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Removing colour and chemical oxygen demand, from palm oil mill effluent (POME) using horizontal roughing filter

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Abstract

Roughing filter can be considered as a major post-treatment process in waste water management. It reduces influent colour and suspended solids to a level that is effective for operation; meanwhile, roughing filter presents a promoting method for improving raw water quality without using any chemicals. This research aims at improving Palm Oil Mill Effluents (POME) using limestone roughing filter to remove colour and chemical oxygen demand. To obtain this goal, four different series of experiment that involved different sizes of limestone filter media and various filtration rates were carried out; the four categories of limestone filter media included small size (3-6mm), medium size (6-12mm), large size (12-20mm) and a combination of the three filter media and were utilized in the experiment with three different filtration rates of 0.3 m/h, 0.8 m/h and 1.5 m/h. The results indicated that achieving efficient COD and colour removals depend on the size of filter media and the applied flow rate. COD and colour, removals were found 59.64%, 63.43%, Removal efficiency was found increased with slower flow rate and the smallest size of media.

Keywords: Roughing filters, Pretreatment, Palm oil mill effluent (POME), Limestone.

1. Introduction

Palm Oil is known as the most compatible harvest product of both neighboring countries: Malaysia and Indonesia (Latif Ahmad *et al.*, 2003). There are seven stages to be completed

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in order to extract palm oil from the fruit Elaeis guineensis; the stages include sterilization, stripping, digestion, pressing, classification, purification, and vacuum drying. For the purpose of extracting palm oil from the fruit, a large amount of water (almost 1.5) has to be consumed, for every tone of Fresh Fruit Bunch (FFB). However, half will be transferred to Palm Oil Mill Effluent (POME). This material is known for being extremely polluting; releasing POME in a single average-size palm oil mill of 30 t/h FFB processing capacity is equal to the pollution produced by 300,000 persons (Zhang *et al*., 2008). When this liquid is raw, it is thick and brownish, and released at the temperature within 80° to 90°c. POME is a colloidal suspension of 95–96% water and 4–5% total solids, including 2–4% suspended solids, with a biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of 26.3 and 65.5 g/l, respectively. POME usually has a PH of 4–5 and contains appreciable amount of nutrients for granulation (Ahmad *et al*., 2011). With the rapid expansion of the palm oil industry and the public increased awareness of preventing environmental pollution, the industry is obliged to be socially and aesthetically responsible and treat its effluent before discharging it. In 1977, Malaysian Government proposed and legalized some standards for POME discharge into watercourses (Oswal *et al*., 2002). Since then, palm oil mills are required to treat their POME prior to discharging it into streams and rivers. The history of parameter limits for POME discharge into watercourses in Malaysia is summarized in Table 1.

There is an urgent need to find a compromising way that will keep the balance between environmental protection and sustainable reuse of the nutrient sources found in the POME. The current treatment systems which are based mainly on biological treatments of anaerobic and aerobic systems are quite inefficient and this unfortunately leads to environmental pollution (Wu *et al*., 2007). Roughing filters are primarily used to separate fine solids from the water which is partly, or not retained at all by stilling basins or sedimentation tanks. Roughing filters mainly act as physical filters and reduce the solid mass from wastewater However, the large filter surface area available for sedimentation and relatively small filtration rates also support absorption as well as

Table 1. Parameter limits for POME discharge into watercourses in Malaysia (Wu, T. Y. *et al*., 2010)

Parameters	1-7-1978 30-6-1979	1-7-1979 30-6-1980	1-7-1980 30-6-1981	1-7-1981 30-6-1982	1-7-1982 30-6-1983	1-7-1984 and there after
BOD$_b$	5000	2000	1000	500	250	100
COD	10,000	4000	2000	500	-	-
Total solids	4000	2500	2000	1500	-	-
Suspended solids	1200	800	600	400	400	400
Oil and grease	150	100	75	50	50	50
Ammoniacal nitrogen	25	15	15	10	150^c	150^c
Total nitrogen	200	100	75	50	300^c	200^c
PH	5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0

a. All parameters are in units of mg/l with the exception of PH and Temperature (°C)
b. The sample for BOD analysis is incubated at 30c^0
c. Value of filtered sample

chemical and biological processes. Therefore, in addition to solid matter separation, roughing filters partly improve the bacteriological water quality and change some other water quality parameters such as colour or amount of dissolved organic substances to a minor extent (Nkwonta and Ochieng, 2009). The depth of the filter bed maximizes the capacity of the filter to store removed solids. Particle removal efficiency in roughing filters is dependent on the design of the filter, particulates, and water quality parameters (Nkwonta and Ochieng, 2010). Roughing filters are long troughs open to the atmosphere with a series of flow rates through different sizes of gravel. The gravel often consist of crushed river rock media from a 20-mm average diameter to a 4-mm average diameter, and common flows range from 0.3 to 1.5 m/h of horizontal filter area (Rooklidge *et al*., 2002). In this research, limestone was used as a filter media because it is easily available and considerably cheaper. Besides, it could be used as a filter media for waste water treatment plants. It is composed of an accurate and closely screened aggregate which provides a surface for bacteria growth to enhance its purification process (Chen *et al*., 2007). This paper will discuss laboratory investigations on the use of different sizes of limestone filter media through various filtration rates for the removal of colour and chemical oxygen demand. Water samples used in the experiment were taken from the influent of Palm Oil Mill factory, Nibong Tebal, Pulau Pinang.

