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Performance of Aerated Fixed Film Biofilter (AF2B) Reactor for Treating Hospital Wastewater

Prayitno†, Hadi Saroso, Sri Rulianah and Hardjono
Department of Chemical Engineering, State Polytechnic of Malang, Jl. Soekarno Hatta No. 9, Malang 65141, Indonesia
†Corresponding author: Prayitno

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ABSTRACT

Hospital wastewater contains some contaminants such as BOD, COD, phenol and faecal coli, which often exceed the quality standards. The ability of the wastewater treatment can be increased by increasing the hydraulic residence time and the selection of proper types of microorganisms. The purpose of this research is to determine the Aerated Fixed Film Biofilter (AF2B) reactor performance in reducing BOD_5, faecal coli and phenol. The AF2B used in this study is divided into 3 equal parts, where each part contains a biofilter made of plastic with a bee nest shape as medium for the growth of EBC (Endogenous Bacterial Consortium). The endogenous bacterial consortium consists of *Pseudomonas capica*, *Pseudomonas diminuta*, *Bacillus* sp1, and *Bacillus* sp2. The experiment was conducted by flowing the hospital wastewater continuously into the AF2B reactor through a number of biofilters. At the effluent of AF2B, a part of the stream was recycled to maintain the growth of EBC. The experiments were conducted with the Hydraulic Residence Time (HRT) for 3, 1.5 and 1 hours. The experimental results show that the greater HRT caused the increasing of pollutant removal capability. At HRT for 3 hours and contact time for 98 hours, the BOD_5, faecal coli and phenol removal yields were 92%, 85% and 63%, respectively. These results indicated that AF2B process using EBC can be used as a promising hospital wastewater treatment for BOD_5, faecal coli and phenol removal.

INTRODUCTION

Hospital wastewater is discharged from all hospital activities, both medical and non-medical activities, including activities at clinic rooms, laboratories, nursery rooms, radiology rooms, kitchens and laundry rooms (Nasr & Yazdanbakhsh 2008). Hospital wastewater contains hazardous pollutants such as pathogenic microorganisms (bacteria, viruses), heavy metals, pharmaceuticals, toxic chemicals (phenol, Pb), radioactive elements and biodegradable organic materials such as protein, fat and carbohydrate (Suarez et al. 2009). The pollutant materials that exceed the quality standards can cause pollution and health problems for human and environment (Nasr & Yazdanbakhsh 2008, Verlicchi et al. 2015). In Indonesia, the processing and management of hospital wastewater need to have great attention due to only 36% of hospitals have a wastewater treatment plant (WWTP). For the others, the wastewaters are discharged directly into receiving water bodies or using infiltration wells. Mostly, the hospital wastewater treatment plant (HWWTP) uses a combination of biological-chlorination processes, but the discharges are often exceeding the quality standards, such as Pb, phenol, free ammonia, orthophosphate and chlorine (Prayitno et al. 2013). Several biological processes have been used in HWWTP, namely anaerobic-aerobic fixed film bioreactor (A2F2B) (Rezaee et al. 2005), submerged membrane bioreactor (SMB) (Wen et al. 2004) and combination of up flow anaerobic fixed-bed (UAF-B) and suspended aerobic reactor (SAR) (Kocadagistan et al. 2005). However, the quality of HWWTP effluents have not been really complied the standard, due to the toxic pollutants (Pb and phenol) which can be caused by the non-optimal biological process.

In biological processes, the pollutant removal is affected by temperature, pH, kinds of microorganisms, contact time, the type of reactor, and the presence of inhibitors (Basha et al. 2010, Nair et al. 2008). Furthermore, endogenous bacterial consortium (EBC) are proven as effective microorganisms to reduce the heavy metal compounds contained in wastewaters (Kim et al. 2002). The biodegradation capabilities of *P. putida* are highly affected by temperature, pH, initial phenol concentration and abundance of the biomass (El-Naas et al. 2009). Thus, process of pollutant removal in hospital wastewater can be maintained by using the selected EBC and increasing the contact time in biological process using circulation flow and aerated fixed biofilters.

The aim of this work is to investigate the capability of EBC in aerated fixed film biofilter (AF2B) reactor in reducing BOD_5, faecal coli and phenol pollutants discharged from hospital wastewater.

