Pergamon

Wat. Sci. Tech. Vol 36, No. 12, pp. 259–266, 1997.

0273-1223/97 $17·00 + 0·00

PII: S0273-1223(97)00727-0

APPLICATION OF AIR BACKFLUSHING TECHNIQUE IN MEMBRANE BIOREACTOR

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ABSTRACT

The optimum air backflushing and filtration cycle was investigated for a 0.1 μm hollow fiber membrane module immersed in an activated sludge aeration tank. It was found that 15 minutes filtration and 15 minutes air backflushing gave the best result both in terms of flux stability and net cumulative permeate volume. Although this cyclic operation could not completely remove the clogging, this process improved the flux by up to 371% compared to the continuous operation.

During the long term runs, three different hydraulic retention times (HRT) of 12, 6 and 3 hours, corresponding to 0.16, 0.32 and 0.64 m^3/m^2 d of permeate flux respectively, were investigated. Stable operation was obtained at the HRT of 12 hours. Decrease in HRT led to rapid formation of a compact cake layer on the membrane surface thus increasing the transmembrane pressure. It was also noted that filtration pressure increases with increase in bioreactor MLSS concentration. With operation time, the MLVSS/MLSS values decreased without significant effect on the process performance, indicating that inorganic mass constantly accumulated in the bioreactor. All the experimental runs produced more than 90% removal of COD, and TKN. In terms of physical, chemical, biological and bacteriological parameters, the membrane bioreactor effluent was superior to the conventional activated sludge process. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Activated sludge, air backflushing, filtration flux, flux decline, hollow fiber membrane, membrane bioreactor, microfiltration, transmembrane pressure

INTRODUCTION

Domestic wastewater contains organic and inorganic matter in the three following states: suspended, colloidal and soluble. Classical treatment by activated sludge can remove up to 95% of both suspended solids and biodegradable organic. However, the quality of the final effluent depends very much on the hydrodynamic conditions in the sedimentation tank and the settling characteristics of the sludge. Consequently, large volume sedimentation tanks offering residence times of several hours are required to effect adequate solid-liquid separation, particularly for fluctuating input flows. At the same time, it is necessary to avoid conditions in the aeration stage which lead to poor settleability or bulking sludge. Various solutions have been proposed for the activated sludge process to overcome these problems.

For years, membrane technology has been instrumental in replacing secondary clarifiers to overcome the limits of the conventional activated sludge. By using the membrane system, the settling characteristics of the solids are no longer of importance, hence there is greater flexibility in the operation of the aeration stage. Moreover, the membrane process can minimize sludge wastage by maintaining low F/M ratio and, reduce the plant size by maintaining high solids concentration in the reactor (Smith et al., 1969). However, concentration polarization and fouling of membranes are problems inherent to high performance. To overcome this problem crossflow membrane (micro or ultra) filtration was reported by many researchers (Chaize and Huyard, 1991, Kimura, 1991; Aya, 1994, Muller et. al., 1995). But maintaining a high cross flow velocity need lot of energy, so the process is not feasible in the economic point of view Therefore, an efficient and optimum cleaning technique of membrane is very important to make the process cost-effective. Yamamoto et al., (1989) reported the direct solid/liquid separation using hollow fiber membrane in the aeration tank can lead to a efficient membrane declogging, where air is sent in the opposite direction to the sludge cake formed on the external membrane surface. This study specifically aimed to: (1) investigate the possibility of using the membrane module for effluent filtration and air diffusion alternately in a cycle; (2) study the effect of operation cycle (effluent filtration and air diffusion) in membrane bioreactor to prolong its operational life; and (3) determine some operational stability parameters for the membrane bioreactor

METHODOLOGY

The experimental set-up is shown in Fig 1 The rectangular reactor (31 cm x 71 cm x 53 cm) was made of transparent acrylic plastic sheet with a working volume of 80 L Two membrane modules were immersed in the reactor of the activated sludge system. Each of this polyethylene 0.1 μm hollow fiber membrane modules has a surface area of 1 m^2 Feed can be allowed to enter from either side of this membrane because of the slit-like micropores at the wall surface of the fibers without any skin layer.

