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Flux Continuity in Membrane Bioreactor for Azo Dye Biodegradation

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Abstract
A modified activated sludge, contact stabilization process coupled with anoxic reactor and combined with external ultrafiltration membrane is used for azo dye biodegradation. Feed consists of azo dye Remazol Black V and co-substrate tempe industry wastewater as organic source. Hydraulic retention time (HRT) of contact, stabilization and anoxic tank are kept in 2, 4 and 3 hours respectively. To obtain the expected HRTs control of the flux stability is required. In this research the performance of two kinds aerobic-anaerobic membrane bioreactor with and without aeration modes on flux continuity is studied. The first mode, air is injected to the feed channels prior discharges into the membrane so that mixed liquor circulates within the bioreactor. In the second mode, the mixed liquor flows only by pump pressure without aeration to feed channels. Flux continuity of the MBRs with and without aeration, backflush effect is evaluated to achieve the required HRT. Both introducing aeration and without aeration on the feed channel of the membrane can keep flux stable by creating wall shear stress and so suppress membrane fouling. However, increasing biomass concentration in bioreactors results in more frequent backwashing, so that aerated MBR is more preferred. Due to changing of permeate rate caused the HRT of stabilization tank changes to 3.98 hrs for non aerated MBR, whereas the HRT of MBR with alternate filtration-backflush time is 4.10 hours.

Keywords: azo dye, flux, membrane bioreactor, contact stabilization

1. Introduction

Membrane bioreactor technology (MBR) is a wastewater treatment technology which rely on biological activated sludge process and membrane system for retaining bacterial flocs and virtually all suspended solids within the bioreactor. Membrane bioreactor offers more advantages compared to conventional biological activated sludge process, in which it operates in higher organic loading, but required only smaller footprint. However, inevitably the performance of filtration decrease with filtration time. Flux decrease with pressure increase (TMP) indicated fouling. Fouling in membrane process can be irreversible or reversible, in which deposition species is retained onto or into membrane (Fane and Cho, 2001). Many methods are carried out to mitigate fouling. So far, aeration is a most common method used in fouling reduction, in accordance with the ability to produce shear stress on membrane surface. Aeration has three functions, to provide oxygen for biomass, to keep biomass in suspension and to reduce fouling by constant scouring on membrane surface (Le-Clech dkk, 2006). Cleaning strategy both physical and chemical is another ways to minimize fouling. Backwashing or also called backflushing is known can overcome reversible fouling case caused by pore clogging, turn the foulant back into the bioreactor and remove out a part of cake layer that attached free on membrane surface. In this research a modified activated sludge, contact stabilization process coupled with anoxic reactor and combined with external ultrafiltration membrane is used for biodegradation of azo dye in textile industry. The release of these compounds into the environment is undesirable, not only because of their color, but also because many azo dyes and their breakdown products are toxic and/or mutagenic to life. (Van der Zee, 2002). Biological azo dye treatment is commonly carried out using a sequenced anaerobic-aerobic treatment (Isik, 2004; Ong, 2005; Van der Zee, 2005) or conversely aerobic-anaerobic treatment (Khehra, 2005; Lodato, 2007). In this study anoxic tank is used for cleavage azo chromosome by aerobic microorganisms which aerated prior stabilized in contact-stabilization process, while hollow fiber ultrafiltration membrane is employed to replace sedimentation process in conventional activated sludge process. In the previous research conducted by Komala (2008) and continued by Ananthi (2008), decolorization of azo dye Remazol Black V at 120 mg/L with co-substrate tempe industry wastewater at 500 mg/L TOC was performed using modified activated sludge process contact stabilization and anoxic tank coupled with an external hollow fiber membrane module in hydraulic retention times of anoxic tank ranging from ½ - 3 hrs, whereas HRT in the contact and stabilization tanks had been kept constant at 2 hrs and 4 hrs respectively. Highest decolorization was obtained at the HRT 3 hrs in the anoxic tank, both studies had limitations to maintain constant flux caused the HRT both in contact and stabilization tanks is not be achieved. Several studies showed that combined use of air induced crossflow and backwash is particularly favorable towards fouling suppression. In this study, evaluation of aeration and backflush on flux stability is performed. The effect of flux stability to stabilization tank HRT, azo dye and organics removal is evaluated as well.