2. Materials and methods

2.1. Wastewater sampling and analysis

POME and palm oil sludge were obtained from the United Palm Oil Mill Sdn. Bhd, Nibong Tebal, Pulau Pinang selected as the case study of the present research. The pounding POME treatment system has been employed to treat wastewater. This study involves two main data collection methods including field measurement and laboratory experiment. Field measurement includes tests for Dissolved Oxygen (DO), pH, and temperature, using DO meter, whilst laboratory experiments involve tests for Chemical Oxygen Demand (COD), Suspended Solids (SS), Colour, turbidity, and Ammonia Nitrogen). All of the tests were conducted in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The typical characteristics of raw POME are illustrated in Table 2.

2.2. Materials

Natural limestone media, provided from Perak

Table 2. Characteristics of raw POME

Parameter	Range	Unit
BOD	230	m/l
COD	1500	m/l
Total solid	500	m/l
OIL and G	50	m/l
Ammonia nitrogen	200	m/l
suspended solids	700	m/l
PH	5.0-7.0	-
Temperature	35	-

Table 3. Composition of limestone

Component	Mgo	SiO_2	Cao	Fe_2o_3	Sro	Zno	Mno	So_3	P_2o_5	Cs_2o
Percentage (%)	2.93	2.49	90.90	0.85	0.05	0.007	0.017	0.014	0.03	0.05

Malaysia, was used in this study. Prior to the experiment, the limestone was crushed into three media size: small size (3-6mm), medium size (6-12mm) and large size (12-20mm). It was washed with water, and dried. The composition of limestone used in this study was tested in the XRD Laboratory, School of Material & Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, as presented in Table 3.

2.3. Batch study

In this study, horizontal roughing filters were selected for the pre-treatment processes .The laboratory filter was made by special perplexes material with 750mm length and 200mm height that was filled using media in various sizes (Figure1). The experiment was carried out at the Environmental Laboratory 2, School of Civil Engineering. Four different configuration of filter media were considered in this study; The first batch that has been deployed included small sizes of limestone (3-6mm), the second batch included medium sizes of media (6-12mm), the third batch involved 12-20mm filter media, and the last batch was a combination of the three sizes of filter media, each tested with various flow rates of waste water (0.3m/h, 0.8m/h and 1.5m/h). Each experiment was carried out over a period of 7 days. Both untreated and treated water samples were tested at different flow rates. The flow through the filter media was provided by peristaltic pumps at laminar flows (R_N: 28-140). Upon completion of the experiment with the first batch, the filter media was removed and the tank was cleaned to be prepared for the next batch and this process was repeated after each level was completed. The removal was calculated as follows:

$$\text{Removal percentage} = \frac{C_1 - C_2}{C_1} \times 100$$

where C_1 and C_2 indicated untreated water and treated water concentration respectively.

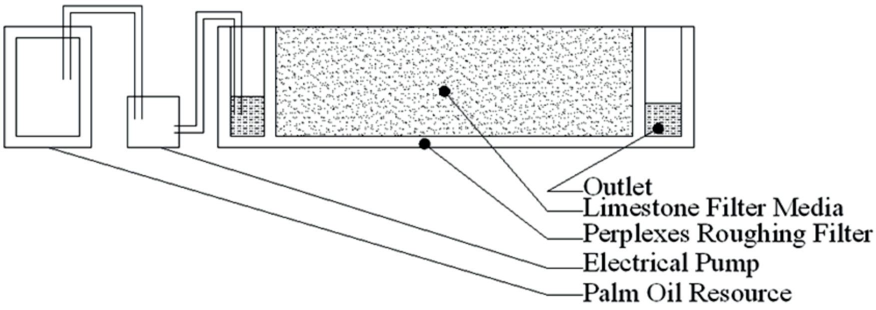

Figure 1. Schematic of laboratory-scale roughing filter

3. Results and Discussion

3.1. Effect of media sizes on chemical oxygen demand (COD)

Figure 2 shows the relationship between different filter media sizes at 0.3 m/h filtration rate and the percentage of COD removal; 3-6 mm filter media's optimum COD removal

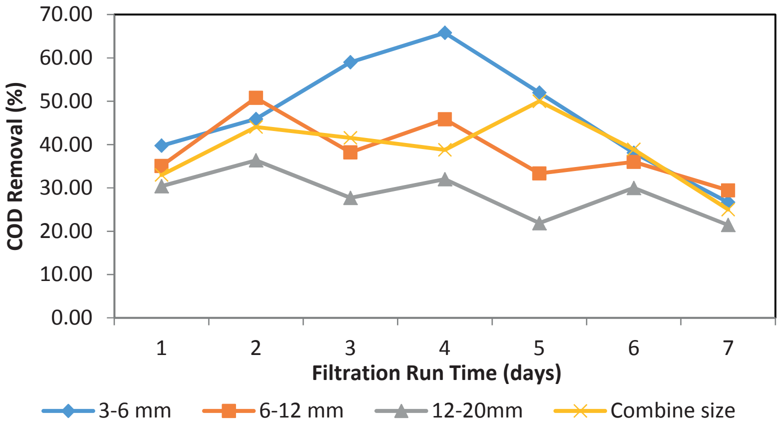

Figure 2. Percentage of COD removal with respect to variable filter media sizes (0.3 m/h)

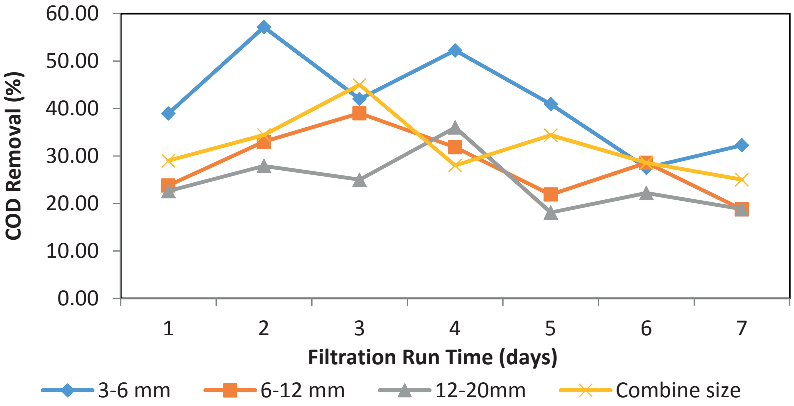

Figure 3. Percentage of COD removal regarding variable filter media sizes (0.8m/h)

