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Research paper



Treatment of Domestic Wastewater with Fixed Bed Biofilm Reactor

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Abstract

Fixed bed biofilm reactors were evaluated with three different arrangements of bio-balls. The performance of different arrangements was evaluated based on chemical oxygen demand (COD), total suspended solid (TSS) and mixed liquor suspended solid (MLSS). The three rectors were fabricated and operated in lab scale model with real domestic wastewater. Considering the TSS removal efficiency, arrangement one was the best followed by arrangement two and arrangement three. While for COD, arrangement one recorded the highest removal efficiency followed by arrangement two and column. The average COD concentration for arrangement one was 23 while for arrangement two and arrangement three was 25 and 36 mg/l respectively. The overall average effluent TSS concentrations for the arrangement one, two and three were 25, 32 and 45 mg/l respectively. TSS and COD removal was almost the same for arrangement one and arrangement two but arrangement one has the highest among them, and all removal is acceptable under Malaysian standards. Besides that, all the three arrangements have the differences in terms of maintenance and installation. There was no clogging occurred in all the three arrangements.

Keywords: *Fixed Bed Biofilm Reactor, Attached Growth Process, Clogging.*

1. Introduction

The attached growth process is an alternative to the widely used suspended growth activated sludge process in wastewater treatment which is using biofilms that grow attached to a bio-carrier. Biofilm develops on many types of surfaces in contact with water. Multi-layered bacterial or fungal cell clusters embedded in an amorphous extracellular material composed of exopolysaccharides (EPS) of bacterial origin is called biofilm. EPS will stick the cells firmly to the surface and to each other [1]. Many different types of biofilm reactors are being used to treat municipal wastes as well as industrial wastes. Zaitsev et.al studied the removal of ammonium and nitrate using fixed bed biofilm reactor. Source of the water is from cold inorganic mine. They introduced 200 plastic carrier disks and 50 g of lignite coke to support biofilm growth. The results showed that this process achieve ammonium removal of 98 % at the load of 0.33 g NH_4^+-N/ m^2/ d. Besides that, 95 % of nitrate removal was obtained at the load of 0.91 kg NO_3-N/ m^3/d [2]. Besides that, winery wastewater treatment was studied by Andreottola et.al using a fixed bed biofilm reactor. They achieved only 91 % of COD removal efficiency because of unbiodegradable soluble fraction of COD which cannot be removed by biological or settling process. They have mentioned that backwashing was not required due to the empty space offered by plastic carries [3]. Choi et.al studied the effect of backwashing on perchlorate removal in fixed bed biofilm reactors. Glass beads were used as support media for biofilm growth in their study. Evaluation of perchlorate removal was at different DO concentration. They mentioned that the immediate effect of backwashing on perchlorate removal depended on influent DO concentration. Daily backwashing had a positive influence on perchlorate reduction while daily strong backwashing resulted in decrease in removal of perchlorate with selected DO concentration [4]. Moreover, Alaves et.al studied the effect of lipids and oleic acid on biomass development in anaerobic fixed bed reactors. They studied using two different reactors to treat synthetic dairy wastes of different lipid content. Both reactors were fed with oleic acid as the sole carbon source. They found out that the biofilm built up in the presence of lipids was thinner but more resistant to the presence of oleic acid then the biofilm formed in the absence of lipids. The biofilm formed with absence of lipids lost 53 % of its solids after contacting with oleic acid [5]. Gupta et.al used fixed-bed bioreactors to remove some heavy metal ions. Activated carbon developed from fertilizer waste was used for the removal of Hg^{2+}, Cr^{6+}, Pb^{2+} and Cu^{2+} [6]. Moreover, anaerobic treatment of winery wastewater treatment was carried out in fixed bed reactors. Three reactors with varying size and specific surface area of media was investigated. It was found that the efficiency of the reactors increased with decrease in size and increase in specific surface area of the media [7]. Bio-carriers in fixed bed bioreactors are the most important element to boost the efficiency of treatment process. The aim of the study by Guo et.al was to investigate the performance of sponge as bio-carrier for attached growth biomass in fixed sponge bio-filter to treat a high synthetic wastewater. The results shows that highest nutrient removal was achieved with 1 cm thickness sponge carriers. The 1 cm thickness sponge exhibited 51.7 % of total nitrogen removal and 89.1 % of total phosphorus removal [8]. Besides that, polyethylene plastic media were used in

