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Biological Nutrients and Organic Removal from Water Pollutants by Using Biofilm Reactor

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Abstract

As the revolution industry has many benefits that make the human life easy and developed; however, there are drawbacks come from sending the waste industry to water rivers. Removing of nutrients and organic pollutants from pollutant water has become an important issue due to the detrimental impact of these components on the receiving bodies. Therefore, the aim of this study is determine the percentage removal of the biofilm come from these pollutants by using the technology of Biofilm reactor system. An effective nutrient and organic pollutants have to be removed from pollutant water at different hydraulic retention time (HRT) (4, 6, and 2 hours). Granular Activated Carbon (GAC) has been used in this treatment which has promising prospects in terms of achieving high nutrient removal efficiency by reducing the operating cost. Biofilm reactor unites were installed at the engineering faculty, in UKM university campus, of which were connected with water polluted river (Langat river). The results show that the maximum removal percentages were 82.47% for COD, 83.47% for NO_3-N, 91.21% for NH_3-N and 82.58% for TSS. Biofilm reactor system was operated for 55 days in the continuous flow process. As a result of this it can be concluded that the biofilm reactor has efficient removal percentage for nutrients and organic pollutants from pollutant water.

Keywords: Nutrients; organic pollutants; biofilm reactor (BR); granular activated carbon (GAC).

1. Introduction

Biofilm Reactor (BR) is now considered as one of the best ways to deal with water and wastewater treatment. Presently, on a global scale, an estimation of more than 500 large-scale wastewater treatment plants, reportedly situated in 50 different nations, are in operation by means of the BR processes. With an increasing awareness of health issues around the globe, reportedly resulting from trace pollutants, a water treatment system which is more efficient and economical than the conventional system is now considered more than necessary. A growing interest in BR technology has recently been observed in the field of wastewater treatment owing to some edge it is believed to have over the conventional system, namely higher capacity, higher efficiency and small footprints. Besides, it is also capable of withstanding some of the challenges posed by the wastewater industry such as retrofitting the old treatment plants, producing less sludge resulting from high biomass retention time, minimizing process complexities and operators, minimizing the need for backwashing, and so forth. BR is a process in which, the flow is ongoing and relatively higher concentration of active biomass intended for biological treatment, can be maintained without having to increase the reactor's size. Interestingly, this system is mainly supported by aeration along with some specially designed carriers,which serve to provide a large surface area for the growth of bacteria [1]. The bioreactor helps provide a more conducive environment for the microorganisms, which serve to completely remove and convert the harmful constituents from the wastewater, to grow. Both the aeration and carrier filling rate equally play significant roles in providing treatments at a more efficient level [2,3] have reported in their study that the biofilm carrier is capable of accommodating BR of up to 70% of the reactor's effective volume, which therefore minimizes the footprint and may facilitate the movement of carriers. Notwithstanding, experiences in other contexts have produced evidences to the contrary. There were cases in which, it had been proven that mixing efficiency may decrease at relatively higher percentage of fills [4], and the performance efficiency of the reactor may vary depending on the types of biofilm carrier being utilized [5]. Considering both the significant influence of carrier packing rate, aeration rate and the hydraulic retention time (HRT) on the organics, and their capacity of increasing the cost and energy, it is of utmost importance to carry out a systematic investigation into the effects of carrier filling rates, aeration rates and HRTs on the treatment efficiency in an ongoing BR system.

As they grow, the microorganisms consume nutrient and organic constituents contained in wastewater. In the event of these microorganisms being placed in more conducive surfaces, it may culminate in their rapid growth; hence they facilitate the wastewater treatment process effectively. In this regard, among the suitable surfaces which have reportedly been identified thus far are wood, sand, mud or plastic materials. Besides, there are other factors which come into play in relation to their growth such as the percentage of carrier filling rate, aeration rate, etc. Despite a plethora of published research has thus far been observed in the literature in relation to using BR, virtually no specific research, to the knowledge of the researches has thus far been found looking into the effects of carrier filling rate and HRT on the removal of nutrients and organics from municipal wastewater. The present study was therefore set out to carry out a series of lab experimental investigations into the effects of the carrier filling ratio, aeration ratio and HRT on the performance of BR.