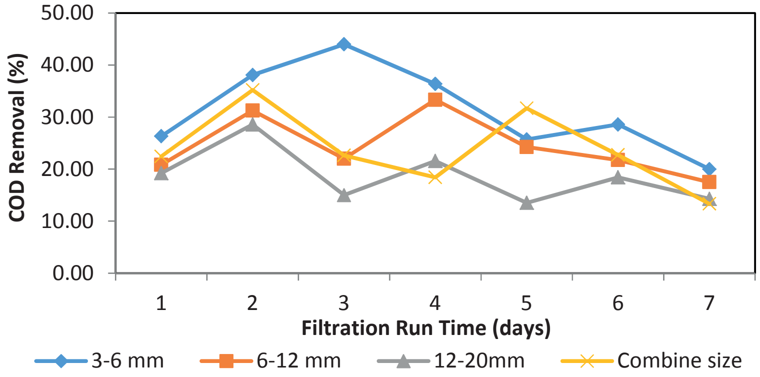

Figure 4. Percentage of COD removal relating to variable filter media sizes (1.5m/h)

was 59.64% while the optimum COD removal of 6-12 mm filter media was 41.96%. The optimum COD removals of 12-20 mm filter media and the combined size were 30.40% and 45.45%, respectively. It is demonstrated that HRF had an optimum COD removal efficiency of 59.64% with 3-6mm filter media and the small size filter media (3-6 mm) gave a higher COD removal efficiency.

Figure 3 shows the relationship between different filter media sizes at 0.8 m/h filtration rate and the percentage of COD removal; 3-6mm filter media's optimum COD removal was 48% while the optimum COD removal of 6-12 mm filter media was 33.05% The optimum COD removals of 12-20 filter media and the combined size were 26.16% and 36.14%, respectively. As it is demonstrated, HRF offered an optimum COD removal efficiency of 48% with 3-6 mm filter media.

Figure 4 indicates that, at flow rate of 1.5m/h, the optimum COD removal was 37.70% with the small size (3-6 mm) and 27.89% with the medium (6-12 mm) filter media. The results show that the optimum COD removal of 12-20 mm filter media was 19.50%, and 30.06% with combined size filter media. The highest COD removal occurred with the small size filter media (3-6 mm). The results indicate that higher COD removals were found at lower filtration rates and the smallest size of limestone gave a higher COD removing at higher filtration rates compared to the bigger sizes of filter media that it's due to larger surface area in small size of lime stone.

3.2. Effect of media sizes on colour

Figure 5 shows the comparison between the four processes of colour removal with different size filter media, at 0.3m/h filtration rate. The highest colour removal was obtained with 3-6 mm filter media (63.43%), and the lowest colour removal was found with 12-20 mm filter media (30.40%). The experiments have shown that 6-12mm and combined size filter media had a colour removal of 42.48% and 44.16%, respectively.

Figure 6 illustrates the results of the experiments with the four sizes of filter media at 0.8 m/h flow rate, the small size filter media (3-6 mm) had resulted in a higher colour removal (48.99%) compared to other sizes of filter media; the combined size filter media demonstrated a colour removal of 37.57%, while 6-12 mm and 12-20 mm filter media have shown colour removal efficiency of 34.50% and 22.54%, respectively.

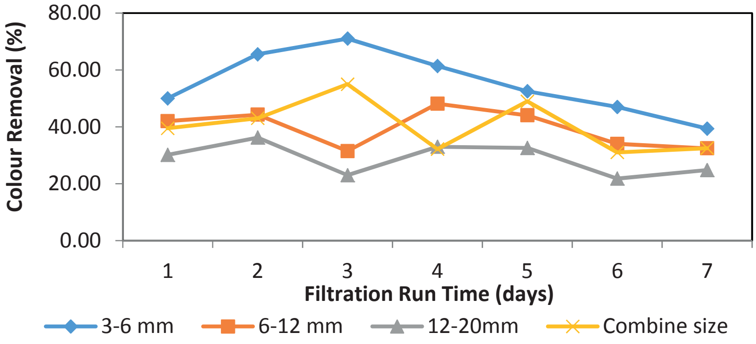

Figure 5. Percentage of Colour removal in different filter media sizes at 0.3m/h filtration rate

Figure 7 demonstrates the colour removal efficiency of the four sizes of filter media at 1.5m/h flow rate: the optimum colour removal of 3-6mm filter media was found to be 44.16% which is regarded as the highest efficiency while the optimum colour removal indexes of 6-12 mm, 12-20 mm, and the combined size filter media were found as 27.14%, 18.47%, and 31.35%, respectively. According to the results obtained from the experiments, the small size filter media (3-6 mm) had the highest colour removal efficiency with 44.16% at 1.5 m/h flow rate.

