BSE-502: A STUDY ON THE EFFECTIVENESS OF BIOFILTER BASED ON EFFECTIVE MICROORGANISM (EM) AND EMPTY FRUIT BUNCH (EFB) FOR WATER QUALITY IMPROVEMENT: AN APPLICATION IN OPEN CHANNEL SYSTEM

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Nowadays, clean water resources are reduced due to water pollution problems. The discharge of solid waste and domestic wastewater into the open channel system leads to the surface water problem. This study emphasizes on the utilization of a biofilter system to treat the domestic water before being discharge into river to preserve the sustainability of water bodies. This biofilter is based on the concept of biological treatment involves the use of Effective Microorganism (EM) Mudball and Empty Fruit Bunch (EFB) with other natural occurring materials such as sand & gravel and activated carbon. This compartmentalized system also contains sponge and charcoal. The biofilter is design to be placed in an open drainage system in a residential area where the flow is continuous. Experiment was conducted at Student Residential College (KK3), Universiti Malaysia Pahang where a site scale filtering system was set up to observe the potential of the system in removing pollutants. The experiments were conducted using three increasing quantity variables. The results were analyzed by evaluating the water quality parameters SS, COD, BOD, AN and turbidity in term of their percentages of removal and comparison to Standard A and Standard B of Environmental Quality Act (1974). The results indicated that the biofilter system is most effective in improving the concentration of turbidity and suspended solid where the percentages of removal is as high as 72.42% and 67.31% respectively, followed by COD with 51.63% removal. The performance of the biofilter is also increased with the increasing quantity of filtering media used.

Keywords: *Continuous flow, Domestic wastewater, Effective microorganism, Empty fruit bunch, Mudball*

- **INTRODUCTION**

Water is an essential and irreplaceable element to ensuring the continuance of life. The demand of clean water increases as population grows. Water pollution is a major problem in the global context. It has been suggested that it is the leading worldwide cause of deaths and diseases and that it accounts for the deaths of more than 14,000 people daily [1]. Domestic waste water is one type of point source pollution instead of a factory or city storm drain.

Conventional wastewater treatment method maybe used to remove unwanted nutrient and dissolved heavy metal ions from wastewaters. Other method that was available but costly is chemical oxidation and reduction, ion exchange, electrochemical and treatment. However, these high-technology processes have significant disadvantages, including incomplete metal removal, requirements, such as expensive equipment and monitoring systems, high reagent, energy and generation of toxic sludge or other waste products that require disposal [2]. In the other hand, implementing a centralized waste water treatment system would be costly due to construction and maintenance. Considerately, biological method is considered as an economical solution in terms of construction, operation, maintenance, and pollution.

Biofilter studies and research are increasingly popular nowadays as the world is moving environmentally sustainable development technologies. Ling et al. [3] have constructed a pilot scale biofilter for treatment of greywater. The biofilter "EcoSan" was implemented at Hui Sing Garden, a residential area located 4.5km from downtown Kuching City. Prior to the implementation of EcoSan, black water from the toilets was partially treated in the septic tanks and the outflow was discharged into the storm drains. Studies on the application of biofilter in the treatment of wastewater had been conducted by the researchers from the Faculty of Civil Engineering, Universiti Teknologi Malaysia. The significant of this study is to determine the efficiency of biofilter application for water quality improvement [4]. This study discovered that the wastewater treatment using Biological Active Filter (BAF) indicated a significant improvement in water quality parameter tested. BAF was capable of removing COD, TSS, turbidity and nutrients such as nitrate, phosphate and sulphate from the studied area.

The focus of this study is to cater the domestic waste water problem. Domestic wastewater is produced from kitchens, bathrooms and laundries in residential homes and from various commercial and industrial sources. Nowadays, the effluent from domestic wastewater is highly untreated. Hence, when the effluents flow to the river it will cause water pollution and will affect water quality of the river. Hence, the aim of the study is to improve the water quality at point source before discharge into river. The biofilter is design in horizontal to be installed at drainage system for continuous flow application.

Biofilters has the prospect of an environmental friendly system but most of them are lack of the capability to be executed at site as the biofilter consist of delicate filtering material that cannot hold up to actual environment force. For this reason, the better design, selection of filtering material and proportion of each material is the design focus of proposed biofilter. The purposes of this study are to determine the design criteria and to evaluate the performance of the biofilter system as a wastewater treatment device. Three different quantity variables were used to investigate the effect of using different quantity of filtering media to the performance of the biofilter system.

• MATERIALS AND METHODS

Location of study

The study was conducted at an open drainage system located at student residential college (KK3), Universiti Malaysia Pahang (UMP). The catchment area consists of a cafeteria and hostel that produces domestic effluent that discharged into Sungai Belat as shown in Plate 1.

