted in the production of car wash wastewater (CWW) [1]. Depending on the size of cars, services, and equipment used, the water used per car varies between 150 litres to 600 litres [2]. CWW consist of water, rust, oil and grease, and elements of soap used to clean the car such as anionic surfactants, phenols, acids, and ammonia [3]. It is wildly assumed by public that the wastewater from car washing is not as contaminated or harmful as compared to industrial wastewater [4]. Other than highly water-consuming, car washing also involves significant amount of chemicals that could potentially toxic effluents that by right needs to be treated before being released [5]. Thus, the characteristic of CWW were being investigated in this study. Up to date, there are various treatment to treat CWW, such as electrochemical treatment, membrane filtration, and ultra-filtration which are extremely costly although it has excellent performance [6]. Therefore, a low cost treatment method like using adsorbent could be implemented especially if it is a natural fibre where modifications could be done to improvise its functionality to treat wastewater [7].

Kapok fibre (KF) originated from the seed hairs of kapok tree (Ceiba pentandra) in which generally is a cellulosic fibre with thin cell wall, large lumen, low density, and exhibit hydrophobic-oleophilic properties [8]. KF is a natural fibre that composed of 35% cellulose, 22% xylan, and 21% lignin. In its natural form, KF is significantly hydrophobic in which it does not get wet if it is exposed by water [9]. With KF being a type of renewable natural plant fibre as it is abundant, various potential...
application of it has yet to be explored as it is currently being focused particularly as oil adsorbent [8]. Therefore, this research identifies the characteristic of KF and assess its efficiency and reusability as an adsorbent in removing COD, O&G, and AS in CWW through a column study with and OLR of 12.41 g COD/L.day. Furthermore, the interaction between KF and AS is novel, where nothing has yet to be published to properly explained this interaction.

Water pollution is the addition of matter or substances directly or indirectly that changes the nature or characteristic of a water body that leads to unwanted or negative impact to the legitimate uses [10]. It is a global issue that be prioritized by everyone in which proper waste disposal system and contaminants should be treated before releasing in to the environment [11]. In Malaysia, any discharge that will be released as sewage, industrial effluent, and leachate to any stream got to refer to the Environmental Quality Regulation 2009. This research focuses on the effectiveness of KF in treating CWW to comply with Standard B of the regulation and the Singapore’s Environmental Protection and Management (Trade Effluent) Regulation of water-course.

2. Materials and Methods

2.1 Wastewater collection
The wastewater samples were collected from a car wash centre in Parit Raja, Johor, Malaysia. The CWW were collected during the afternoon where the samples include multiple amount of car wash. It was kept in several 1 litre Duran bottles that were placed in an ice box before transferring to a cold room. The CWW samples were homogenised after characterisation and prior to the column study. The homogenous sample should be adjusted to a pH value of approximately 9 as it is the optimum for the KF [12].

2.2 Analytical Procedures
Characterisation of KF were done using the Field Electron Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (FESEM-EDX). Raw and treated CWW samples were analysed for their COD, O&G, and AS according to standard methods. The analysis of COD (APHA 5200 D) includes the usage of COD Reactor (Hach DRB 200) to digest the CWW and followed by Spectrophotometer (Hach DR 6000) for analysis. As for O&G (APHA 5220 D), a mixture of n-hexane and Methyl tert-Butyl Ether (MTBE) of 80:20 ratios in volume were used to separate the O&G content in the CWW using a separatory funnel. Filtration were done with a Whatman 11cm diameter filter paper with sodium sulphate anhydrous crystal on it where the filtrate was placed in a water bath of 80°C where the difference of mass determines the concentration of O&G. The determination of AS complies to APHA 5540 C where Methylene Blue Absorbing Substance (MBAS) were used. A calibration curve was done using Sodium Dodecyl Sulphate (SDS) where a correlation relationship of $R^2 > 0.9$ were obtained. Filter paper of Whatman Silicone Treated Filter Paper Phase Separator 1PS with 125mm diameter were used to filter the solution and the filtrate were analysed using a single wavelength of the Hach DR6000 at 652nm.