2. Materials And Methods

Microorganisms

A mixed culture was developed from mixed liquor drawn from a textile and dye industry activated sludge treatment plant. The culture was fed with a medium mixture containing 10% tempe wastewater and 120 mg/L azo dye and aerated.

Co-substrate and dye

Dyes are toxic material and biodegradation without external carbon source very difficult. Tempe wastewater as co-substrate was used along with dye in the study. From previous batch study (Komala, 2008) the optimum co-substrate tempe wastewater was 10% v/v for aerobic microorganisms growth in medium mixture of tempe wastewater and azo dye. Tempe wastewater has high concentrations especially for nutrient such as nitrate, phosphate and trace mineral (Komala, 2009) due to high nutrient content in tempe. Azo dye used is Remazol Black V in concentration of 120 ppm, the optimum wave length of this concentration is 609 A°.

Membrane module

The membrane used in this study is a hollow fiber ultrafiltration, polyacrolynitryle (PAN) membrane module with 0.38 m^2 and 0,538 m^2 surface area were used.

Experimental Setup

The experiments was conducted with two paralel MBRs, the MBR setup is shown in **Figure 1**. The reactor I used 20 kDa membrane module and 100 kDa for reactor II. The total working volume of the plexyglass bioreactors is 14 L (3L anoxic, 2L contact and 4L stabilization reactors respectively based on the HRT of 3, 2 and 4 hrs for the anoxic, contact and stabilization tanks). Feed consisting of azo dye and tempe wastewater solution with 2 l/hrs flow rate is pumped to the anoxic reactor equipped with mechanical stirring (40-60 rpm). The mixed liquor from the anoxic reactor is discharged gravitationally to the contact reactor and then pumped into the membrane with average 0,2-0,8 bar pump pressure. For reactor 1 the incoming feed from contact reactor into the membrane just flows only by pump pressure without introducing of air, whereas the reactor 2 with introducing of air into the feed channel to create mixed liquor circulation in the membrane. The air pressure from compressor to the feed channel is controlled so, that backflow is not occurred. The base of the contact and stabilization tanks is equipped with diffusers connected to the compressor to fluidize and aerate the mixed liquor. Retentate, the concentrated biomass, is drawn from the membrane lumen into the stabilization tank and then the biomass is recycled to the anoxic tank. To achieve the required HRTs of contact-stabilization tanks, 2 L/hours permeate rate is expected. The effort to maintain constant permeate rate is to be an objective. Backwash or flow reversal was applied periodically by using water, while backflush was carried out with mixed of air and water. The backflushing interval was controlled by the timer and solenoid valves. The operational condition for both membrane bioreactors system are shown in Table 1. Reactor 1 was operated for 21 days. Reactor 2 from day 1 to day 22 was operated with aeration and weekly backwash with water. In the following day 23 to day 33 aeration followed by setup of filtration and backflush time with 3 hours and 1 minutes was arranged. The permeate and flux was calculated from measuring the time taken to collect a known filtrate volume. The changing of TMP was monitored over each experiment.