Plate 1 Location of study

Biofilter Design

Based on the Figure 1(a), the arrangement of biofilter start with larger particle and end with smaller particles. Design issues include the sizing of the biofilter bed which is packing the inlet sections of a biofilter with larger particles can reduce the surface area and increase the porosity, thus avoiding biomass overgrowth and lowering the pressure drop in the inlet section, while packing the biologically less active outlet sections with smaller particles can increase the degradation capacity in those sections and compensate for the reduction of degradation capacity in the inlet sections [5].

Based on Richard Nicolai et al. [6], closed bed biofilter typically have deeper media (61-91 cm or more) to reduce the space needed to achieve the required treatment. The length for this biofilter is 0.97 m which is including the partition of the filtering material. The high is 0.68 m with 0.8 m width. Every partition is 1cm thickness. The length for each material is 15 cm. Figures 1(a) and 1(b) shows the detail dimensions of the biofilter.

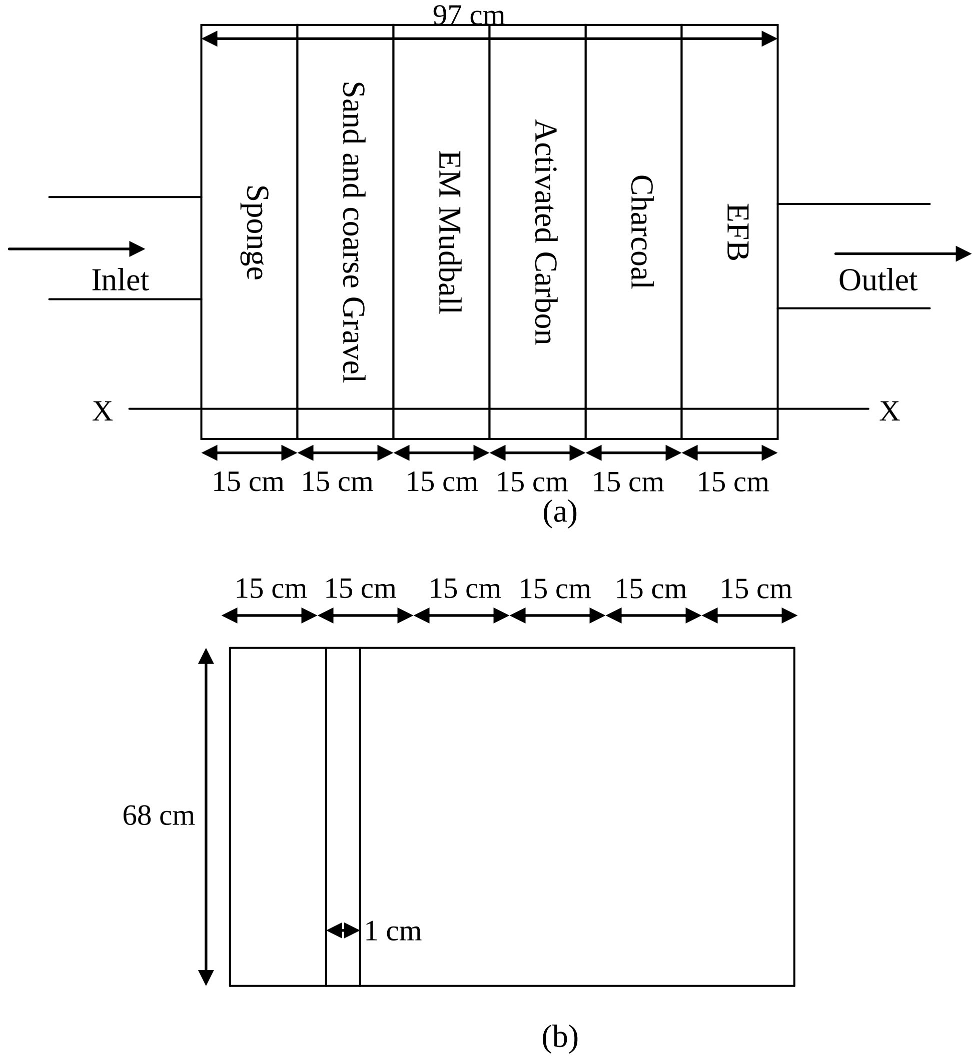


Figure 1 Schematic diagram: (a) Plan View and Arrangements of medium filter, and (b) Side View (Section X-X)

Filtering Media

The main media in the biofilter system are EM (effective microorganism) Mudball and Empty Fruit Bunch (EFB). The other filter media used are sponge, sand and gravel, activated carbon and charcoal. Sponge is functioned to adsorb oil pollutant. The oil will adsorb onto its surface during the treatment. Sand and gravel are used in the system to provide maximum turbidity entrapment. Activated carbon is capable to remove Chemical Oxygen Demand (COD) and suspended solid [7] while charcoal is used to remove odor. The arrangement of the filtering media is illustrated in Figure 1(a) where the treatment starts with sponge, then followed with sand and gravel, EM Mudball, activated carbon, charcoal and EFB.