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a study to purify river water and it achieved 58 % of COD removal, 80 % of TSS removal and 75 % of ammoniac hydrogen removal [9]. Many different bio-carriers were used in different studies related to fixed bed biofilm reactors. Bio-carriers are playing a major role in attached growth process. Clogging is the main problem in attached growth process. Clogging occurs when excess biofilm collects in the void space of bio-carriers. Uncontrolled growth of biomass leads to an accumulation in the bio-carriers. The further development of biofilm stops when there is clogging. Organic loading rate, aeration, and hydraulic retention time can be the reasons for the clogging problem. Biofilm growth can be controlled with the above-mentioned reasons. This can reduce the chances of clogging.

The purpose of this study is to evaluate the performance of fixed bed biofilm reactors with three different arrangements of bio-balls. The performance of different arrangements will be evaluated based on chemical oxygen demand (COD) test, total suspended solid (TSS) test and mixed liquor suspended solid (MLSS) test.

2. Research Methodology

2.1. Reactor Operation

Fiber-reinforced plastic tank were used as reactor tank. There were three different tanks with three different bio-balls arrangements set up as shown in Figure 1. The dimension of the tank is 1.2 m (length) x 1.2 m (width) x 2 m (height). Fin ball were used as bio-carriers in this study. It has inner diameter of 7.5 cm and outer diameter of 8.5 cm with 0.5 cm of fins around it. The source of the wastewater for the study was from a local sewage treatment plant. From the sewage treatment plant intake, the influent was pumped into the tank. Water pumps were installed inside the sewage treatment plant intake to pump the influent to the three tanks. The submersible pump has maximum flow rate up to 6000 l/h. Aeration was introduced to the tanks to provide oxygen to feed the microorganism in the tank. By doing this, the attached growth developed in the tanks to have better performance. Air pump with pressure of 0.046 MPa with output of 35 L/min were used for the aeration. The diffusers were positioned at bottom of the tanks to provide oxygen for the microorganism's growth and agitate the sludge continuously. Round shape air stone diffusers were used. Hydraulic retention time (HRT) of 6 hours was adopted for this study. A timer was used and set to operate the water pump for 12 minutes every three hours to maintain 6 hours of HRT.