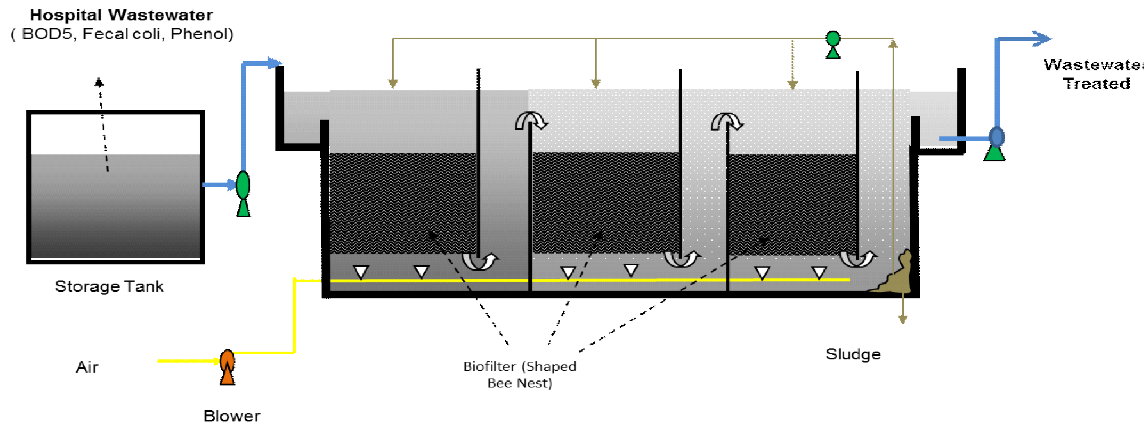

Fig. 1: Schematic view of AF2B reactor.

MATERIALS AND METHODS

Materials: The experimental apparatus system used in this study, AF2B was designed as illustrated in Fig. 1. Table 1 gives the detailed characteristics of the reactor. The AF2B is divided into 3 equal parts, where each part contains biofilter, which is made of plastic with a bee nest shape. The diffuser is placed at the bottom of the biofilter connected with a blower to supply the air for the growth of microorganisms and the perfection of the mixing process. A pH controller is fitted on the inlet of the AF2B while the pump is fitted on the sedimentation tank to recycle a part of the sludge into each biofilter. The material of the biofilter is plastic with a density of 0.125 g/cm^3, volume of 2160 cm^3 and specific surface area of 150-240 m^2/m^3. The totals of the biofilter placed in the AF2B are three.

Wastewater was taken from hospitals in Malang City which had characteristics as follows: Temperature 29°C, pH 6-8, BOD$_5$ 240.25 mg/L, phenol 0.04 mg/L, and faecal coli 2,400 MPN/100 mL. The used microorganisms were EBC obtained from the isolated bacteria in hospital wastewater (bacterial endogenous). The isolated EBC has been grown through the acclimatization process by dissolving in the distilled water. The nutrients and hospital wastewater were added gradually in order to reach their maximum growth.

Methods: ***Acclimatization of EBC*:** Endogenous bacterial consortium (EBC) was mixed culture of several types of bacteria such as *Pseudomonas capica*, *Pseudomonas diminuta*, *Bacillus* sp1, and *Bacillus* sp 2, where the bacteria are obtained from the selection and isolation of potential bacteria in hospital wastewater. The EBC cultures were obtained from biotechnology laboratories, PAU ITB Bandung, Indonesia. The process of acclimatization EBC: In a container, 200 g culture of EBC was added to 2 litres of distilled water. Then into the EBC solution were added nutrients of 1000 ppm, stirring and checking the pH until pH = 7. Further, the EBC solution was aerated continuously until the EBC growth increased as judged by examining the number of bacteria using the method of haemocytometer and VSS. Further, the EBC solution was made 5%, 10% and 15% by volume by adding the hospital wastewater. The acclimatized EBC is known as starter. The starter has gone under further acclimatization in a AF2B reactor, which already contains hospital wastewater added with nutrients. The aeration was then done continuously until EBC has grown significantly.

Table 1: The physical characteristics of AF2B.

Parameter	Amount
Material	Acrylic
Wall thickness (mm)	5
Total Volume (L)	20
Effective volume (L)	18

***Biodegradation of pollutants in AF2B reactor*:** The acclimatization of EBC step was finished when the amount of EBC on the surface biofilter was sufficient significantly. It can be identified by slime production on the surface of biofilter. The AF2B reactor containing biofilter was made from plastic with a bee nest shape as the medium. In the AF2B reactor, the hospital wastewater was introduced using a pump (Type: Voss SN 3500). The influent flow rate of wastewater was adjusted using a flowmeter of 0.1 L/min (HRT: 3 hours), 0.2 L/min (HRT: 1.5 hours) and 0.3 L/min (HRT: 1 hour). Wastewater was introduced continuously from the top of the biofilter towards the bottom and then circulated in every part of the biofilter. The outlet stream of the AF2B was collected into a sedimentation tank and a