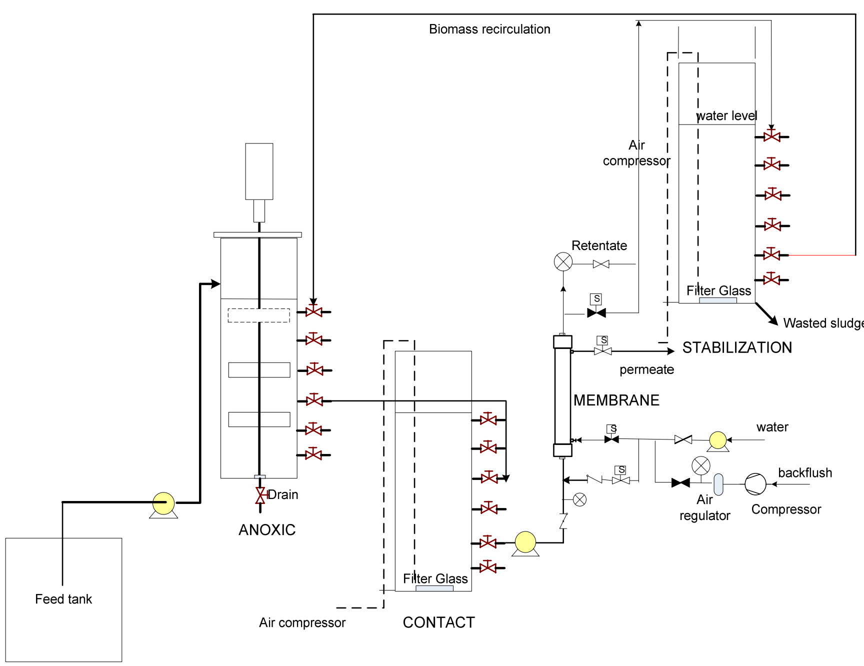


Figure 1 Aerobic-anaerobic membrane bioreactor set-up

Table 1 Aeration arrangement in Membrane Bioreactor

Reactor	Day	Aeration setup
MBR 1	1-21	Without aeration
MBR 2	1-22	Continuous Aeration with weekly backwash
	23-33	Alternate aeration-backflush

Analytical method

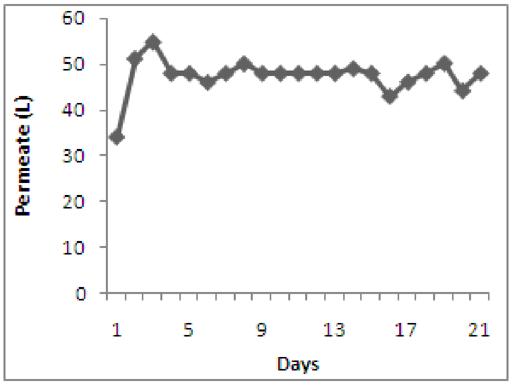
The samples taken daily from feed, anoxic, contact, stabilization tanks, membrane permeate and then filtered for COD and color measurement. The soluble COD was measured by using titrimetric closed reflux method and color was measured using UV spectrophotometer. Biomass was measured as SS and VSS in anoxic, contact and stabilization tanks and membrane permeate (APHA, 1995)

3. Results And Discussion

Effect of aeration on permeate flux

Figure 1 to Figure 6 gives an overview of the results achieved by MBR treatment of azo dye wastewater with and without aeration on the membrane feed. The permeate and fluxes even without aeration were almost stable (Figure 1 and Figure 3), nevertheless the system required a periodic weekly backwash especially when the pressure gauge at the retentate indicated over 2 Bar. It seemed that backwashing is able to recover membrane flux caused by reversible fouling with particulate material to achieve expected permeate volume 48 L. During filtration with operating pressure between 0,4-0.8 Bar can create the shear stress on the membrane surface, that the particulate matter not clogged on the membrane pore. Basically, the TMP recovery of non aerated MBR is relative stable after sequential cleaning during the experiments (Figure 5), however increasing the biomass concentration in bioreactors results in more frequent backwashing, so aerated MBR with short periodic backwashing is more effective. For aerated MBR followed by weekly backwashing (Figure 2 and Figure 4), the permeate rate initially varied due to air pressure from compressor had not been set up yet, so the feed pressures were fluctuated. After aeration intensity had been arranged between 10-15 lb/cm^2, was able to keep the TMP stable, the permeate rate and flux relative constant as well. Nevertheless, aeration with weekly backwash can not keep the permeate constant as membrane pore starts to clog, henceforth alternate aeration and backflush with 3 hours and 1 minute on day 23 was employed.