3.3. *Effect of filtration rates on Colour and COD*

Figure 8 and Table 4 illustrate colour removal indexes of 3-6 mm filter media at various filtration rates (0.3 m/h, 0.8 m/h, and 1.5 m/h); the optimum colour removal of the applied filter was observed to be 55.27% at 0.3m/h filtration rate while at 0.8m/h and 1.5m/h filtration rates the colour removal indexes were 43.70% and 38.512%, respectively. The maximum colour removal efficiency of 55.27% was found when the horizontal roughing filter was run with the lowest filtration rate (0.3 m/h). In Table 4, the value of $P<0.05$ indicates that there was a significant difference between untreated POME samples and treated ones. All in all, the table demonstrates the effects of various filtration rates on colour removal efficiency of the media applied.

According to Figure 9 and Table 5, the observed colour removal indexes of 6-12 mm filter media at 0.3 m/h, 0.8 m/h, and 1.5 m/h flow rates were 39.49 (standard deviation:

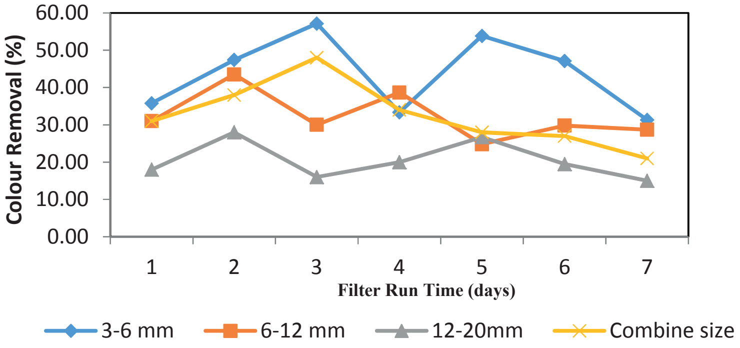

Figure 6. Percentage of Colour removal with respect to variable filter media sizes at 0.8 m/h flow rate

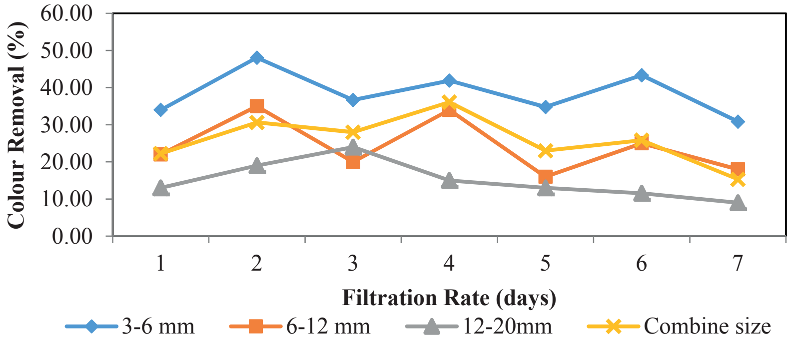

Figure 7. Percentage of Colour removal with respect to variable filter media sizes at 1.5m/h flow rate

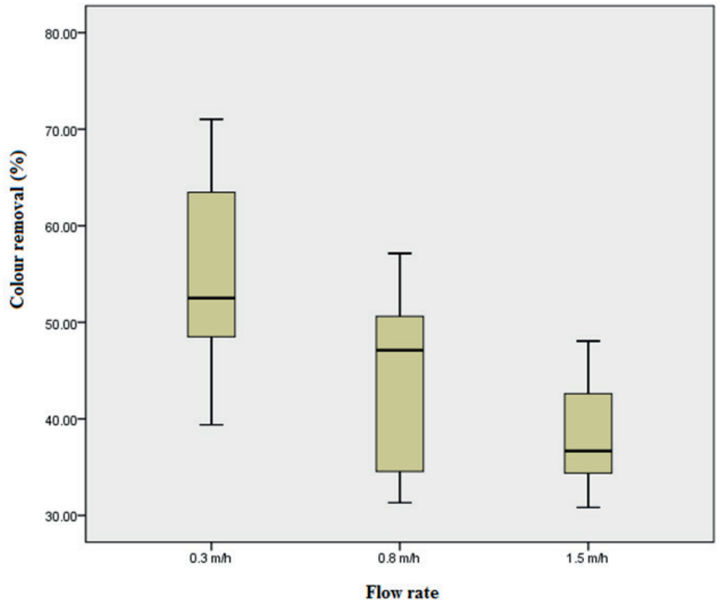

Figure 8. Colour removals regarding flow rate at 3-6 mm filter media

Table 4. One-way ANOVA: Colour removal versus filtration rates at 3-6mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	1029.936	514.968	5.785	0.011
Error	18	1602.415	89.032		
Total	21	46734.102			

R squared = .391 (Adjusted R Squared) = .324

```
Individual 95% CIs For Mean Based on Pooled St Dev

Level    N   Mean   St Dev     -+---------+---------+---------+--------
0.3 m/h  7  55.266  11.159               (--------*--------)
0.8 m/h  7  43.704  10.267        (---------*--------)
1.5 m/h  7  38.512   6.092     (--------*---------)
                              -+---------+---------+---------+--------
                              32.0      40.0      48.0      56.0
Pooled St Dev = 6.543
```

6.692), 32.35%(standard deviation: 6.435), and 24.28% (standard deviation: 7.544), respectively. The maximum colour removal efficiency of 39.49% was found when the horizontal roughing filter was run with the lowest filtration rate (0.3 m/h). The value of $P<0.05$, indicated in Table 5, confirms that that there was a significant difference between untreated POME samples and treated ones. The table presents an overview of the effects of different filtration rates on colour removal efficiency of the applied filter.