The activated sludge has over hundred years or so gained enormous popularity of being considered one of the most economical and widely used methods in biological treatment of wastewater. However, it is noteworthy that massive modifications have also been made in attempts to meet better effluent quality requirements along with more stringent regulations put in place for discharging treated wastewater into the natural water bodies. On a global scale, both policymakers and industry players now prefer compact wastewater treatment plants which are capable of producing effluents of higher standards in the presence of smaller footprints and, at the same time, minimizing waste. This is more so in densely populated areas at which, the space available for these treatment plants is limited [6]. Biological processes, especially the BR is considered one of the advanced treatment processes of wastewater treatment, which offers a compact treatment plant design to help overcome the drawbacks of GAC process and thus culminate in higher quality effluents even in relatively smaller footprints.

It should be noted that BR has widely been employed in full-scale treatment of both municipal and industrial wastewater [7]. Biomass carriers, which are specially designed with highly specific surface area, surface roughness, higher durability, strength and porosity, are one of the significant parts of BR. It has been reported that in BR system, the biofilm helps retain a higher biomass age, which is believed to provide conducive environments specifically, the bacteria for which, the growth rate is relatively slower (i.e., nitrifiers) [1]. Various studies in different contexts looking into removal from wastewater using BR, carried out to date discovered that the BR technique is very useful as it reportedly helps meet the stringent rules in relation to nutrient discharge limits. In BR technique, it is notably possible to carry out both nitrification and denitrification simultaneously in the continuous aerated reactor by means of bringing in biofilm carrier to the reactor. In this regard, [5] carried out an experimental study looking into BR using Polyurethane form (PU) cubes in varying sizes representing carrier and the researcher managed to achieve a 100% phosphorus removal. In a similar vein, [8] attempted to investigate the performance of the PU foam and biodegradable polymers including poly capro lactone (PCL) as biofilm carriers separately and the findings re-

vealed that the BR filled with PU carriers helped effective removal of ammonium (at 65% removal efficiency) whereas BR filled with biodegradable PCL carriers facilitated TN removal (at 58% removal efficiency).
BR system is now widely used for the wastewater treatment owing to the massive improvements which have been made over the years with regards to its membrane stability and cost effectiveness. Notwithstanding, findings from research in various contexts indicate that GAC, which is specially designed for media in the BR, is proven to be one of the best options available to help keep these problems at bay and enhance the nutrient removal efficiency. It is noteworthy that the use of media for attached growth in the BR system has now become more popular in the field of biological nutrient removal from different types of wastewater. In relation, [9] carried out an experiment by means of both suspended and attached growth BR for nutrient removal from synthetic wastewater and they argued that the attached growth BR may have higher efficiency for the nutrient removal in comparison with the suspended growth BR.
Malaysia has recently indicated a vested interest for BR system to carry out treatment of water pollutants. The present study is considered an experimental study, in which, the effectiveness of river water was looked into. One of the aims of the study was to identify the percentage of removal of BR system for an effective removal of nutrient and organic pollutants from water pollutant at varying hydraulic retention time (HRT) by means of Granular Activated Carbon (GAC).

2. Material and Methods

2.1. Site description

The polluted river water (Langat River) is located opposite to the building of Engineering Faculty, which is on the campus of the University Kebangsaan Malaysia "UKM". The water sources of the river come from four streams, which are discharged into the river, from engineering building streams which consist of the faculty water along with rain water which is available during rainy season, canteen stream, Fakulti Teknologi Sains Maklumat (FTSM) stream, and finally, the small river stream (see Figure 2.1). The river has rock screening to filtrate a part of water which comes