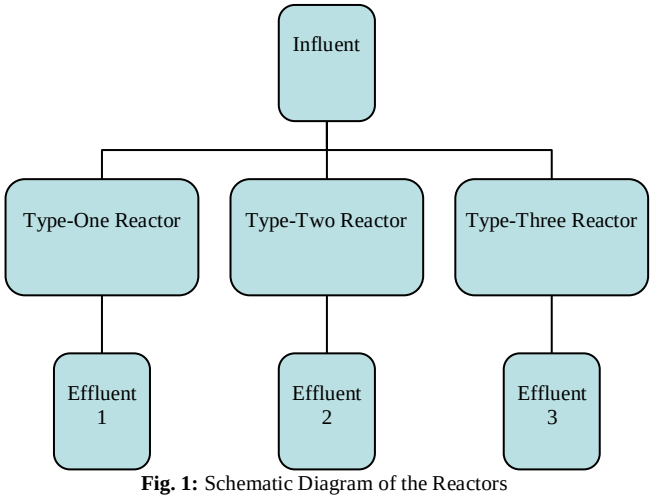


Fig. 1: Schematic Diagram of the Reactors

Bio-ball arrangement was very important in this study to ensure the better biofilm growth and to prevent clogging. The three arrangements were referred as arrangement one, arrangement two and arrangement three. For the arrangement one, two half bio-balls were tied together and fixed on a plastic net. The net was placed inside the tank in zigzag shape that looks like curtain. Sticks have been provided to hold the curtain style net on top of the tank. Besides that, for arrangement two, three half bio-balls were tied together and filled inside a bag made up from plastic net. The bag was 0.65 m height and 0.6 m wide and total of 10 bags were used. In arrangement three, 26 half balls were inserted into a 1.2 meter length plastic thread. Total of 8 sticks were used to hold the plastic thread with half bio-balls and there are 12 plastic thread with 26 half bio-balls in each stick. Stainless steel chains were tied at the end of arrangement three and arrangement one to make it heavy and to make sure it remains inside the wastewater.

2.2. Sample Collection

Seven sampling points were identified for the samples to be collected and tested for TSS and COD test. The seven different points are influent, effluent from arrangement one, effluent from arrangement two, effluent from arrangement three and from the three tanks mixed liquor. Besides that, MLSS test were to measure the attached and suspended biomass. The bio-balls were collected from all the three tanks to measure the attached biomass while wastewater sample inside the tanks were collected to measure the suspended biomass.

3. Results and Discussion

3.1. Chemical Oxygen Demand (COD)

Influent for all the three tanks was obtained from the treatment plant. Figure 2 shows the COD concentration measured throughout the project period. The highest influent COD concentration achieved was 1131 mg/l which was obtained in second trial. During the 2nd trial, the COD concentration of influent exceeds 1000 mg/l due to the high concentrated influent which contained more soluble and organic matters to dissolve. COD value of influent in constantly decreased from 1130 mg/l to 165 mg/l which was the 7th trial. This can be happened due to raining. The rain water dilutes the highly concentrated influent. The average influent concentration was 396 mg/l. The lowest COD concentration achieved for arrangement one was 11 mg/l, for arrangement two was 10 mg/l and for arrangement three was 14 mg/l. The arrangement one and three had slow start in the removal while arrangement two started with good removal. In the first trial, arrangement one and three achieved COD removal of 77 mg/l and 105 mg/l respectively while arrangement two removed 25 mg/l of COD. Somehow, the removal for all the three arrangement was almost the same after the second trial. The average COD concentration for arrangement one was 23 while for arrangement two and arrangement three was 25 and 36 mg/l respectively. According to Environmental Quality (Sewage) Regulations 2009 (Malaysia), all the COD concentrations were within the allowable condition. The allowable COD value from the standard A is 50 mg/l while B is 100 mg/l [10].

The minimum percentage of removal for arrangement one, arrangement two and arrangement three were 84 %, 80 % and 78 % respectively. For maximum percentage of removal, arrangement one and arrangement two had the same percentage which is 97 %. 99 % of removal has been recorded for arrangement three as maximum removal. This removal was only achieved once throughout the project. Arrangement three average percentage removal of 83 % while arrangement one and arrangement two had average percentage of removal of 93 % and 92 % respectively. In the seventh test, the percentage of removal achieved for arrangement three was very low (36 %). This is maybe because of human error during the lab test. In conclusion, it is clearly proven that arrangement one and arrangement two are more efficient than arrangement three. The COD test results shows that all the three types arrangement have good percentage of removal. All the three type effluents meets the requirements of Environmental Quality (Sewage) Regulations, 2009 (Malaysia) in term of COD [10].