Figure 10 indicated total colour removal using boxplots. It shows that highest colour removal was obtained in lowest flow rate and the lowest colour removal was achieved in highest flow rate. Table 6 shows that the highest colour removal of 28.80% was achieved in the 0.3m/h filtration rate. Colour removal of 20.45% was found in 0.8m/h filtration rate. The lowest colour removal

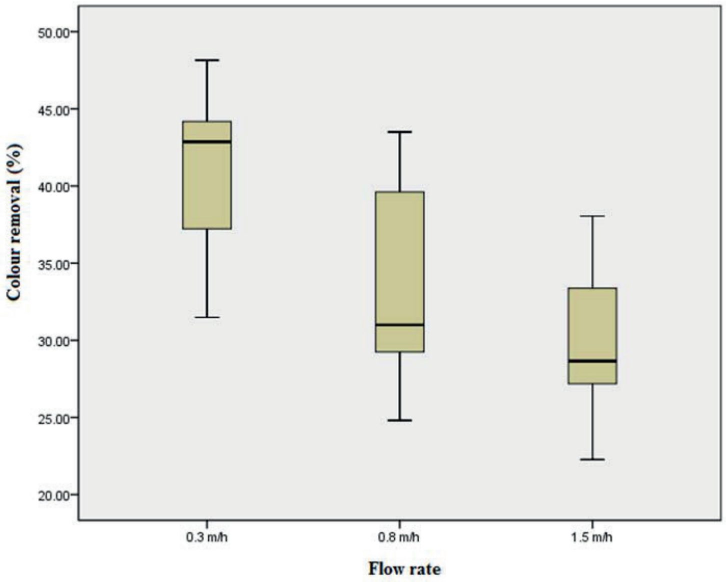

Figure 9. Colour removals with respect to flow rate at 6-12 mm filter media

Table 5. One-way ANOVA: Colour removal versus filtration rates at 6-12mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	415.107	207.553	5.143	0.017
Error	18	726.360	40.353		
Total	21	26657.486			

R squared = .364 (Adjusted R Squared) = .293

```
Individual 95% CIs For Mean Based on Pooled St Dev

Level    N   Mean  St Dev   ---+---------+---------+---------+------
0.3 m/h  7  39.491  6.692                (------*-------)
0.8 m/h  7  32.351  6.435         (-------*-------)
1.5 m/h  7  24.286  7.544   (-------*-------)
                            ---+---------+---------+---------+------
                             21.0      28.0      35.0      42.0
Pooled St Dev = 6.906
```

efficiency of 14.93% was recorded in 1.5m/h filtration rate for the 12-20 mm sized filter media. The maximum colour removal efficiency of 28.80% was found when the horizontal roughing filter was run with low filtration rates. In Table 6 also, P<0.05 indicates that there was significant difference between untreated POME samples and treated POME, the effect of filtration rates in terms of colour removal.

Figure 11 shows comparison of different flow rate for combined size of filter media. It indicated that highest colour removal was obtained in lowest flow rate and the lowest colour removal was achieved in highest flow rate. Table 7 illustrates that the combined size filter media had the highest colour removal of 40.31% at 0.3m/h filtration rate while the lowest colour removal efficiency of the filter was observed at 1.5 m/h

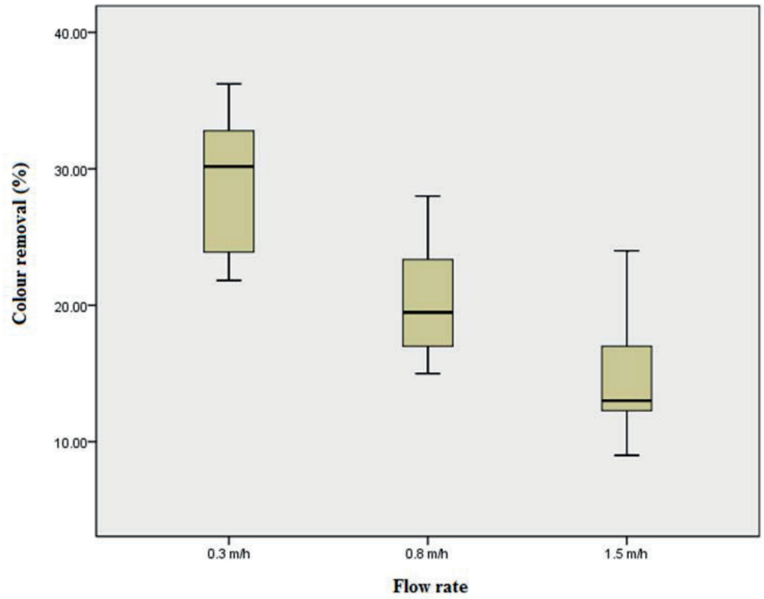

Figure 10. Colour removals concerning flow rate at 12-20 mm filter media

Table 6. One-way ANOVA: Colour removal versus filtration rates at 12.20mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	681.631	340.915	12.454	.000
Error	18	492.825	27.452		
Total	21	10789.676			

R squared = .580 (Adjusted R Squared) = .534

Individual 95% CIs For Mean Based on Pooled St Dev

```
Level    N   Mean   St Dev     --+---------+---------+---------+-------
0.3 m/h  7  28.801  5.590                (------*------)
0.8 m/h  7  20.455  5.046           (------*------)
1.5 m/h  7  14.939  5.045      (------*------)
                             --+---------+---------+---------+-------
                             12.0      18.0      24.0      30.0
```

Pooled St Dev = 5.233

filtration rate with 25.86%. According to the table the optimum colour removal of combined size filter media was 32.42% at 0.8m/h filtration rate. The maximum colour removal efficiency of 40.31% was found when the horizontal roughing filter was run with the lowest filtration rate (0.3 m/h) that this due to longer retention time compare to higher flow rate. The value of $P<0.05$ indicates that there was a significant difference between untreated POME samples and treated ones. The table presents an overview of the effects of different filtration rates on colour removal efficiency of the applied filter.