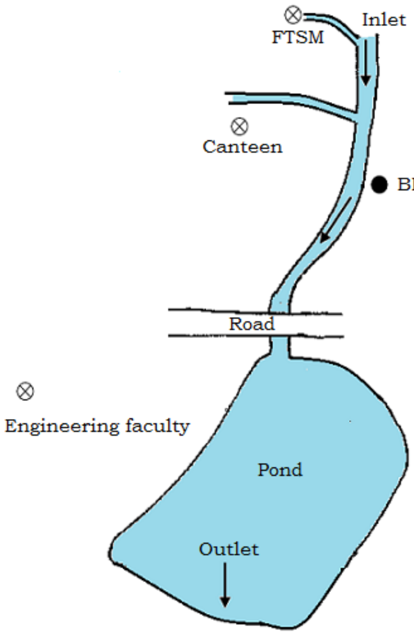

Figure 2.1: Sketch showing BR and inlet, outlet points of Pollutant River in UKM campus.

from the canteen, FTSM stream and small river. The water which originates from the canteen has two sources; the first source is resulting from hand washing and floor cleaning, going direct to the pond without treatment, and the second source resulting from cooking and dish washing which go to the point treatment through an underground sewer. The main pollutants are canteen and Engineering Laboratory as they contain a big amount of COD especially the stream which comes from Engineering Faculty. The surface water, which is collected in the parking heads to the river as well.

2.2. Experimental

In this research, a 290 litters BR treatment method was employed to treat the polluted river (Langat River). Figure 2.2 shows the BR for thewater pollutant treatment system, the process was designed as a biofilm reactor. Certain amount of the water, which was extracted from the Langat River, was fed into the BR and the same amount of the liquid from the BR was drained before the feeding. The operating steps are described in the following:
The water sample for the present study was collected from the polluted Langat River. Every day,

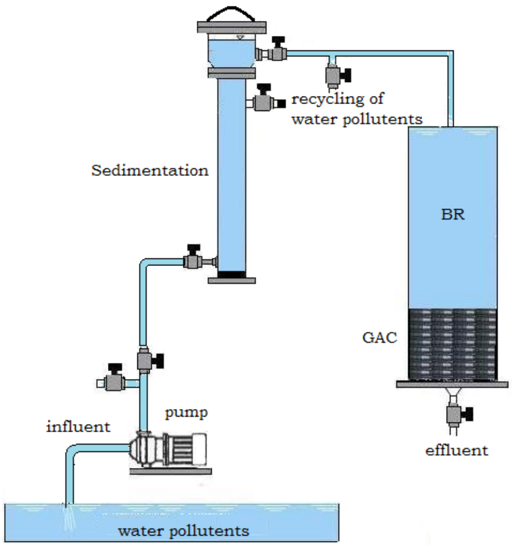

Figure 2.2: Scheme of BR system for water pollutant treatment.

two samples, i.e., A and B were collected. Sample A (input) was taken before entering the BR. On the other hand, Sample B (output) was taken after entering the BR for hydraulic retention times (HRT) (4, 6, and 2 hours). Certain quantity of the liquid had to remain within the BR.

2.3. Biofilm used

Large specific surface area is reportedly a major factor for GAC being used in this study because of its empirically-proven efficiency in removing organic matter in adsorption. Exploitation activities in the colonies of microorganisms GAC particles without the need for regeneration have been widely used in many treatment plants. Activated carbon granules particle in this study used ranged from 0.25 mm-2.00 mm with a mean diameter of 1.30 mm and a particle density of 1200 kg/m^3. It was used as an adsorbent and supporting media material for biofilm growth.

2.4. Sampling parameters

A total of four water quality parameters were studied, namely COD, NO_3-N, NH_3-N and TSS, which entered the water body of the Langat River to biofilm, both before and after treatment. For COD, NO_3-N, NH_3-N and TSS, samplings were carried out two times for a period about two month.

Table 3.1: Labels for each HRT for figures.

label	HRT
Part A	2 hours
Part B	4 hours
Part C	6 hours

2.5. Sample analysis

The inflow sample and outflow sample were analyzed. Samples were filtered by filter paper (0.45 µm) and the nitrogen nutrient concentration was analyzed by means of a HACH spectrophotometer while the COD values were measured by means of the HACH reactor digestion method.