1. EM Mudball. Effective microorganism contains selected species of microorganisms including predominant populations of lactic acid bacteria and yeasts and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture. Organic materials within wastewater originate from plants, animals or synthetic organic compound, and enter wastewater via a number of routes including human waste, detergents, and industrial sources [8]. EM can be used to solve this problem as it contains various organic acids due to the presence of lactic acid bacteria, which secrete organics acids, enzymes, antioxidants, and metallic chelates [9]. E.M decompose organic matter by converting it to carbon dioxide (CO_2) and methane (CH_4) or use it for growth and reproduction through the mechanism shown in Eq. (1):

$$C_aH_bO_cN_d \rightarrow C_wH_xO_yN_z + CH_4 + CO_2 + H_20 + NH_3 \quad (1)$$

The mud balls used in this study are produced from EM liquid, food waste and clay soil (content ratio 3 litre, 1 kilo and 2 kilo). The final product of mudball is shown in Plate 2.

2. Empty Fruit Bunch (EFB). Oil palm fibres belong to the group of lignoselulosik material, which contain components polimerik as hemiselulosa (20-21%), cellulose (35-40%) and lignin (17-21%), which can be processed to be converted to carbon products through carbonization process. The fibres are suitable as agents for water filtration. EFB is function to removing suspended solid matter contained in water. This EFB will absorb onto its surface during the treatment. The EFB used in this study is shown in Plate 3.

Plate 2 EM Mudball

Plate 3 Empty Fruit Bunch

Experimental Set-up and Flow Mechanism

Plate 4 shows the biofilter setup at site. The biofilter have six compartments and each compartment is filled with filtering material. The biofilter is installed at the sump before the wastewater goes into the river. The biofilter design used the basic concept of water filter where it uses a closed system. Water intake will first run through sponge which filters large materials, then filtered with Empty Fruit Bunch (EFB), followed by mud ball, then chemical reactions by activated carbon, further filtered subsequently by coarse gravel and sand, and lastly run through charcoal to eliminate odor before output to water body.

Plate 4 Biofilter Set-Up

Quantity Variables on Filtering Media

To determine the effect of different quantity of filtering media to the performance of biofilter system, three different quantities are used. The quantity increase by ratio 1:2:3 of each material to get the appropriate data. Table 1 shows the three types of filtering media quantity; QV1, QV2 and QV3 used in this study.

Table 1: Quantity of Variables

Quantity	Quantities					
	Sponge (Packet)	**Sand & Granite (kg)**	**EM Mudball (Pieces)**	**Activated Carbon (kg)**	**Charcoal (kg)**	**EFB (kg)**
QV1	3	10: 5	40	10	5	3
QV2	6	20: 10	80	20	10	6
QV3	9	30: 15	120	30	15	9

Lab Scale Experiment

In 2012, the design of biofilter had been improved to smaller size to fit drainage system for open channel application. The biofilter is proposed to be installed in drain at residential area. To check the capability of the biofilter for that purpose, a lab scale biofilter had been designed as shown in Plate 5(a) and 5(b).

(a) (b)

(b)

Plate 5 Lab-scale biofilter (a) Flow mechanism and (b) Arrangement of filtering media.

- **RESULTS AND DISCUSSION**

The performance of the biofilter system is evaluated in terms of water quality improvement, comparison with Standard A and Standard B of Environmental Quality Act (1974) and removal efficiency. Experiment has been started on 4th October 2010, evaluated five parameters; Suspended Solid (SS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (AN) and turbidity. The result in Figure 2 shows that the concentration of SS decreased from 88 mg/L to 73 mg/L after the treatment with 17% improvement. The high concentration of COD enters the biofilter (1023 mg/L) managed to be improved to 495 mg/L i.e. 52% of removal. However, no improvement recorded for BOD while AN shows 29% improvement in quality of water from 0.42 mg/L to 0.3 mg/L. Turbidity shows a great performance with 72% of removal where the concentration decreased from 97.17 NTU to 26.8 NTU.

