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Biofilter-Potential And Application For The Treatment Of Polluted River Water

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Abstract
One of the ways to reduce the pollution of rivers is to treat wastewater at the source point. This can be accomplished by building a Biologically Active Filter (BAF) at source point of drainage system to treat the wastewater before it is being discharged into the river. The BAF is distinguished from other filtration system because there is a separation between the microorganisms and the treated wastes. The method of filtration is a combination of both physico-chemical adsorption and in-situ bioremediation. A bench scale BAF was setup using natural materials as its filtering media. Indigenous microorganisms from the wastewater with optimum pollutant degradation capabilities have been isolated and added into the BAF, to enhance the biodegradation of wastewater. With its biological regeneration capabilities, this system should serve as a sustainable, effective, and economic filtration method for various industrial wastewater and discharge. Influent and effluent qualities have been evaluated based on physical, chemical and biological parameters.

Key Words : *Biologically Active Filter (BAF), physico-chemical adsorption, in-situ bioremediation, multiple filtering materials.*

Introduction
Modernization and industrialization, added by the increase in the world population, has greatly affected our river system. Downstream industrial processes coupled by various industrial and domestic activities often produce discharges that are harmful and toxic to the environment. About 80% of the water that we use in our everyday life comes from surface waters such as streams and rivers; this makes our rivers an increasingly scarce resource. With the current awareness and emphasis on environmental health hazards and pollution threats, there is a dire need to dispose waste water safely and professionally. In principle, almost all types of wastewater can be treated biologically, if proper analysis and environmental controls are caried out Gavriles (2002). A Biologically Active Filter (BAF) can be build at a source point of a drainage system, to treat the wastewater before it is being discharged into the river. The BAF uses a combination of physico-chemical adsorption and in-situ bioremediation as its filtration method Corbitt (1999). Generally, organic compounds and pollutants will adsorb onto the surfaces of the filtering material, this in turn creates an environment that is suitable for bacterial growth. The bacteria will then biodegrade the pollutants and convert them to microbial biomass and energy. The BAF is distinct from other biological wastewater treatment system because there is a separation between the microorganisms and to treated waste. In the BAF, the microorganisms are held immobilized when they form biofilm on the surfaces of the filtering material. The BAF is an ideal habitat for the propagation of microorganisms due to its relatively high humidity, stable temperature and continual nutrient input (wastewater). The unique feature of the BAF is that it uses granular activated carbon, granite, zeolite, lime stones, coarse and fine sand, fiber sponges, leaves and peanut shells; which are mainly found naturally, relatively cheap and easy to obtain. The usage of naturally occurring microorganisms enables the BAF to operate with minimal maintenance due to its biological regeneration. The BAF has unlimited potential in treating various wastes and discharges by substituting some of the filtering materials or by introducing different types of bacteria that can biodegrade the particular contaminant.

Experiment

A bench scale BAF was setup in the early stage of the experiment. The schematic diagram of BAF was shown in figure 1. After the setup, the experiment was conducted in three phases. The first phase was the isolation and cultivation of dominant biofilm forming bacteria, which were capable of degrading or removing pollutants. These bacteria were further selected and used as seed culture (or inoculums) for the BAF in a process known as bioaugmentation. The second phase involved the analysis and characterization of waste water samples before and after being treated by the BAF. The third phase involves the microbiological analysis whereby dominant types of bacteria isolated from the biofilm formed in the BAF were characterized and identified by their genera.

Biofilter

The bench scale BAF was made of glass. The system consisted mainly of 2 tanks, the sedimentation tank and the compartmentalized Biofilter. The BAF measures at 50 cm X 120 cm X 40 cm and was made up of 12 compartments containing the filtering materials. Schematic diagram of the BAF and its filtering material was shown in figure 1. The filtering materials were chosen based on their ability to adsorb certain pollutants and their large water holding capacity; with no clogging risk and minimal pressure drop. A glass lid was used to cover the compartmentalized filter tank to prevent direct exposure to atmospheric air, thus creating a partial anaerobic condition. In the experiment that followed, wastewater was circulated into the BAF continuously for 7 days. The first 7 days was to propagate biofilm growth and from that onwards the BAF was used in the treatment of polluted river water. The wastewater used in this experiment was taken from a drain flowing into Sungai Melana, Taman Universiti. The flow rate of the BAF was set at 250ml/min.

Selection of Bacteria for bioaugmentation
Isolation and screening of dominant biofilm forming bacteria from raw wastewater was carried out. The isolated bacteria were cultured on nitrate, sulfate and phosphate containing specialized media to select bacteria capable of removing these nutrients. Since the increased concentration of these nutrients may be used as a pollution indicator.

Water Quality Parameter Analysis

Wastewater qualities were analyzed based on physical and chemical parameters. Analysis of BOD,COD, nitrate, phosphate, sulfate, turbidity and ammonia were determined using HACH DR 4000 SPECTROPHOTOMETER. pH was measured using Orion Model 420A pH meter. Total suspended solids were analyzed using Whatman 0.45µm glass fiber filter paper.