Alternating aeration and backflush shows a relative stable pressure of retentate compared to previous weekly backwashing with fluctuated pressure (Figure 6). It corroborated also by Chang (2002), that the pressure variations inside the channel caused by air pulsation appear to promote permeate flux; a periodic decrease in pressure creates back-transport of permeate which would then be expected to help to dislodge the cake layer.



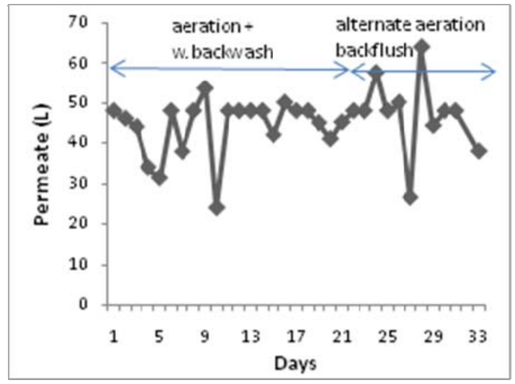
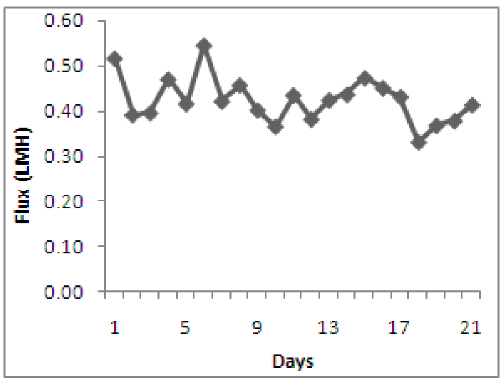


Figure 1 Permeate rate of MBR without aeration   Figure 2 Permeate rate of MBR with aeration



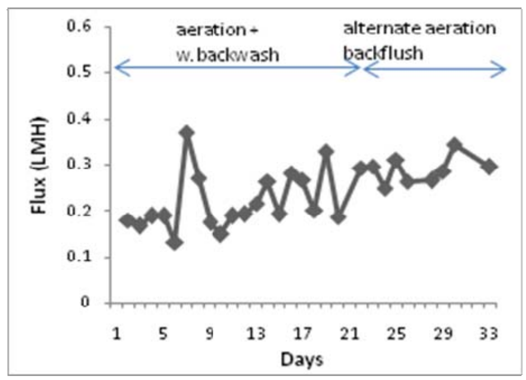


Figure 3 Flux of MBR without aeration   **Figure 4** Flux of MBR with aeration

Hydraulic retention time

The permeate rate was kept constant at approx. 2 L/h during entire study to obtain the HRT of contact and stabilization 2 and 4 hours. However, flux decreases with filtration time due to the deposition of soluble and particulate materials of activated sludge components onto and into the membrane.The changing of permeate flux changes also the HRT of contact and stabilization tanks, where the feed and retentate coming from and out. If the permeate rate too fast results in the HRT of contact tank too short, thus the HRT of stabilization tank shorter than 4 hours due to the incoming retentate is smaller. Conversely if the permeate is smaller the retentate will be larger, that the stabilization tank's HRT will be shorter than 4 hours. The average HRT of stabilization tank in MBR I (without aeration) due to changing of permeate rate drops to 3.98 hrs, rather small than MBR II with alternate filtration-backflush time 4.10 hrs, whereas MBR II with weekly backwash the HRT only 3.77 hours. It coincided with Chang (2002), that the flux was found to increase by 43% when aeration was introduced to the air-lift module.

