Investigation of using sand filter in treating grey water

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Abstract. The ability of sand filter in treating grey water collected from the college residential is studied. Sand filter was used because it is among the most effective methods to clean the burden of pollution in the wastewater. Six sand filters with different compositions were set up in which three sand filters only consist of sand and gravel while another three sand filters were added with coconut shell activated carbon. These sand filters were used to treat the grey water based on water quality parameters which are pH, AN, TSS, BOD₅, COD, and PO₄³⁻. The results show that concentration of AN, TSS, BOD₅, COD, and PO₄³⁻ was reduced up to 37%, 94%, 96%, 93% and 57% respectively while pH was neutral with a value of 7.60. Furthermore, the results also indicated that the sand filter added with coconut shell activated carbon was better in removing the pollutants as compared with sand filter without added activated carbon.

1. Introduction

Grey water production is one of the forms of distribution of water consumption. Grey water is characterized as the urban wastewater that includes water from drinking and cooking use, toilet flushing, gardening, washing, and cleaning of the house, shower, and bath, hand basin, laundry, and kitchen sinks [1].

Grey water contains a considerable amount of BOD, COD, turbidity, chlorides, and suspended solids. Grey water also contains a mixture of chemicals used in a variety of household products resulting in a complex chemical composition [2]. The addition of household chemicals can also change the bulk chemical characteristic of water such as pH, suspended solids, biological oxygen demand, and conductivity. Untreated grey water can have impacts on water quality and public health through high bacterial loads, nutrients discharge, biological oxygen demand, and salinity impacts. This situation, in turn, converts the streams to become unsuitable for aquatic flora and fauna. Because of this effect, the discharge of grey water into the stream needs to be treated to avoid that effect. Therefore, an economical and easy treatment should be applied to treat the grey water before it being released to streams.

Sand filtration is one of the methods used to treat wastewater. The sand filter is considered to be a simple technique for potable water treatment, low cost, efficient, and reliable [3]. In the filtration system, physical, and biological processes can be used to remove solids. However, this review considers only the physical removal of solids since this is the method used in most grey water treatment systems. This is because there have been several studies carried out sand filtration in treating grey water. Results showed that the sand filter may reduce the concentration of water quality parameters such as AN, TSS, BOD₅, COD, and PO₄³⁻. Therefore, this study is aimed to investigate the capability of sand filter to act as a pre-treatment of grey water as well as to compare the quality of grey water produced from the sand filter with and without additional activated carbon based on of pH, AN, TSS, BOD₅, COD and PO₄³⁻.
2. Material and methods

2.1. Location of water sampling
Tan Sri Aishah Ghani Residential of Universiti Malaysia Perlis (N 6°27′46.3104″ E 100° 9′54.342″) was chosen as a sampling location. The sample was collected at the final discharge of the laundry operation before being transferred to the laboratory for further study.

2.2. Preparation of coconut shell activated carbon
The coconut shell used in this study was collected from the local market that selling coconut milk and washed with distilled water to remove impurities before being dried in the oven. The coconut shell was burned in the furnace at 300 °C for 2 hours before being sieved to the desired size. Activation of activated carbon was performed by using an activating agent which is sulphuric acid, H₂SO₄. A respective amount of coconut shell was soaked with 5N H₂SO₄ for 12-18 hours to become activated carbon. The carbon was washed with distilled water and spread on the tray at room temperature to be drained for 3 hours before being dried in the oven at 105 °C temperature. Then, activated carbon was placed in an airtight container after cooling [4].

2.3. Preparation of sand filter
Six different compositions of sand filters were prepared in this study. Three filters consisted of only sand and gravel while another three filters were added with coconut shell activated carbon in the sand filter. All sand filters were constructed in the transparent plastic column. Each column had a height of 295 mm while the top and bottom diameter of the column were 75 mm and 25 mm, respectively. For each of the plastic column, a hole was created at the bottom so that the effluent of the water sample can be channelled and collected for testing. In this study, sand with an effective size of 1.12 mm while gravel with its effective size of 95 mm was used. Before the experiments started, all materials used in this study were washed with distilled water to remove impurities and air-dried before being filled up in the plastic column. The plastic net was used to avoid the materials from spilling out. Figure 1 shows the illustration of six filters prepared for the study.