Figure 12 and Table 8 reveals that COD removal efficiency of 3-6 mm filter media was dependent on the filtration rates applied. Application of the roughing filter at 0.3m/h filtration rate resulted in a COD removal of 46.74% (standard deviation 13.34) while the COD removal of the filter was 41.57% (standard deviation 10.40) at

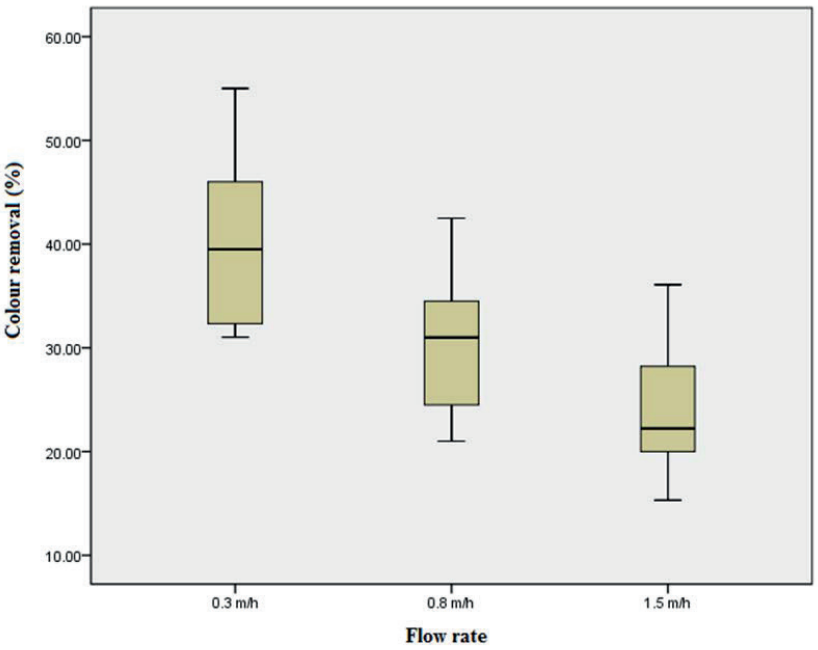

Figure11. Colour removals with respect to different flow rates (m/h)

Table 7. One-way ANOVA: Colour removal versus filtration rates at combined size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	915.986	456.993	7.029	0.432
Error	18	1172.906	65.161		
Total	21	23134.561			

R squared = .439 (Adjusted R Squared) = .365

Individual 95% CIs For Mean Based on Pooled St Dev

```
Level     N   Mean   St Dev      --+---------+---------+---------+-------
0.3 m/ h  7  40.318  9.240                (---------*--------)
0.8 m/h   7  32.429  8.734            (--------*---------)
1.5 m/h   7  25.866  6.641       (--------*--------)
                              --+---------+---------+---------+-------
                              21.0      28.0      35.0      42.0
```

Pooled St Dev = 8.282

0.8m/h filtration rate, and at 1.5m/h filtration rate, the COD removal was found to be 31.29% (standard deviation 8.41). The maximum COD removal efficiency of 31.51% was found when the horizontal roughing filter was used with the lowest filtration rate (0.3 m/h). The value of P<0.05 indicates that there was a significant difference between untreated POME samples and treated ones. The table is to present a general view of the effects of different filtration rates on COD removal efficiency of the filter applied.

Figure 13 indicated total COD removal using boxplots. It shows that the lowest COD removal was achieved in highest flow rate and highest COD removal was obtained in lowest flow rate. Table 9 demonstrates information on COD removal efficiency of 6-12 mm filter media and its associations with various filtration rates; COD removal of the applied filter at 0.3m/h filtration rate was observed to be 38.37% while the COD

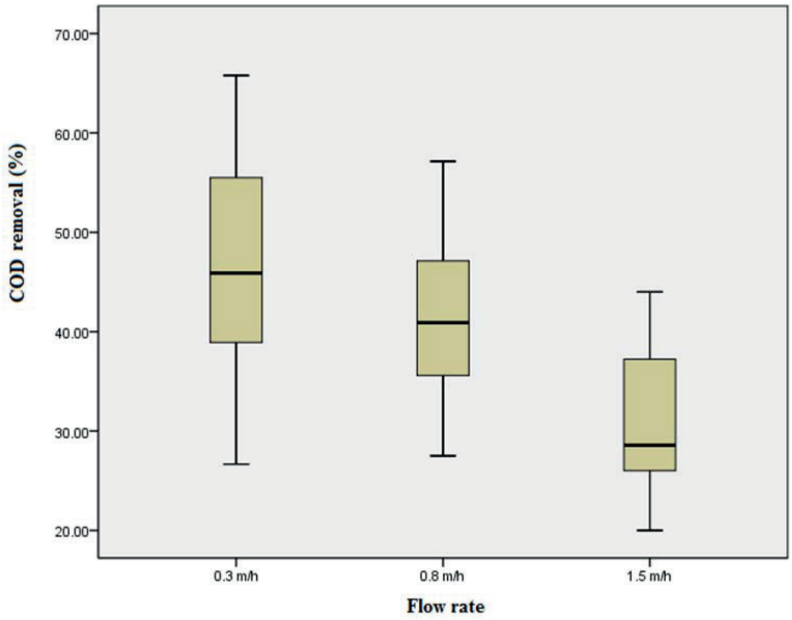

Figure12. COD removals concerning different flow rates (m/h)

Table 8. One-way ANOVA: COD removal versus filtration rates at 3-6mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	765.717	432.852	3.640	0.047
Error	18	2140.762	118.931		
Total	21	36387.637			