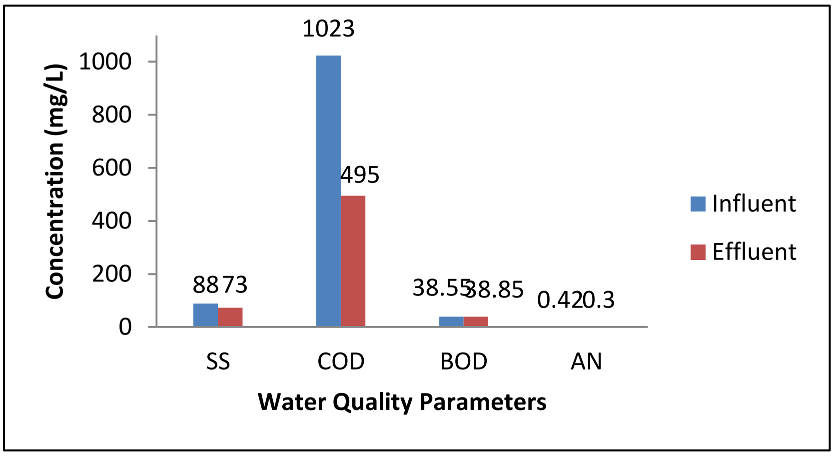


Figure 2: Water Quality Results for Event 1

Data collection on 4th October 2010 will refer to as Event 1 in the next section. Another four data collection taken from 6th October to 14th October 2010 is Event2, Event 3, Event 4 and Event 5 respectively. Each experiment was repeated with different quantities of filtering media as shown in Table 1. The system flows continuously during the data collection, hence the influent for each event is difference depending on the domestic waste generated on that day (event).

Water Quality Improvement and Comparison with Standard A and Standard B of Environmental Quality Act (1974)

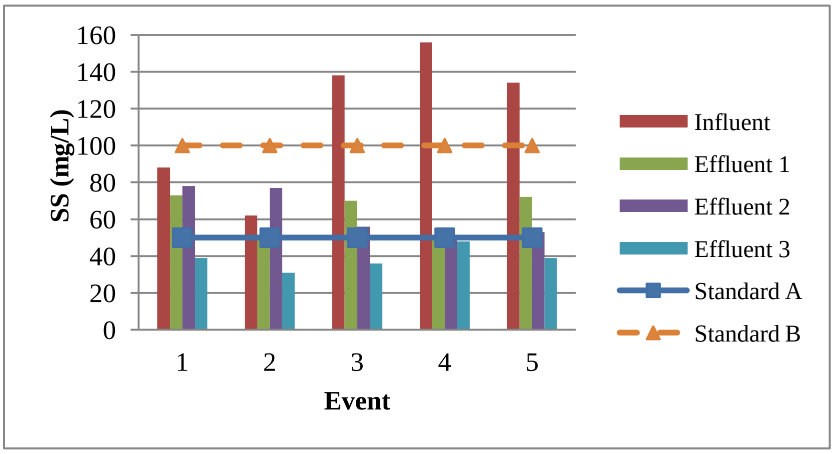
Figure 3(a) to 3(e) are the water quality results for parameters SS, COD, BOD, AN and Turbidity. Effluent 1, Effluent 2 and Effluent 3 refers to the concentration of parameters after treated using three types of quantity variables QV1, QV2, and QV3 respectively.

The performance of biofilter in improving water quality can be observed by comparing the concentration of SS at Influent and Effluent 1 where the treatment is done with initial quantity (QV1). Figure 3(a) shows the concentrations of SS improve at Effluent 1 for all the five events. The highest removal is recorded at Event 4 where the concentration decreased from 156 mg/L to 51 mg/L. For quantity variables evaluation, it can be seen from Figure 3(a) that the values of SS decrease from Effluent 1 to Effluent 2 and decrease again at Effluent 3. There are three influent samples which are Event 3, Event 4, and Event 5 that SS values exceed 100 mg/L which mean it not achieved standard B. However, the values of Effluent 2 are fulfill Standard B after the treatment and all the Effluent 3 managed to comply Standard A. This result proved that the biofilter are capable to improve SS and the concentration of SS decreased with the increasing quantity of filtering media applied.