2.3 Experimental Design
Experimental setup was divided into two that is characterisation and column study where characterisation was done on the CWW and KF while column study associates with the efficiency and reusability of KF in treating CWW. The column study was set up (Figure 1) with a column of 40mm x 50mm x 100mm where 1.33g of KF was loosely placed in the column. A flowrate of 6.67ml/min was fixed using a digital standard drive pump to which attaining a hydraulic retention time of 30 minutes. A total of 3 runs were executed with 38 hours per run. Within the 38 hours, samples of treated CWW were collected at time intervals of 30, 60, 120, 180, 300, 420, 600, 780, 1020, 1260, 1560, 1920, 2280 minutes. KF used in the column study were reused in which it was rinsed with pure water, filtrated under mild suction using vacuum pump and dried using a drying oven before commencing the next study.
3. Result and Discussion

3.1 Characterisation of Kapok Fibre

The EDX indicates that KF were 65.13% Carbon (C) and 34.87% Oxygen (O). The morphology of KF (Figure 2) shows that the lumen of KF were homogenous and has smooth surface with diameter of 21.5µm to 30.6µm (Figure 3).

3.2 Characterisation of Car Wash Wastewater

The data obtained were referred to the Malaysia’s Environmental Quality (Industrial Effluent) Regulation, Standard B for pH, COD, and O&G while AS will refer to the Singapore’s Environmental Protection and Management (Trade Effluent) Regulation, Controlled Watercourse as per Table 1. The effluents released from the car wash centre in Parit Raja will flow to the Sungai Simpang Kanan in which were not listed in the Third Schedule of Environmental Quality Act 1974, Malaysia. Therefore, Standard B and Controlled Watercourse regulation were complied. The results in Table 2 indicates that the effluent of car washing industry in Parit Raja exceeds both of the standards.
### Table 1: Standards used as guideline towards CWW effluents

| Standards                          | pH   | COD (mg/L) | O&G (mg/L) | AS (mg/L) |
|------------------------------------|------|------------|------------|-----------|
| Standard B (Malaysia)              | 5.5 - 9 | 200        | 10         | -         |
| Controlled Watercourse (Singapore) | -    | -          | -          | 15        |

### Table 2: Characterisation of CWW from a car wash centre in Parit Raja

| Day | pH      | COD (mg/L)     | O&G (mg/L)     | AS (mg/L)     |
|-----|---------|----------------|----------------|---------------|
| 1   | 10.65   | 302.30 ± 1.25  | 244.50 ± 31.44 | 39.20 ± 0.07  |
| 2   | 9.85    | 249.30 ± 2.62  | 188.90 ± 15.70 | 36.10 ± 0.10  |
| 3   | 10.85   | 326.70 ± 3.09  | 255.50 ± 31.44 | 40.00 ± 0.14  |
| 4   | 10.30   | 259.00 ± 1.63  | 177.80 ± 15.70 | 31.10 ± 0.33  |

3.3. Column Study

The efficiency of KF were analysed by looking at the removal of pollutants at the selected time intervals within the 38 hours. With a total of 3 runs, Figure 4, 5 and 6 shows the first, second, and third run, respectively. The analysis of AS was completed with the calibration curve that produces a good linear correlation relationship where the $R^2 = 0.9941$ in order to determine the concentration of AS in the untreated and treated CWW. The concentration of COD for the homogenised CWW were calculated to be 12.41g COD/L.day.

![Figure 4. Treatment of CWW using KF with OLR 12.41 (First run)](image1)

![Figure 5. Treatment of CWW using KF with OLR 12.41 (Second run)](image2)

![Figure 6. Treatment of CWW using KF with OLR 12.41 (Third run)](image3)

Based on Figure 4, 5, and 6 the COD removal and O&G removal were similar where decrease in O&G would lead to the decrease of COD as well. In three of the runs, the removal of COD at 30 minutes were 88.37%, 83.4% and 81.01% for 1st, 2nd, and 3rd run, respectively. The efficiency of removing COD are similar to the efficiency of using membrane where the removal was 54.9% to
91.5% [4]. At that point, the concentration of COD in the treated CWW were 30, 43, and 49mg/L. The O&G concentration however were 0 which means it has 100% removal efficiency at the beginning while AS removal were 83.8%, 81.6%, and 78.8%. Treatment like chemical oxidation too achieved a removal percentage of O&G as high as 96% [13].