Collected samples were immediately sent to the laboratory for analysis on a daily basis. Both weather and the surrounding physical environments were recorded. The sampling strategy employed to investigate the chemical quality in Langat River and streams employed either a single sample, or a series of samples which were collected simultaneously. However it is noteworthy that they have to be representative of the entire flow for the constituent of interest at the sampling point for that specific instant. The chemical analyses were administered in the analysis laboratory which is located at the Environmental laboratory in UKM.

3. Results and Discussion

In this study, the reactor was operated for 55 days continuously with an ambient temperature (30 ± 2 °C). This study involved 4, 6, and 2 HRT which aimed to remove the NH_3-N, COD, NO_3-N and TSS by means of demystification process at the same temperature. The results of this experiment are delineated in the following tables as to ease comprehension.

3.1. COD removal

When this operation was carried out, the daily variations of both influent and effluent concentration of heavy metal and inorganic contaminant was looked into. Referring to part A in Figure 3.1, the range of influent and effluent concentration of COD was at 55 to 99 mg/L and 14 to 37 mg/L, respectively, for which, the average COD removal was 69.45%. The maximum removal of COD was 82.47% during the course of the study.

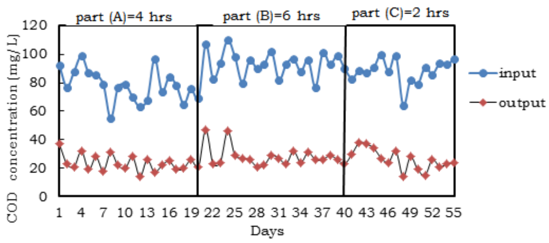

Figure 3.1: COD removal for different HRT.

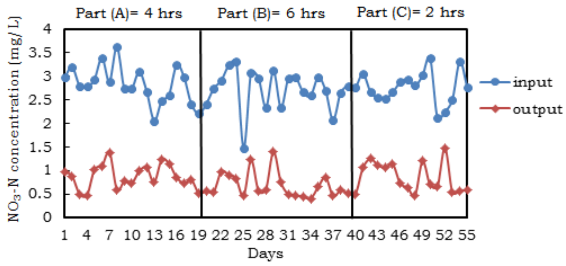

Figure 3.2: Nitrate-Nitrogen removals for different HRT.

As illustrated in part B-C of Figure 3.1, the range of influent and effluent COD concentration was reportedly 77 to 110 mg/L, 21 to 47 mg/L and 64 to 100 mg/L, 14 to 38 mg/L for which, the average removal was reported at 70.12%, and 70.40%, respectively. The maximum removal recorded were 76.67%, 83.52% during the course of the study.

3.2. Nitrate-nitrogen (NO_3-N) removal

The changes in nitrate concentration within the bioreactor at different HRT are delineated in part A to C. At HRT of 4, 6 and 2 hours, significant differences in the NO_3-N removal were observed throughout the experimental period. Denitrification is the reduction of nitrate to nitrogen gas by means of certain heterotrophic bacteria. As can be seen in part A, the range of both influent and effluent concentration of nitrate was observed at 2.06 to 3.63 mg/L and 0.48 to 1.39 mg/L, respectively for which, the average nitrate removal was at 69.23%. The maximum removal of NO_3-N was observed at 83.47 % at 4 hours HRT. From part B of Figure 3.2, it can be seen that at 6 hours, the range of influent and effluent concentration of nitrate was observed at 1.48 to 3.33 mg/L and 0.41 to 0.98 mg/L, respectively for which, the average nitrate removal was at 75.08%. The maximum and minimum removal of NO3-N was from 84.23% to 55.13%, respectively when the HRT was 2 hours. The range of influent and effluent concentration of nitrate was 2.11 to 3.39 mg/L and 0.47 to 1.48 mg/L, respectively for which, the average nitrate removal was at 67.24%. The maximum removal of NO_3-N was at 83.27% (See part C of Figure 3.2).