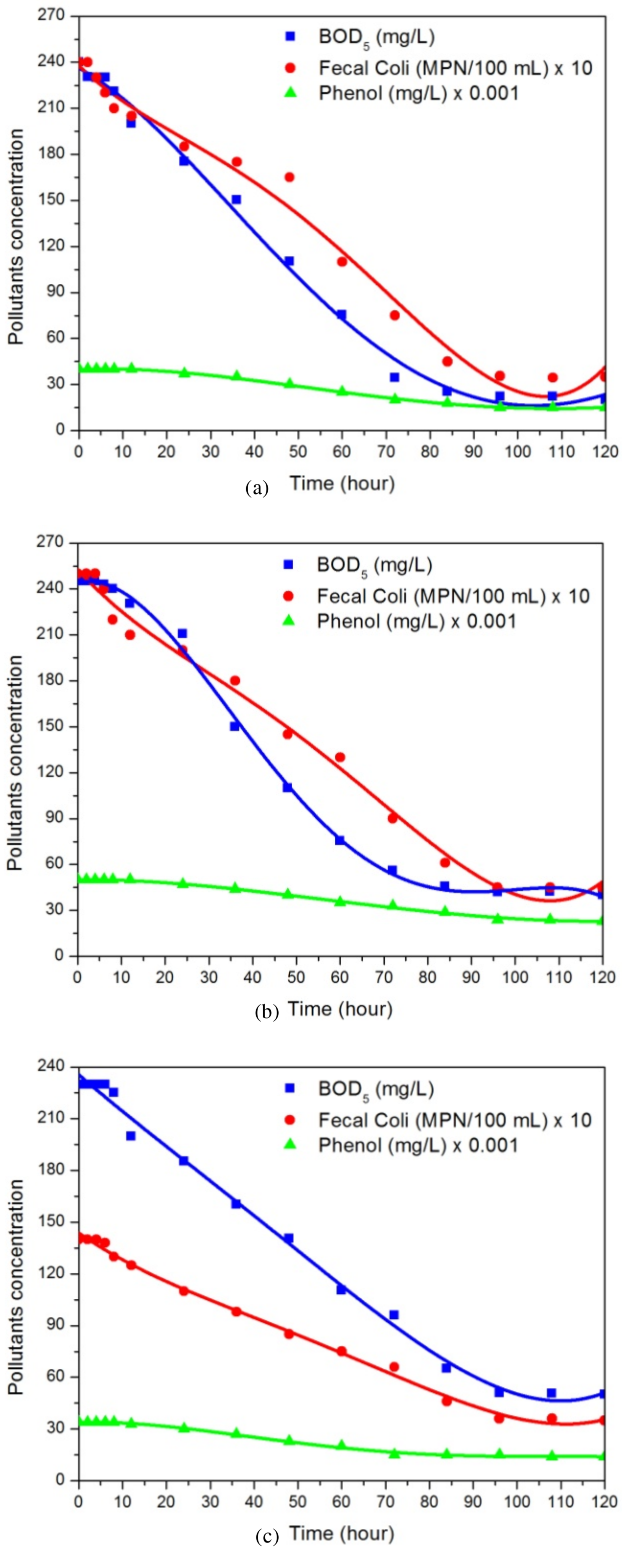

Fig. 2: The performance of an AF2B reactor for different HRT: (a) HRT: 3 hours; (b) HRT: 1.5 hours; and (c) HRT: 1 hours.

part of the stream (25% influent) was recycled.

The samples were taken from the effluent of the AF2B at every 2 hours for 24 hours, followed by every 12 hours for 120 hours. The samples were analysed by using APHA standard procedures in order to investigate the BOD_5, phenols and faecal coli contents. Faecal coli was measured as most probable number (MPN), phenol by using a UV-Vis (Type: Hitachi-U900), and BOD_5 (oxygen) by the modified Winkler's method. The mixed liquor suspended solids (MLSS) was measured by gravimetric method.

RESULTS AND DISCUSSION

In this study, the treatment of the hospital wastewater containing different initial concentration of pollutants has been investigated using the AF2B experimental apparatus. The AF2B performance was analysed based on the initial concentration of pollutants in the feed stream. The sampling of biofilter surface indicated that the EBC had grown and adapted to fit well with its surroundings and was ready for use in the biodegradation of pollutants.

The results of this study are shown in Fig. 2. As shown in Fig. 2 (a), the concentration of BOD_5 and faecal coli decreased in the first 4 hours and reached a maximum decrease at 96 hours with the percentage of BOD_5 removal of 91%. The largest decreasing of the pollutants concentration occurred in the period of 12-96 hours when BOD_5, faecal coli and phenol were 74%, 68% and 62%, respectively. This condition occurred, because at the first 4 hours, microorganisms (EBC) were still adapting to the environment, so the growth of EBC was not maximized, and it was indicated by the less slime formed on the surface of the biofilter . While, after 4-12 hours, the EBC began to adapt so its growth and the biodegradation process also began to take place, and it was shown by increased slime thickness on the surface of the biofilter. Kaplan et al. (2003) said that the biofilm formation in a submerged biofilter takes place in five stages: initial attachment, irreversible attachment, maturation 1, maturation 2 and dispersion.