R squared = .288 (Adjusted R Squared) = .209

Individual 95% CIs For Mean Based on Pooled St Dev

```
Level    N  Mean  St Dev   -------+---------+---------+---------+--
0.3 m/h  7  46.74  13.34           (--------*-------)
0.8 m/h  7  41.57  10.40       (--------*-------)
1.5 m/h  7  31.29   8.41     (-------*--------)
                         -------+---------+---------+---------+--
                         30        40        50        60
```

Pooled St Dev = 10.91

removal efficiency of the filter was 28.11% at 0.8m/h filtration rate, and at 1.5m/h filtration rate, the COD removal index was found to be 24.128%. The table demonstrates that the highest COD removal efficiency was achieved at 0.3m/h filtration rate while the lowest COD removal occurred at 1.5m/h filtration rate; this might be due to the fact that fine solid particles could have flown into the existing spaces between limestone particles in the filter media. The value of $P<0.05$, in the table, presents that there is a significant difference for COD removal between untreated POME samples and treated POME samples.

A subjective comparison, using one-way analysis of variance (ANOVA), was carried out to determine COD removal indexes of each filter media at various flow rates (as indicated in Figure 14 and Table 10.). Table 10 shows a comparison between COD removal efficiency of 12-20mm filter media at different filtration

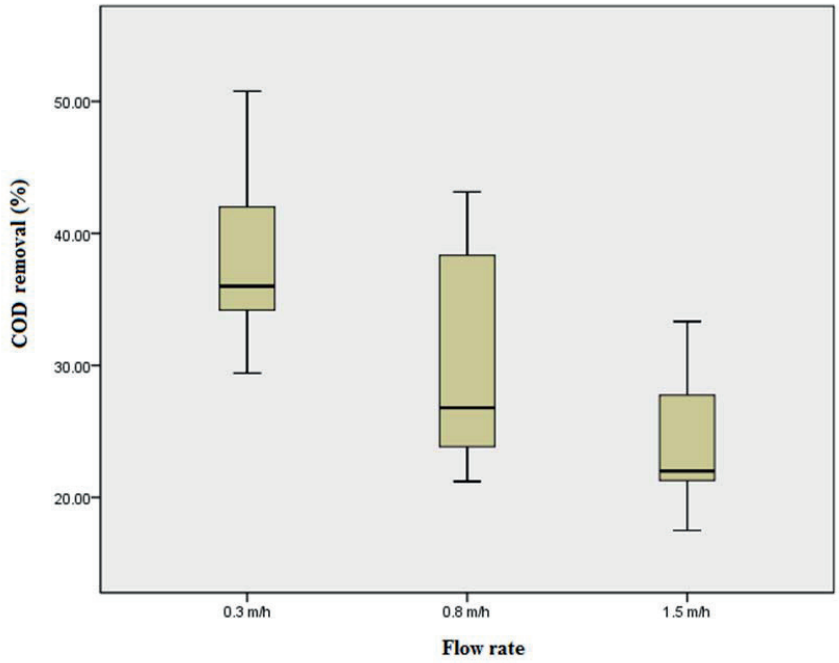

Figure13. COD removals relating to different flow rates at 6-12 mm filter media

Table 9. One-way ANOVA: COD removal versus filtration rates at 6-12mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	683.391	340.696	5.990	0.017
Error	18	1026.368	57.020		
Total	21	22136.402			

R squared = .400 (Adjusted R Squared) = .333

Individual 95% CIs For Mean Based on Pooled St Dev

```
Level    N   Mean   St Dev      ---+---------+---------+---------+------
0.3 m/h  7  38.370  7.434                 (-------*-------)
0.8 m/h  7  28.111  7.093            (-------*-------)
1.5 m/h  7  24.128  5.958       (------*-------)
                           ---+---------+---------+---------+------
                             21.0      28.0      35.0      42.0
```

Pooled St Dev = 6.857

rates. At 0.3 m/h flow rate, the COD removal efficiency of the selected filter media was 28.53% which is found to be the highest compared to other rates. The experiments have shown that COD removal indexes of 12-20 mm filter media at 0.8 m/h and 1.5 m/h flow rates were 22.53% and 18.65%, respectively. According to Table 10, the optimum COD removal was achieved at 0.3m/h filtration rate while the lowest COD removal occurred at the 1.5m/h filtration rate; this might be due to the fact that fine solid particles could have flown into the existing large spaces between limestone particles in the filter media. The value of $P<0.05$, shown in the table, suggests that there is a significant difference between untreated POME samples and treated

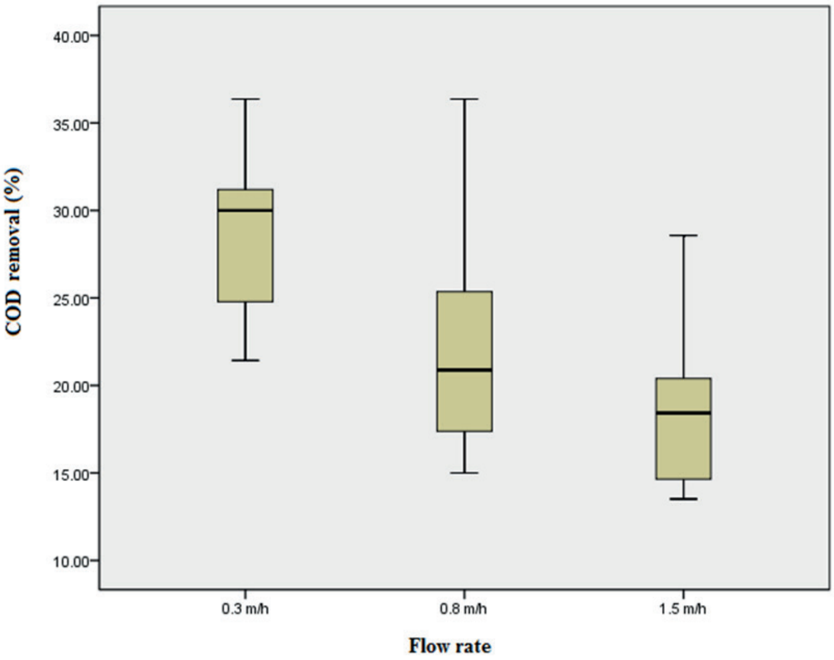

Figure 14. COD removals with respect to different flow rates at 12-20mm filter media