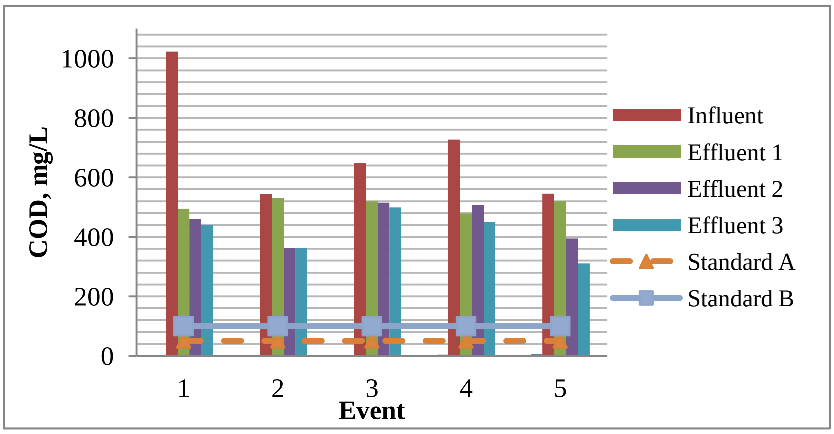
Encouraging results of COD removal can be seen at Figure 3(b), where at Event 1, as high as 1023 mg/L Influent decrease to 495 mg/L after the treatment. The values decreased to 460 mg/L and 440 mg/L at Effluent 2 and Effluent 3 respectively. The same trend of results can be observed at Event 2, Event 3, Event 4 and Event 5 respectively. Despite of that, all the effluents value of discharge water in term of COD concentrations are high thus still not complying both Standard A and Standard B, EQA 1974. From Figure 3(b) we can observe that the concentration of COD enters the system is high, which is in the range 544.33 mg/L to 1022.67 mg/L.

Figure 3(c) shows that the concentration of BOD decreases as the quantity of filtering media increase for all five events. The concentration of BOD decreases from 35.95 mg/L to 35.60 mg/L at Effluent 1. The BOD concentration continues to decrease at Effluent 2 and Effluent 3 to 30.65 mg/L and 29.85 mg/L respectively. The slight improvement also can be observed at Event2, Event 3, Event 4 and Event 5. All the effluent discharge complies Standard B except Event 3.

Results for parameter AN and turbidity are illustrated in Figure 3(d) and Figure 3(e) respectively. Concentration of AN in effluent samples were improved in Event 1, Event 2 and Event 4. Only Effluent 3 fulfill Standard B. Effluent discharges for turbidity for all events were improved and the removal increase with the increasing values of filtering media used.



(a)



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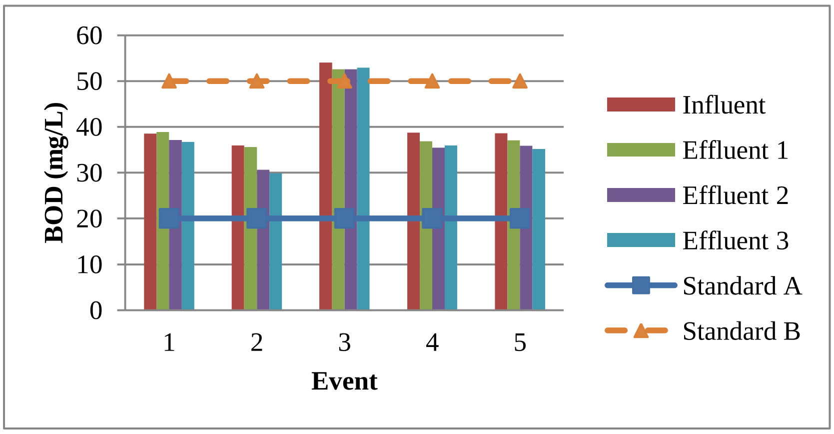

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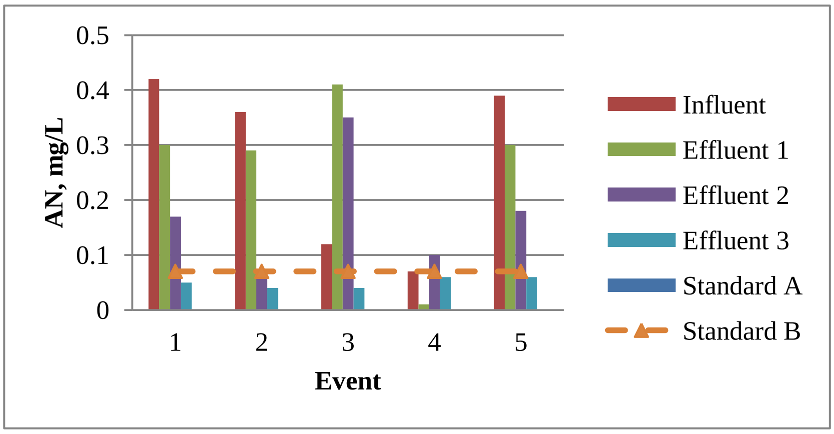
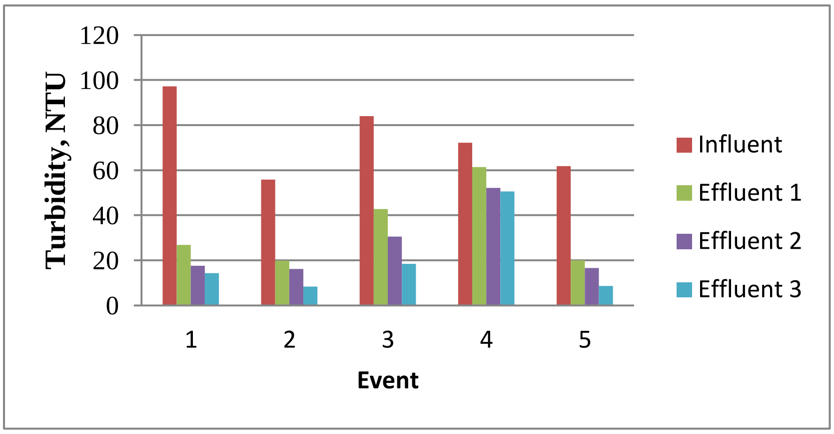