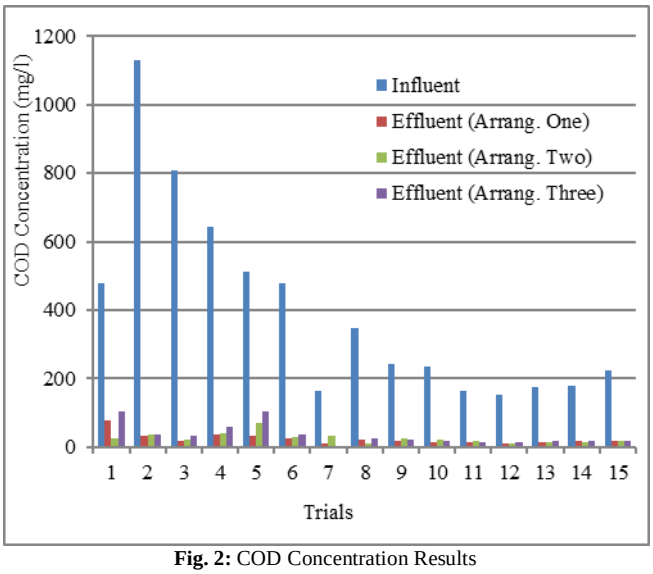


Fig. 2: COD Concentration Results

3.2. Total Suspended Solid (TSS)

The influent for all the three arrangements was from the same source. Figure 3 shows the TSS test results.

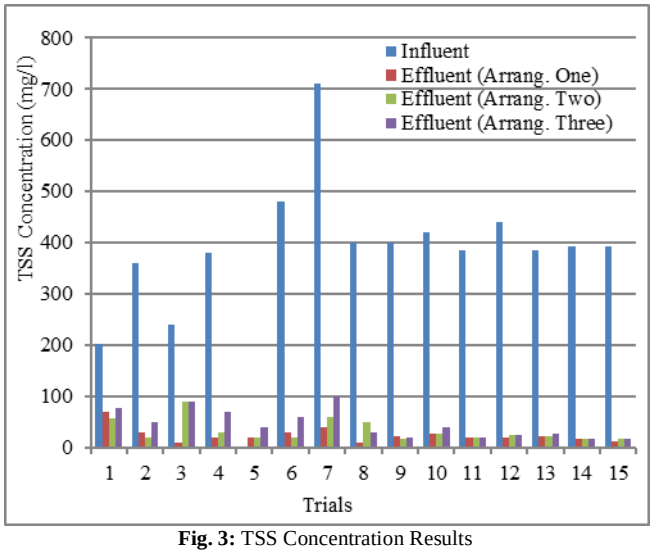


Fig. 3: TSS Concentration Results

The highest and average TSS concentration of influent was 710 mg/l and 488 mg/l respectively. For the arrangement one, the lowest effluent TSS concentration achieved was 10 mg/l. For the arrangement two and arrangement three, the lowest effluent TSS concentration achieved was 16. The overall average effluent TSS concentrations for the arrangement one, two and three were 25, 32 and 45 mg/l respectively. The reading for influent in trial 5 was ignored because of error during measurement. In the beginning, the arrangement one and three had a slow start in removal where TSS removal of 70 and 77 mg/l were achieved respectively. In contrast, TSS removal of 57 mg/l was achieved by arrangement two.

The minimum percentage of removal for arrangement one, arrangement two and arrangement three were 94 %, 92 % and 86 % respectively. For maximum percentage of removal, arrangement one was 98 % and arrangement two had the percentage of 96 %. As for arrangement three, the maximum removal percentage was 95 %. This removal is only achieved once throughout the project. Arrangement three had average percentage removal of 88 % while arrangement one and arrangement two had average percentage of removal of 93 % and 91 % respectively. In conclusion, it is clearly proven that arrangement one and arrangement two are more efficient than arrangement three. The TSS test results show that all the three arrangements have good percentage of removal. All the three arrangements' effluents meets the requirements of Environmental Quality (Sewage) Regulations, 2009 (Malaysia) in term of TSS [10]. Further investigation can be done by using numerical simulation of the attached growth reactors with different arrangements of Bio-Balls [11].

Figure 4 and Figure 5 show the measured suspended biomass and attached biomass in all three arrangements respectively. The suspended biomass is the free moving microorganisms inside the reactor while the attached biomass is the microorganisms attached to bio-ball. MLSS test were used to measure the amount of suspended and attached biomass.