![Figure 1](image-url)

Figure 1. Schematic diagram of sand filter composition of (a) Sand (180 mm), Gravel (80 mm), (b) Sand (130 mm), Gravel (130 mm), (c) Sand (80 mm),Gravel (180 mm), and (d) Sand (180 mm), Gravel (80 mm), Coconut shell activated carbon (50 mm), (e) Sand (130 mm), Gravel (130 mm), Coconut shell activated carbon (50 mm) and (f) Sand (80 mm), Gravel (180 mm), Coconut shell activated carbon(50 mm).
2.4. Experimental study

2.5 L of water sample collected from the laundry operation was pumped and flown continuously into each of the sand filter. At the bottom of each filter, a container was placed to collect the water discharge for analysis. Six parameters of water quality (pH, AN, TSS, BOD$_5$, COD, and PO$_4^{3-}$) were examined in which all the procedures were in accordance with the American Public Health Association (APHA) [5] and HACH [6].

3. Results and discussion

3.1. Characteristics of grey water

Grey water mainly consists of organic as well as inorganic pollutants. Few important parameters of the wastewater were measured before and after the sand filter treatment. The average values of the measured parameters were present in Table 1. The water characterizations were in terms of pH, TSS, BOD$_5$, COD, AN and PO$_4^{3-}$.

| Parameter (mg/L) | Grey water concentration (before treatment) | Grey water concentration based on sand filter (after treatment) |
|------------------|---------------------------------------------|---------------------------------------------------------------|
|                  |                                             | SF1   | SF2   | SF3   |
| pH               | 9.97                                        | 8.89  | 9.40  | 9.59  |
| TSS              | 33                                           | 6     | 8     | 10    |
| COD              | 630                                         | 391   | 466   | 478   |
| BOD$_5$          | 393                                         | 244   | 363   | 344   |
| AN               | 0.38                                        | 0.27  | 0.28  | 0.27  |
| PO$_4^{3-}$      | 0.98                                        | 0.72  | 0.80  | 0.83  |

Initially, high pH was discovered in the grey water (9.97) indicating that the wastewater was in basic condition. However, after the wastewater which passed through the sand filter treatments, the results showed a good finding where the pH recorded were decreased from 9.97 to 8.89 in SF1 which was slightly alkaline. According to Seenirajan et al. [2], the pH in grey water to a large extent depends on the pH and alkalinity in the water supply. Besides that, it is also due to the presence of organic hydroxyl detergents [7] which the residues of the detergents will go out with the wastewater thus affecting the pH of the water.

Total suspended solids (TSS) was another parameter tested in this study. The results showed that there were decreased in TSS levels throughout the sand filtration treatments. TSS level was reduced by more than 70% from 33 mg/L to 8 mg/L on average using sand filter SF1, SF2, and SF3. A similar finding was also reported by Shegokar et al. [8] which indicating the sand filter used in his study can remove the amount of TSS in grey water very well from 132.20 to 12.32 mg/L. Commonly, suspended solids from the laundry were hair and fibres which lead to higher solids contents in grey water. These particles and colloids can cause turbidity in the water and may cause physical problems such as clogging of pipes, pumps as well as filters used in treatment processes [9].

BOD$_5$ and COD are the quantity of oxygen required to oxidize organic and inorganic matter present in grey water. In this study, the results showed that COD and BOD$_5$ concentrations of grey water before undergo treatment were 630 mg/L and 393 mg/L, respectively. High levels of BOD$_5$ and COD in the wastewater released directly to the receiving water may affect the quality of the water body as more oxygen needed to deplete the organic and inorganic matters thus less oxygen available for aquatic life. However, there were reductions recorded in the COD level after the wastewater treated with the sand filters. The results showed that the lowest COD concentration was recorded by SF1 with 391 mg/L. Similar findings were also shown by BOD$_5$ as the levels of BOD$_5$ after undergoing sand filter treatments
were also decreased up to 244 mg/L by SF1. These results indicated that the sand filters used in this study were able to remove organic and inorganic matters in the water sample.

Total nitrogen and total phosphorous were the nutrients found in the grey water. Generally, nitrogen in the grey water was presented in the form of organic such as ammonia (NH$_4^+$, NH$_3$-N) and inorganic such as nitrate (NO$_3^-$) and nitrite (NO$_2^-$). Likewise, orthophosphate (PO$_4^{3-}$) was a common form of P in the grey water which results from the utilization of detergent builder and hygiene products [10]. Based on table 1, the AN and PO$_4^{3-}$ of the grey water recorded in this study were 0.38 and 0.98 mg/L, respectively. However, nitrogen and phosphorous in the grey water decreased after used sand filtration. The results showed that the average reduction concentration of nitrogen and phosphorous were 0.27 and 0.78 mg/L, respectively. Normally, grey water had low nutrient levels compared to wastewater from toilets. However, the high phosphorous content that was sometimes found in the grey water can cause problems in receiving water such as algae growth [2]. Overall, the results showed that SF1 was a good sand filter which its’ composition was sand (180 mm) and gravel (80 mm) while the least removal was SF3 with the composition of sand (80 mm) and gravel (180 mm). This indicated that the size and composition of the materials were affecting the efficiency of the sand filters.