(d)



(e)

Figure 3 Water quality result for (a) SS, (b) COD, (c) BOD, (d) AN and (e) turbidity

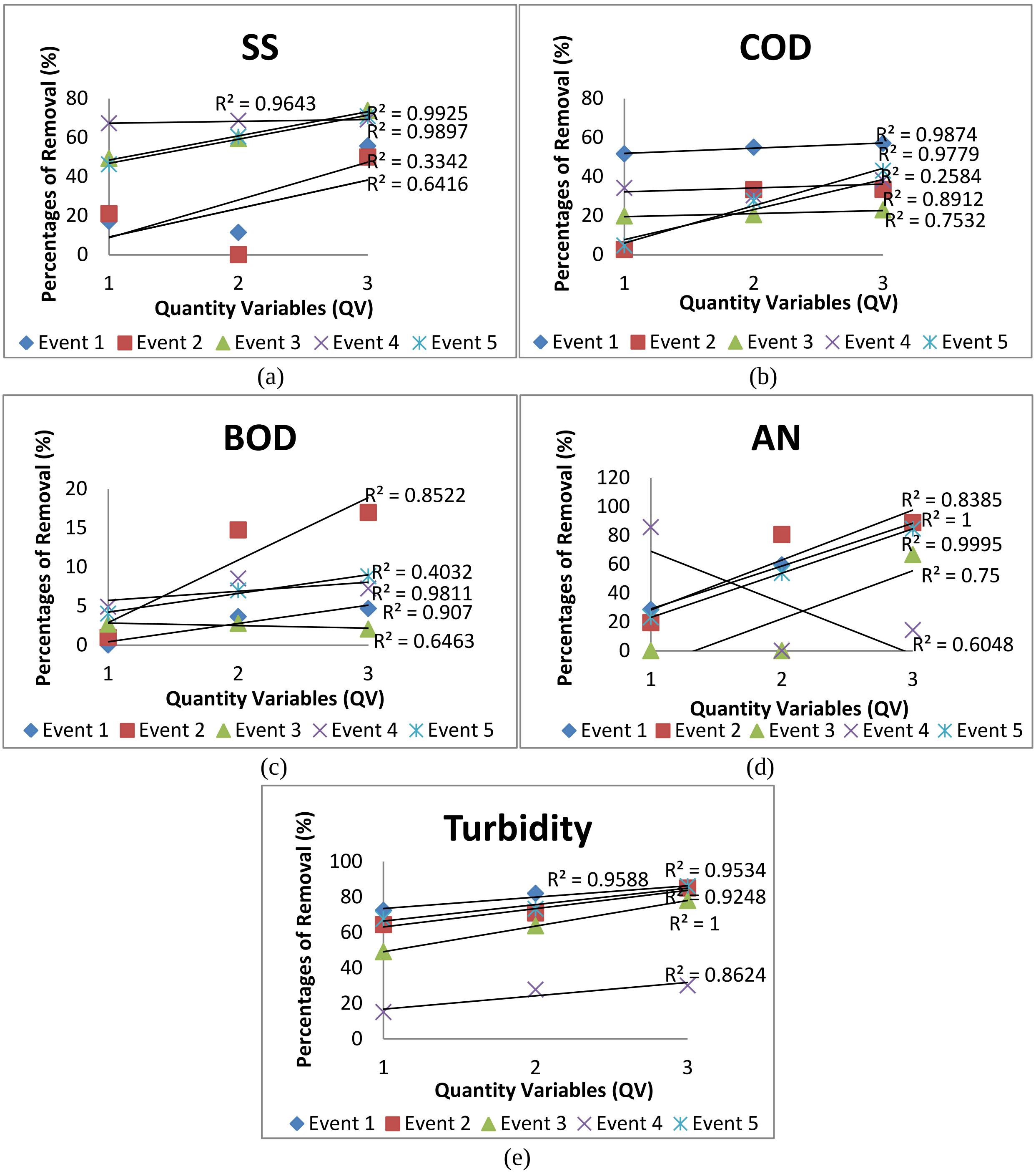


Figure 4 Removal efficiency result for (a) SS, (b) COD, (c) BOD, (d) AN and (e) turbidity