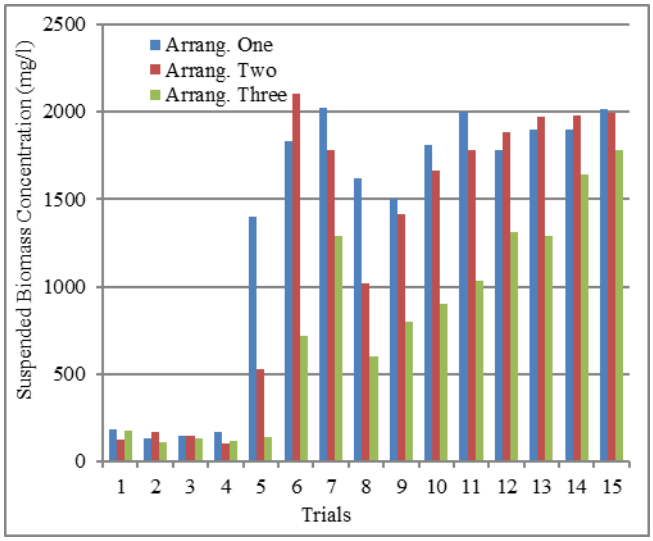


Fig 4: Suspended Biomass Results

The highest suspended biomass measured in arrangement one was 2020 mg/l while in the arrangement two 2100 mg/l was measured. In arrangement three, the highest suspended biomass was 1780 mg/l and this was the lowest compared to the other two arrangements. In the beginning, expected biomass was not achieved due to the characteristic of influent. At trial 5, sludge was added to achieve MLSS of 2000 mg/l. Sludge adding process is the reason for the sudden increase in the suspended biomass inside tank. The MLSS value was maintained until the end of the study period.

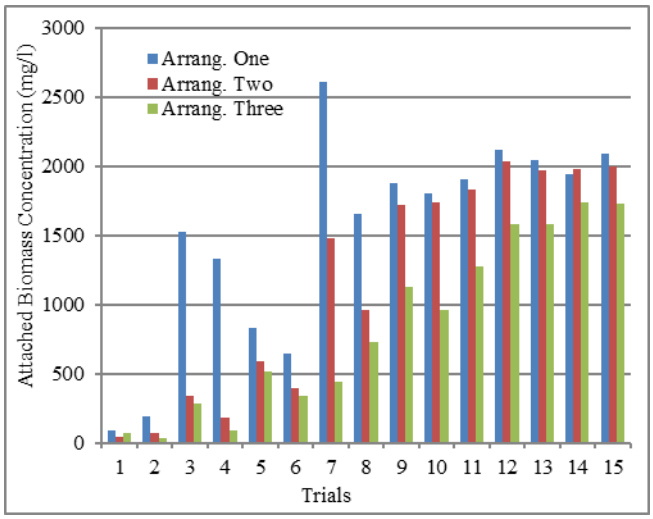


Fig. 5: Attached Biomass Results

Meanwhile, the highest attached biomass was obtained with arrangement one which was 2608 mg/l followed by arrangement two (1155 mg/l) and arrangement three (833 mg/l). Sludge adding process does affect the attached biomass value. After the sludge adding process, the attached biomass value increased in arrange-

ment one and two. The arrangement three recorded the lowest attached biomass value. This is shows that the arrangement three faced difficulties in term of biofilm growth.