3.2. Removal of various parameter in grey water after using sand filter with additional activated carbon

Further investigation of using sand filters in treating grey water were carried out in this study. Three composition of sand filters were prepared similar to the previous study with the addition of coconut shell activated carbon as its materials. The composition and height of each sand filter materials were sand (180 mm), gravel (80 mm) and coconut shell activated carbon (50 mm) for SF4, sand (130 mm), gravel (130 mm) and coconut shell activated carbon (50 mm) for SF5 whilst sand (80 mm), gravel (180 mm) and coconut shell activated carbon (50 mm) for SF6. Visual assessment revealed that the colour of the grey water turned from grey to nearly colourless after treated by using sand filters with additional coconut shell activated carbon as the media. Besides, the removal efficiency of the effluents grey water from the treatment system after using coconut shell activated carbon in terms of pH, TSS, BOD$_5$, COD, AN and PO$_4^{3-}$ were also studied and the results were shown in figure 2.

![Figure 2. Removal efficiency of various parameter for treated grey water using sand filter with additional activated carbon.](image)

The result showed that the highest removal in grey water after added activated carbon was SF4 and the lowest removal was by SF6. The percentage removal for SF4 was 26.3 %, 26.11 % for SF5 and 24.15 % for SF6. It revealed that coconut shell activated carbon that added in the three types of sand filtration with the range of pH between 6.89 to 7.02 and high 50 mm in the column of the sand filter can remove
organic in the grey water very well. According to DeSilva [11], the removal of organic by activated carbon is more effective at a pH level of less than 7.

COD is the amount of oxygen consumed to chemically oxidize organic water contaminants to the inorganic end product and BOD5 is used to measure the self-purification capacity of streams as means of checking the quality of effluents discharged to stream waters [12]. Figure 2 showed the removal efficiency of all sand filters for COD exceeded 90 % when added coconut shell activated carbon in the media. Similarly, the removals of BOD5 in grey water were also increased from 37.84 % (without activated carbon as media) to more than 90 % (addition of activated carbon in the sand filters). SF4 showed the highest removal for both COD and BOD5 with 97.21 and 96.31 %, respectively while the least removal was recorded by SF6 with 92.77 and 93.12 %, respectively for both parameters.

The removal efficiency of nutrients in term of PO43− and AN in grey water were also measured in this study. The results showed that the PO43− removal were 57.01 % in SF4. As for SF5 and SF6, the removal was 57.07 % and 47.11 %, respectively. Lower percentages of AN removal were observed in this study which less than 40 % removal were recorded by all sand filters ranging from 28 % to 37 %. Then, further study was carried out by examining the level of suspended solids. The highest removal result of TSS was SF4 with 93.84 %, which is higher as compared to SF5 and SF6. These results indicated that the concentration of nitrogen, phosphate and total suspended solids removal efficiency were strongly affected by the variable selected for this study.

Further investigation on sand filter revealed that activated carbon had improved the efficiency of the filters. The results showed that the percentage removals for all parameters tested were increased when coconut shell activated carbon was added as part of the media. This is because activated carbons based on coconut shells are the least dusty and are mainly microporous which ideal for organic chemical adsorption. It also has the highest hardness compared to other types of activated carbon, which makes it the best carbon for purifying water [13].

4. Conclusion
This study showed that the grey water from laundry operation was high with pH, AN, TSS, BOD5, COD, and PO43−. Therefore, six sand filters with different compositions were created to improve the quality of the grey water generated. Three types of sand filters with different height of sand and gravel were constructed while another three filters were added with activated carbon produced from coconut shell. Based on laboratory tests, the best sand filter in this study was SF4 with the composition of sand (180 mm), gravel (80 mm) and coconut shell activated carbon (50 mm). It can be seen the percentage of removal for all parameters increased after added with coconut shell activated carbon. Therefore, this study revealed that sand filter which was added with activated carbon is better than a conventional sand filter and can be one of the alternatives for the treatment of grey water.

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