Removal Efficiency

The biofilter system shows encouraging results in terms of removal efficiency for parameters SS, COD, BOD, AN, and Turbidity as shown in Figure 4(a) to 4(e) respectively. The highest removal efficiency for SS is achieved in Event 4 where the biofilter system managed to remove 67.31% of SS when QV1 is used, as illustrated in Figure 4(a). The SS removal increase to 68.59% and 69.23% after treatment with QV2 and QV3 respectively. The removal efficiency increase as the increase value of filtering media applied for all five events. The best fit result is at Event 5 where the R-squared value is 0.992.

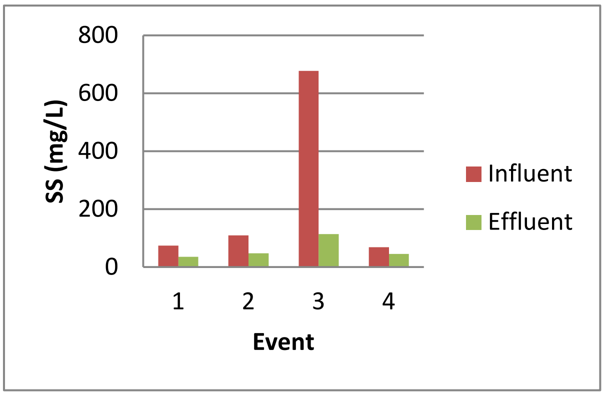
The highest percentage of removal for COD is at Event 1 with 51.63% of removal obtained with QV1, then increase to 55.02% and 57.01% at QV2 and QV3 respectively (Figure 4(b)). A poor performance is detected for parameter BOD where the removal efficiency is the range 0.97% to 4.90% only after treatment with quantity of filtering media QV1. However, the performance of BOD removal increase as the quantity of filtering media increased, as shown in Figure 4(c). The R-squared is more than 0.50 for all events except in Event 4 for both parameters COD and BOD.

The removal efficiency for AN range from 19.44% to 85.71% with QV1. However, no improvement shown in Event 3 and the percentages of removal decrease with increasing quantity variables in Event 4.

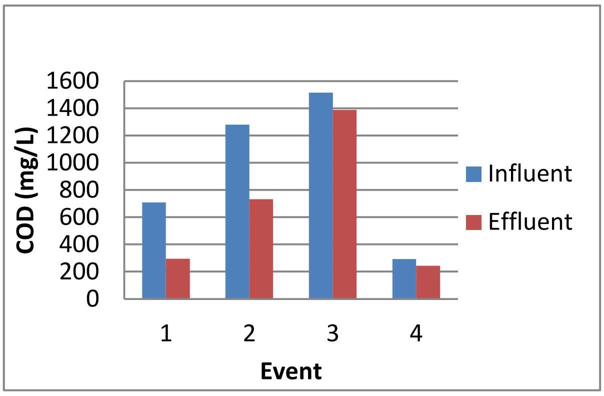
The performance of the biofilter system in improving the turbidity of domestic water is excellent where the removal efficiency range from 15.09% to 72.42% after treatment with initial quantity variable (RV1). The percentages increased up to 85% when the quantity of filtering media increased in Event 1.

Lab Scale Experiment Result

An attempt has been made to improve the design of the biofilter system. The size of the filter is reduced to fit the drainage system in residential area. The lab experiments were conducted at Environmental Laboratory, Faculty Civil Engineering and Earth Resources, UMP from 2nd February 2012 to 18th February 2012 consisting of four numbers of data collections. The water quality results for parameters SS, BOD, COD, AN and turbidity are illustrated in Figure 5(a) to 5(e) respectively, while the removal efficiency results are shown in Table 2.