4. Conclusion

From the study of the problem raised concerning the clogging issue and difficulties faced during the operation and maintenance of the attached growth treatment system; a conclusion was reached to alter the configuration and installation. Three different arrangements were the outcome of the study sharing the idea of splitting the bio-ball into two identical parts. At the end of the project, the results show that these wastewater treatment arrangements were working efficiently. It's proven by the percentage of removal calculated from both the Total Suspended Solid (TSS) test and Chemical Oxygen Demand (COD) test results. Percentage of removal is the amount of soluble and organic matters that have been removed by a treatment system. High percentage of removal shows the good efficiency of a treatment system while a poor treatment system yields low percentage of removal. Considering the TSS removal efficiency, arrangement one was the best followed by arrangement two and arrangement three respectively. While for COD, arrangement one recorded the highest removal efficiency followed by arrangement two and column. It can be concluded that arrangement one is the best for overall parameter measured. TSS removal and COD removal was almost the same in between arrangement one and arrangement two but arrangement one has the highest among them. Arrangement two and arrangement three still can be used in a treatment plant since the TSS and COD removal is acceptable under Malaysian standards. Besides that, all the three arrangements have the differences in terms of maintenance and creativity. In term of maintenance, curtain and arrangement two are the best because easy maintenance and sample collection for lab testing. The arrangement three was very hard to do maintenance as well as collect samples. In term of creativity, the arrangement one was the best. The other two arrangements were normal in term of creativity. Throughout this project, there was no clogging occurred in all the three arrangements, indicating that all three arrangements are solving the issue of clogging. This presented positive outcome can make the system more effective. The resulted development of attached growth in arrangement one showed that the performance is better compared to arrangement two and arrangement threes. In addition, the performance was relevant to the arrangement as the bio-balls in arrangement one were position closely so that more bio-balls were fixed in the tank. In conclusion, arrangement one is the best in term of removal efficiency, maintenance and creativity followed by arrangement two and arrangement three.

Acknowledgement

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References

[1] Pajkos, A., Vickery, K., & Cossart, Y. (2004). Is biofilm accumulation on endoscope tubing a contributor to the failure of cleaning and decontamination?. Journal of Hospital Infection, 58(3), 224-229.

[2] Zaitsev, G., Mettänen, T., & Langwaldt, J. (2008). Removal of ammonium and nitrate from cold inorganic mine water by fixed-bed biofilm reactors. Minerals Engineering, 21(1), 10-15.

[3] Andreottola, G., Foladori, P., Nardelli, P., & Denicolo, A. (2005). Treatment of winery wastewater in a full-scale fixed bed biofilm reactor. Water Science and Technology, 51(1), 71-79.

[4] Choi, Y. C., Li, X., Raskin, L., & Morgenroth, E. (2007). Effect of backwashing on perchlorate removal in fixed bed biofilm reactors. Water research, 41(9), 1949-1959.

[5] Alves, M. M., Vieira, J. M., Pereira, R. A., Pereira, M. A., & Mota, M. (2001). Effect of lipids and oleic acid on biomass development in anaerobic fixed-bed reactors. Part I: biofilm growth and activity. Water Research, 35(1), 255-263.

[6] Gupta, V. K., Srivastava, S. K., Mohan, D., & Sharma, S. (1998). Design parameters for fixed bed reactors of activated carbon developed from fertilizer waste for the removal of some heavy metal ions. Waste management, 17(8), 517-522.

[7] Ganesh, R., Rajinikanth, R., Thanikal, J. V., Ramanujam, R. A., & Torrijos, M. (2010). Anaerobic treatment of winery wastewater in fixed bed reactors. Bioprocess and biosystems engineering, 33(5), 619-628.

[8] Guo, W., Ngo, H. H., Dharmawan, F., & Palmer, C. G. (2010). Roles of polyurethane foam in aerobic moving and fixed bed bioreactors. Bioresource technology, 101(5), 1435-1439.

[9] Sidek, L. M., Mohiyaden, H. A., Basri, H., Salih, A., Hayder, G., Birima, A. H., Ali, Z., Sabri, M., Fauzan, A., Noh, M. & Nasir, M. (2015). Experimental Comparison between Moving Bed Biofilm Reactor (MBBR) and Conventional Activated Sludge (CAS) for River Purification Treatment Plant. Advanced Materials Research, 1113.

[10] Department of Environment, Malaysia, EQ(S) R (2009).

[11] Hayder, G., & Perumulselum, P. (2018). Akademia Baru. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 41(1), 10-20.