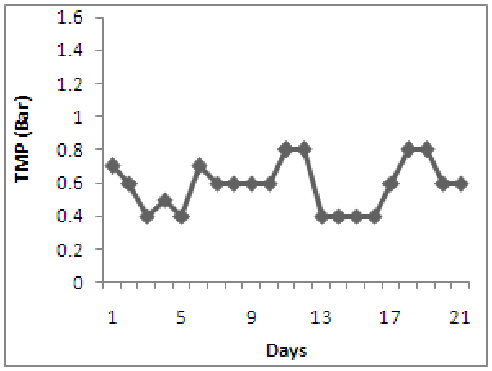


Figure 5 TMP of MBR without aeration

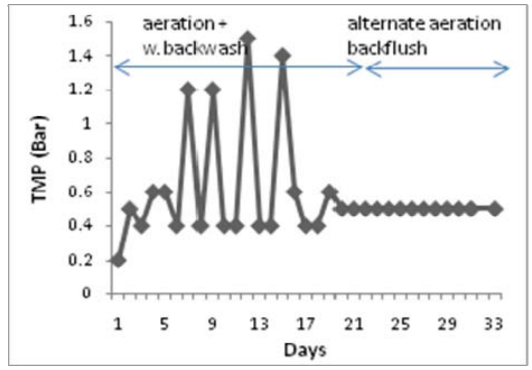


Figure 6 TMP of MBR with aeration

Dye and organics removal

Figure 7 shows color and organics removal of the MBR without aeration are 46% and 55% respectively from initial color and COD concentration between 110-120 ppm and COD 5,200-6,700 mg COD. With alternated aeration-backflush MBR removal efficiency for color and COD is 45% and 75%, rather adversely for color removal compared to MBR without aeration, nevertheless higher in organic removal. It is suggested the attached biomass growing on the membrane surface of aerated MBR with continuous feedings of air contributes to higher organics removal, whereas the color removal was more depend on the microorganism concentration throughout the bioreactor (Komala, 2009). To develop the optimum conditions the MBR process will be further subjected to increasing hydraulic retention times in contact-stabilization and anoxic tanks.

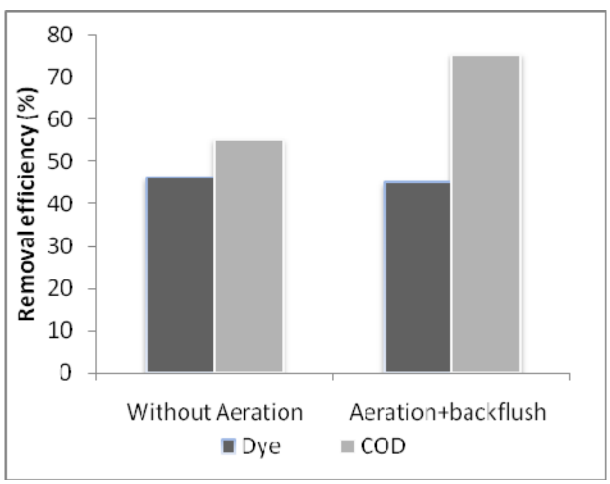


Figure 7 Dye and organics removal

4. Conclusions

Both aeration and without aeration on the feed channel to the membrane can keep flux stable by creating wall shear stress and so suppress membrane fouling. However, increasing biomass concentration in bioreactors results in more frequent backwashing, so that aerated MBR is more preferred. The alternate aeration-backflush MBR removal efficiency for color and COD is 45% and 75%, rather smaller for color removal compared to MBR without aeration, 46%, nevertheless higher in organic removal by 55%. Attached biomass growing on the membrane surface of aerated

MBR with continuous feedings of air contributes to higher organics removal. Due to changing of permeate rate caused the HRT of stabilization tank changes to 3.98 hrs for non aerated MBR, whereas the HRT of MBR with alternate filtration-backflush time is 4.10 hours. Higher flux is occurred as a result of the pressure inside an air-lift membrane channel fluctuates with response to the air pulsation

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