Microbiological Analysis

Biofilm was collected from the fiber sponges in every compartment of the BAF. The samples were plated out to determine bacterial population and their dominancy. Dominant bacteria were isolated and grown as pure colonies. Biochemical tests were carried out to determine the types of bacteria present in the BAF. Biofilm dry weight analysis was also carried out.

Results and Discussion

Parameters

The BAF operated under partial anaerobic condition generally improved the influent condition from murky colored with foul odor to a clear and odorless effluent. Formation of slimy layers that may be associated with biofilm was examined microscopically. Besides that, black precipitation found in the BAF was indicative of the presence of sulfate reducing bacteria (SRB). The BAF was also proved to be effective in removing a maximum of 93.6% and 80.0% of TSS and tubidity respecively. A significant decrease in TSS may be implied to organic substances and pollutants being adsorbed onto filtering materials. This in turn will create an environment suitable for the propagation of indigenous microorganisms. These microorganisms will then biodegrade the pollutants as part of their metabolic activities. Consequently, the COD level; which is associated with the organic content of wastewater also showed a maximum removal percentage of 70.5%. The pH of the effluent was monitored and found to be in the range of pH 7 to 7.5.

Nutrient Removal

Apart from the physical parameters, chemical parameters were also evaluated based on the removal percentage of nitrate, phosphate, sulfate and ammonia. The BAF was able to remove nitrates may be facilitated by denitrification process due to the partially anoxic condition created in the filter. This indicates that denitrifying bacteria present in the BAF had reduced nitrate to nitrite and finally to gaseous nitrogen. As for ammonia removal, zeolite inserted in the BAF was capable of adsorbing ammonia (Matsumoto 1997). When the concentration of ammonia in the bulk solution is reduced, the adsorbed ammonia is then released from the zeolite and will then be oxidized by denitrifying bacteria present. The maximum removal of phosphate was only 40.7%. This poor removal suggested that under anaerobic conditions, the presence of polyphosphate bacteria may release phosphate into their surrounding, resulting in the increase of phosphate. In this study, the role of limestones as a phosphorus-adsorbing agent was insignificant in reducing the phosphorus content. As for sulfate removal, an average removal of 63.4% was reported. The removal was mostly due to the BAF being operated under anaerobic condition, which favored the reduction of sulfates by the SRB.

Table 1 : Nutrients Removal

Nutrient (mg/L)	Raw Wastewater	Biofilm	Suspension
Nitrate	35	15.3	29
Phosphate	3	1.83	2.45
Sulfate	80	40.5	78

Role of Bacteria in Wastewater Treatment

To determine whether the microorganisms immobilzed in the BAF or the microorganisms in the bulk solution were responsible for the degradation of pollutants in the wastewater, 2 parallel studies were carried out in which similar water quality parameters were analyzed using the untreated wastewater and wastewater treated using the BAF.

Table 2 : Comparison of final effluent concentration during treatment of wastewater with and without the BAF

Parameter	Without	BAF
BOD(mg/l)	3.4	8.2
COD (mg/l)	580.5	215.5
Turbidity (FAU)	74	22
TSS (mg/l)	79	21
Nitrate (mg/l)	18.9	0.6
Ammonia (mg/l)	5.11	2.97
Sulfate (mg/l)	24.7	15

Table 3: Comparison between BAF with Standard B (DOE)

Parameter	Influent	Effluent	Standard B
COD(ppm)	1075.5	215.5	100
TSS (ppm)	93	21	100
Cu (ppm)	0.019	0.011	1
Pb (ppm)	0.012	0.001	0.5
pH	7.25-7.39	7.24-7.48	5.0-9.0

The results proves that the microorganisms immobilized in the BAF are responsible for the major removal of pollutants in the wastewater compared to the indigenous microorganisms naturally present in the bulk solution.

Microbiological Analysis

For the microbiological analysis, the dominant bacteria in each compartment were determined using biochemical tests. The results showed that the dominant bacteria consisted of *Pseudomonas sp*, *Bacillus sp*, *Aeromonas sp*, *Actinobacillus sp* and *Moraxella sp*. These results also demonstrated that the bioaugmentation process has been proved successful in increasing selected bacteria such as those of *Pseudomonas sp* and *Moraxella sp*.

Conclusion

It may be concluded that the BAF, is capable of removing COD, BOD, turbidity, TSS and nutrients such as nitrates, phosphates and sulfates from the drainage system studied. Although it is impossible to remove the pollutants totally, this wastewater treatment system was successful in minimizing the level of pollutants released into the river system. This system is also capable of functioning for a long period of time with minimal maintenance due to its biological regeneration. The BAF can be very useful equipment in various industries due to its compactness and efficiency for biological purification, their good integration in the environment, their low energy consumption and sludge production and the fact they do not need secondary clarifiers (Jacob *et al.* 1996). The BAF is indeed a sustainable technology ; as building a sustainable future has been a great challenge today, this new innovation may improve the quality of the enviorment by means of practicing efficient and quality waste management system.

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Close up view of the BAF and its filtering material

The Bench Scale BAF setup in the lab. Sedimentation tank is situated at the sight hand casher