Table 10. One-way ANOVA: COD removal versus filtration rates at 12-20mm size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	346.951	173.475	4.589	0.025
Error	18	680.377	37.799		
Total	21	12369.842			

R squared = .338 (Adjusted R Squared) = .265

```
Individual 95% CIs For Mean Based on Pooled St Dev

Level    N   Mean  St Dev      --+---------+---------+---------+-------
0.3 m/h  7  28.537  5.391                      (---------*---------)
0.8 m/h  7  22.530  7.529               (---------*---------)
1.5 m/h  7  18.656  5.261         (--------*---------)
                            --+---------+---------+---------+-------
                            15.0      20.0      25.0      30.0
Pooled St Dev = 6.149
```

ones, with regards to their COD content. Figure 14 shows total COD removal using boxplots. It demonstrates that the lowest COD removal was achieved in highest flow rate and highest COD removal was obtained in lowest flow rate.

Figure 15 shows comparison of different flow rate for combined size of filter media. It indicated that highest COD removal was obtained in lowest flow rate and the lowest COD removal was achieved in highest flow rate. with other flow rate this due to fewer retention time compare to lowest flow rate Table 11 illustrates the results of the experiment carried out to identify the associations between COD removal efficiency of the combined size filter media and various filtration rates; the highest COD removal

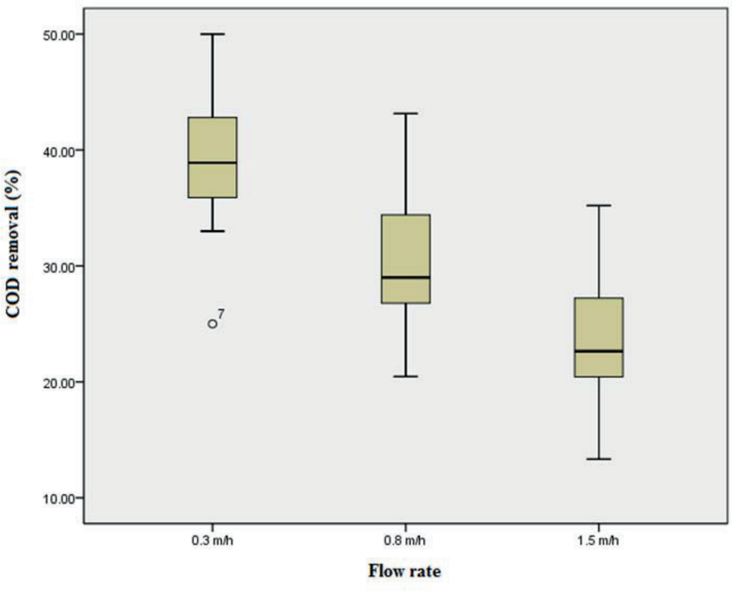

Figure 15. COD removals concerning different flow rates (m/h) at combined size filter media

Table 11. One-way ANOVA: COD removal versus filtration rates at combine size of filter media

Source	DF	SS	MS	F	P
Flow rate	2	735.506	392.753	6.750	0.006
Error	18	1047.402	58.158		
Total	21	22120.689			

R squared = .429 (Adjusted R Squared) = .365

```
Individual 95% CIs For Mean Based on Pooled St Dev

Level    N   Mean  St Dev     ---+---------+---------+---------+------
0.3 m/h  7  38.750  8.006              (--------*-------)
0.8 m/h  7  32.053  6.662          (-------*--------)
1.5 m/h  7  27.274  5.001       (-------*--------)
                              ---+---------+---------+---------+------
                                24.0      30.0      36.0      42.0
```

Pooled St Dev = 6.670

index of the combined size filter was observed at 0.3m/h filtration rate with 38.75% while the lowest COD removal efficiency of the filter was found at 1.5 m/h flow rate with 27.27%. The experiment demonstrated that the optimum COD removal of the combined size filter at 0.8 was found to be 32.05%. The value of P<0.05, shown in Table 11, suggests that there was a significant difference between COD content of untreated POME samples and the treated ones.

Conclusions

The results adopted of horizontal flow roughing filter treating wastewater from POME at different filtration rates showed that when the filter was run at lower flow rates the removal efficiencies had increased due to longer retention time that caused fine solid particles have more time for flown into the existing large spaces between limestone particles in the filter media. Conversely, when the flow rate was increased, removal efficiencies had decrease. Subsequently, it was observed that the performance of the roughing filter using limestone has been effective in reduction of chemical oxygen demand and colour, where the removal was between (59.64%, 19.50%) and (63.43%, 18.47%) the maximum removing achieved in small sized due to larger surface area in small size of lime stone and large of media gave the least removal efficiency. Thus the role of limestone in filtration, particularly in roughing filter has shown a promising result to be used for future undertaking for water and waste water treatment. The roughing filtration using limestone as a filter media for waste water treatment is a simple process and the cost will be reduced in area where limestone are abundant. Therefore, this technique could be used an alternative to other forms of filtration.

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