At 600 minutes, in all three runs, the removal efficiency started to decrease significantly as shown in the figures where the removal percentage of the first, second, and third run were 77.52%, 65.25%, and 62.02% for COD, 93.8%, 75%, 75% for O&G, and 75.9%, 74.4%, and 55% for AS respectively. Treatment like chemical oxidation too achieved a removal percentage of O&G as high as 96% [13].

3.4. Reusability

The reusability of KF was determined by comparing its removal efficiency to the standards of Table 1. The column operations were numerically labelled; for example, COD₁ represents the COD data of the first run and AS₃ represents the AS data of the third run. The initial pH of the three runs were 9.08, 9.11, and 9.15 for the first, second, and third run, respectively and Figure 7 shows the pH of treated CWW over the time interval of 38 hours. Generally, the pH value increases slight over time however even at the time of 2280 minutes, the pH of the treated CWW were lower than 9 which does not exceed the regulation of Standard B.

The concentration of COD in the treated CWW of all three runs of column studies were shown in Figure. 8 over the course of 38 hours (2280 minutes) where the initial COD value were 258, 259, and 258 mg/L for the first, second, and third run, respectively. The regulation set the concentration of COD to be less than 200mg/L, the KF in the first run exceeds the limit after 1260 minutes while the second and third run exceeds after the time of 1020 minutes. This indicates that the KF could be reused where the KF were just cleaned with pure water and filtrated under mild suction using vacuum pump followed by drying process.

The concentrations of O&G initially were 177.8mg/L for all three runs where Figure 9 shows the O&G residue in the treated CWW over the time intervals of 38 hours. The O&G limitations were exceeded after 420 minutes for the first run, after 120 minutes for the second, and 60 minutes for the third run. The standards set by the legislation were 10mg/L which will be exceeded when there is O&G present in the treated CWW as every increase is in the multiple of 11.1mg/L. The O&G residue of treated CWW were 11.1mg/L for the first run at the time of 600 minutes, second run at 180 minutes, and 120 minutes for the third run. Therefore, the reusability of KF in adsorbing O&G were limited to about a couple of hours in this case.

Figure 7. pH Value of Treated CWW over Time Interval

Figure 8. Concentration of COD in Treated CWW over Time Interval
The concentrations of AS were obtained through MBAS with dilution factor of 10 and Figure 10 shows the concentration of AS of the treated CWW over the course of 38 hours. The standard of AS will refer to the Singapore’s regulation as there is no regulation on the presence of AS in the Malaysia’s regulation and the watercourse of Singapore’s regulation is similar to the Standard B of Malaysia’s regulation. Based on Figure 10, The first run exceeds the limit of 15mg/L after 1020 minutes while the second run exceeds after 780 minutes and for the third run its 420 minutes. Therefore, the reusability of KF in terms of AS were possible with time limit of 420 minutes.

Nevertheless, it appears that the treatment of CWW using KF column requires maintenance after 38 hours of operation. This is because at 2280 minutes, the removal efficiencies were minimal as it was 4.65 for COD, 6.3 for O&G and 3.8 for AS. The reusability of KF in CWW treatment is believed to be practicable after three runs with the same KF being cleaned with just pure water in between of runs. After three runs, the KF could still remove 81% of COD, 100% of O&G and 78.8% of AS at the early stage and 62.02%, 75%, and 55% subsequently after 600 minutes of treatment. This suggests that KF as an adsorbent could be applied as a low cost, sustainable CWW treatment to treat the effluents before releasing them.

4. Conclusion
The column studies showed that the treatment of CWW using KF is effective where the pH of treated CWW were in standard that is lesser than 9, COD concentration less than 200 mg/L, O&G concentration less than 10 mg/L and AS concentration less than 15 mg/L. The maximum removal percentage of COD were 88.37%, 100% on O&G and 83.8% for AS. The study shows that the KF column can be operated for at least 3 times, including maintenance after some time. The display of excellent performance of KF column in treating CWW shows promising future.

5. References
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