(a)



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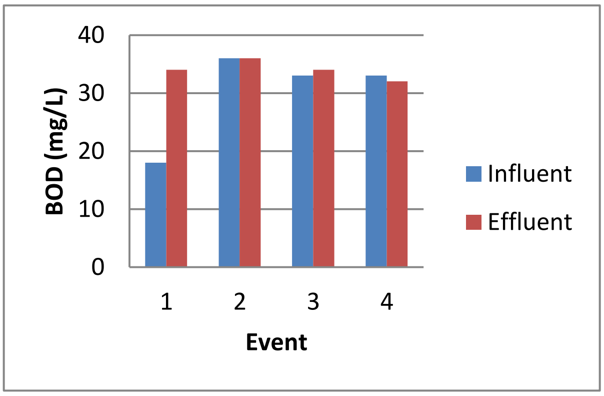

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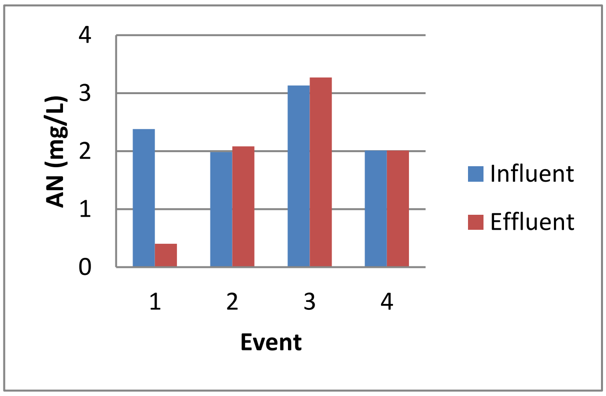

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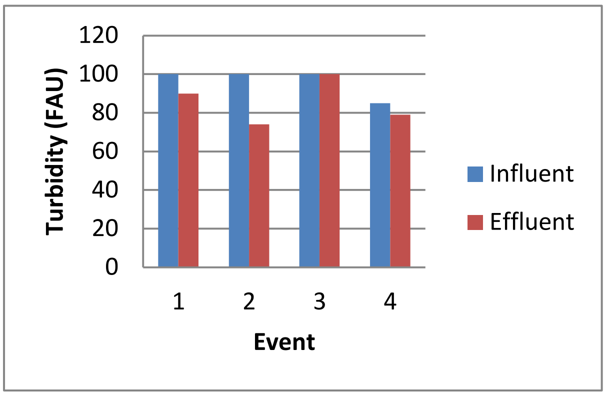

(e)

Figure 5: Water quality result for (a) SS, (b) COD, (c) BOD, (d) AN and (e) turbidity

The water quality improvement can be seen at Figure 5(a), 5(b) and 5(e) for parameter SS, COD, and turbidity respectively. The concentration of BOD increased at Event 1 and Event 3, as shown in Figure 5(c). Same trend of result can be observed for AN where only Event 1 shows an improvement. As can be observed at Table 2, the removal efficiency for SS and COD is in the range 33.8% to 52.7% and 8.4% to 58.2% respectively. Turbidity of domestic water also improved by 7.1% to 26%. However, no percentages of removal recorded for BOD and AN.

Table 2: Removal Efficiency

Event	**Percentages of Removal (%)**				
	BOD	**COD**	**SS**	**An**	**Turbidity**
1	-	58.2	52.7	83.2	10.0
2	-	42.8	56.9	-	26.0
3	-	8.4	83.2	-	-
4	3.0	16.7	33.8	-	7.1

- **CONCLUSIONS**

The site scale biofilter system is found to be effective in improving water quality where for overall the concentration of parameters SS, COD, BOD, AN and turbidity decreased after the treatment. The biofilter is most capable in improving SS and turbidity where the highest removal efficiency achieved is as high as 67.31% and 72.42% respectively. The percentages of removal for COD are in the range 4.7% to 51.63%. Poor performance were shown in AN and BOD improvement. The average removal efficiency recorded for the five events is only 3.7% and 2.4% for AN and BOD respectively.

The performance of biofilter increased with the increase quantity of filtering media used. In Event 1, the removal efficiency of turbidity increased by 34.7% from 26.8 mg/L to 17.51 mg/L when the quantity of filtering media is increased. The concentration improved to 14.36 mg/L with another increment of filtering media. The same trend of increasing performance can be observed at other parameters SS, COD, BOD and AN in all five events. In terms of comparison with Standard A and B of Environmental Quality Act (1974), all Effluent 1 are not complying Standard A and only concentration of SS is below Standard B. However, when the quantity of filtering media used is increased, the concentration of SS at Effluent 3 managed to comply Standard A and B.

Instead of encouraging results shown by the site scale biofilter, more efforts and further research has to be applied to improve the performance of lab scale biofilter. The experiment found that the lab scale biofilter only manage to improve SS, COD and turbidity with highest removal efficiency recorded is 83.2%, 58.2% and 26% respectively.

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