An AF2B is composed of several biofilters with a shape like a bee nest that has a large specific surface area (150-240 m^2/m^3) where microorganisms grow and are in contact with wastewater. At the time of 12-96 hours, the EBC growth is increasing, in line with the increase of substrate (pollutant) consumption by EBC which could be attributed to the all surfaces of biofilter covered by the EBC. On the other hand, by making the flow circulation in the reactor, a better air supply will increase the contact time in the biofilter. Thus, the biodegradation process of pollutants occurred rapidly (Dey & Mukherjee 2010, Wen et al. 2004).

At the time 96-120 hours, the stationary phase was reached where the rate of growth was equal to the rate of death of EBC in the biofilter so that the biodegradation of pollutants reached the steady state. These conditions reduced BOD_5 and faecal coli up to 92% and 85%, respectively. In the aerobic biological process, biodegradation rate of organic material and phenol by microorganisms was affected by the temperature, initial concentration, pH, type of microorganism, HRT, the type of reactor and the presence of inhibitors where the organic matters were decomposed by EBC into new cells, CO_2, H_2O and energy (Basha et al. 2010, Nair et al. 2008). The phenol was decomposed gradually by the EBC into a phenol derivatives as carboxylic acids and CO_2 (Sridevi et al. 2012). The reduction of phenol concentration was slower than the BOD_5 and faecal coli.

As comparison with other wastewater treatment processes in case of organic matters, the A2F2B process could reduce the concentration of pollutants in the hospital wastewater, namely BOD_5, COD and coliforms up to 89%, 82% and 90%, respectively (Rezaee et al. 2005). The submerged membrane bioreactor (SMB) could reduce the BOD_5 (48-70%) and coliform (50-75%) (Wen et al. 2004). The combination of up flow anaerobic fixed-bed (UAF-B) and suspended aerobic reactor (SAR) equipped with the micro filtration could reduce the concentration of COD (94-98%) (Kocadagistan et al. 2005).

The phenol concentrations began to reduce at 12 hours and reached a maximum decrease at 96 hours with the removal percentage of 62% (Fig. 2a). The biggest decrease of phenol occurred in a period of 24-84 hours which was 55%. Then, it reached steady state condition at 96 hours with the percentage of phenol as 63%. Phenols are aromatic organic compounds and toxic substances (inhibitor) for microorganisms, so the biodegradation of phenol by microorganisms is slower than that of BOD_5 and faecal coli in AF2B. Phenol biodegradation by microorganisms is influenced by the shape of phenol compound, HRT, initial concentration and the form of enzyme (Dey & Mukherjee 2010). The biodegradation of phenol by mixed cultures is more efficient than that by pure cultures with the product of phenol biodegradation as simple compounds such as carboxylic acids and CO_2 (Sridevi et al. 2012). This work used mixed cultures (EBC) so that the biodegradation of phenol was faster than the others at the biodegradation period of HTR as 3 hours. At the biodegradation time of 120 hours, phenol could be reduced up to 62.5%. EBC consists of *Pseudomonas capica* and *Bacillus* sp1 that has the ability to degrade the organic compounds such as phenols in aerobic/anaerobic process (González et al. 2001, Sridevi et al. 2012). In other study, UASB reactor with HRT of 40 days was able to reduce the phenol by 80% while SBR reactor with HRT of 30 days was able to reduce phenol by 95% (Dey & Mukherjee 2010).

Further, based on Fig. 2 (a, b and c), it showed that the greater HRT caused the increasing of pollutant concentration removal per unit of time. Where, at t=36 hours, the decreasing of BOD_5 at HRT 3 h, 1.5 h and 1 h was 37%, 39% and 30%, respectively. This condition could be described as the greater HRT caused the rate of biodegradation between the pollutants with EBC on the surface of the biofilter media much longer. Meanwhile, the smaller HRT caused the greater driving force on the surface of biofilter so that the rate of biodegradation by EBC was decreased. The AF2B was able to reduce BOD_5, faecal coli and phenol with the biggest pollutant removal capability at 96 hours with the BOD_5, faecal coli and phenol removal up to 92%, 85% and 63%, respectively. The results concluded that the AF2B could be operating optimally at 96 hours.

CONCLUSION

This paper has investigated the capability of EBC in aerated fixed film biofilter (AF2B) reactor in reducing BOD_5, faecal coli and phenol pollutants discharged from hospital wastewater. Based on the results obtained, conclusion can be drawn that the aerated fixed biofilter reactor process has a large capability of pollutants removal in hospital wastewater such as BOD_5, faecal coli and phenol up to 92%, 85% and 63%, respectively.

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