3.3. Ammonia-nitrogen (NH_3-N) removal

The influent and effluent concentrations of NH_3-N for different HRTs are presented in the following

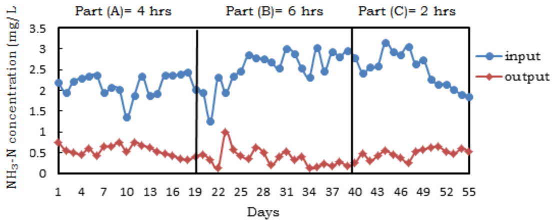

Figure 3.3: NH_3-N removals for different HRT.

figure. The maximum ammonia removal during this study period was 86.48 at 4 HRT. From Figure 3.3 part A, the range of influent and effluent concentrations of NH_3-N for different HRTs was 1.37 to 2.44 mg/L and 0.33 to 0.76 mg/L, respectively for which, the average NH_3-N removal was 73.41%. On the other hand, the removal efficiency was observed to decrease as the HRT kept increasing from 4 to 6 hours.
The range of influent and effluent concentration of ammonia-N was 1.27 to 2.97 mg/L and 3.03 to 0.63 mg/L, respectively for which, the average NH_3-N removal was 85.03% at 6 HRT. (See part B in Figure 3.3). During the 4 hours HRT, the maximum NH_3-N removal was 94.72%. From Figure 3.3 part C, throughout the 2 hours, it was discovered that the range of influent and effluent concentration of ammonia-N was 1.86 to 3.16 mg/L and 0.27 to 0.65 mg/L, respectively. The average NH_3-N removal was 79.27% and the maximum removal was 91.21 %, as can be seen from Figure 3.3 part C.

3.4. TSS removal

Variations on a daily basis in relation to influent and effluent concentration of inorganic contaminant and suspended solids were studied during

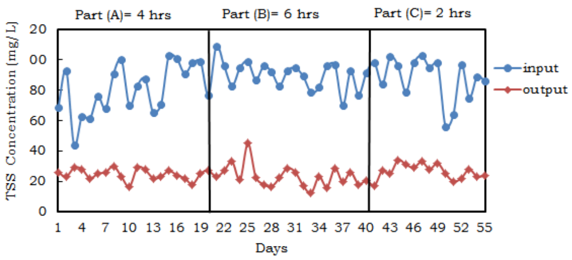

Figure 3.4: TSS removals for different HRT.

the course of the operation. From part A in Figure 3.4, the range of influent and effluent concentration of TSS was 44 to 103 mg/L and 16.4 to 30 mg/L, respectively, for which, the average TSS removal was 67.74%. The maximum removal of TSS was 81.64% throughout the study period. From part B in Figure 3.4, it can be seen that the range of influent and effluent concentration of TSS was at 70 to 109 mg/L and 12.2 to 45 mg/L, respectively, for which, the average TSS removal was at 74.25%. The maximum removal of TSS was at 84.46% during the course of the present study. From part C in Figure 3.4, the range of influent and effluent concentration of TSS was at 56 to 103 mg/L and 17.07 to 34 mg/L, respectively, for which, the average TSS removal was 69.19%. The maximum removal of TSS was 82.58% throughout the course of the study.

4. Conclusion

This research was focused on the treatment of pollutant river water (Langat River) by means of media BR system over a time period of 55 days in a continuous flow process. From this process, the polluted Langat River water was used and the treatments performed were the elimination of organic matter (COD), nutrients of nitrogen (ammonia and nitrate) and total suspended solids (TSS) at different hydraulic retention time (HRT) (i.e., 4, 6, and 2 hours). The results revealed that the BR is effective in removing COD and (NH_3-N) to effectively treat Langat River. In this regard, the performance study on laboratory scale BR for treating Langat River revealed good results and hence Langat River may successfully be treated with BR.

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