Speed-controlled roller pump was used to extract the permeate from one module, while filtered compressed air at a pressure of 101 325 kPa was injected through the second module alternatively The alternative operation of filtration and air injection was controlled by an intermittent controller and solenoid valves. The transmembrane pressure was measured by mercury manometer Compressed air was also introduced to the aeration tank with a flow rate of 12 L/min through stone diffusers located at the bottom of the reactor.

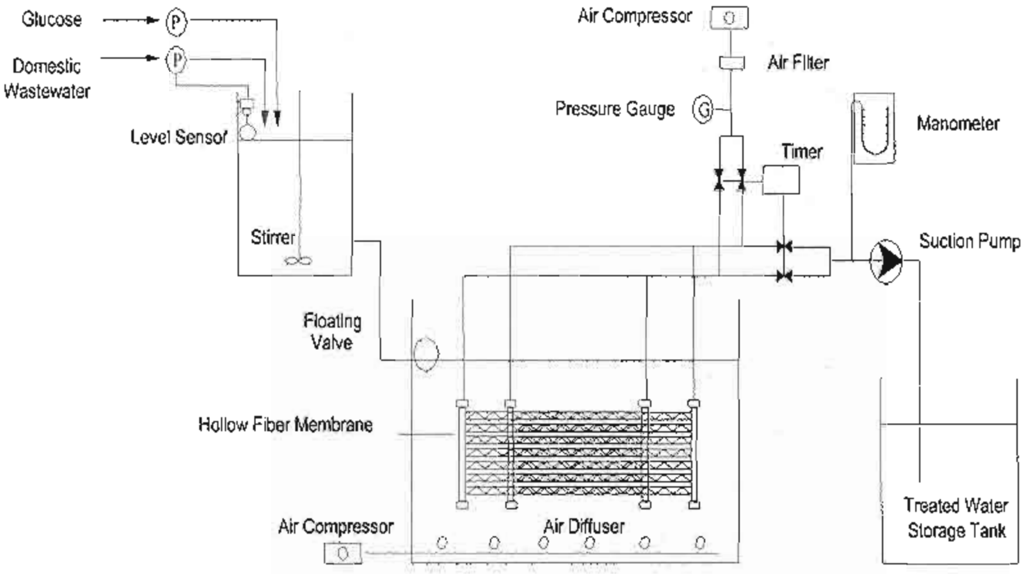

Fig. 1. Schematic diagram of the membrane bioreactor

The effect of operation mode of alternative air diffusion and effluent filtration on short term performance of the hollow fiber microfiltration membrane was studied. All runs were conducted as batch experiments for a duration of 8 hours. The following six different modes were studied (1) continuous operation (2) 60 : 60 (3) 30 . 30 (4) 15 15 (5) 10 : 10 (6) 5 . 5 where *60:60* indicates 60 minutes of filtration then 60 minutes of air diffusion. After each run, the membrane was cleaned by soaking in 2.5% sodium hypochlorite solution for about thirty minutes.

The effect of HRT was also studied in this experiment The initial HRT of membrane bioreactor process was varied at 3, 6 and 12 hours by controlling the effluent permeate fluxes at 640, 320 and 160 L/d respectively The change in transmembrane pressure was monitored everyday to detect the clogging of membrane during operation Solids Retention Time (SRT) in the reactor was infinity since there was no sludge wasting (except sample taken for analysis) throughout the study period

RESULTS AND DISCUSSION

Effect of Mode of Operation

During these experimental runs, the effects of different operational mode on permeate flux was investigated This was done by varying the time duration allocated for air diffusion and water filtration. In all these runs transmembrane pressure was maintained at the limiting pressure of 13.3 kPa The MLSS value was in all cases maintained within the range of 4800-5300 mg/L

Figs 2, 3 and 4 show performances of different modes of operation Continuous operation shows rapid decrease in flux with time, while the cyclic operation (discontinuous mode) can partially recover flux after the air diffusion period. Although cyclic operation could not completely remove the clogging which could be noticed by gradual decrease of permeate flux with time, air backflush technique could improve the flux by up to 371% compared to the continuous operation. Moreover, net cumulative permeate volume also increases (Fig. 5). The improvement in permeate flux by membrane air diffusion aeration process can be attributed to:

- removal of external deposit which are formed on hollow fibers thus preventing the compaction of cake layer under filtration pressure; and
- removal of particles which clog the pores of the membranes

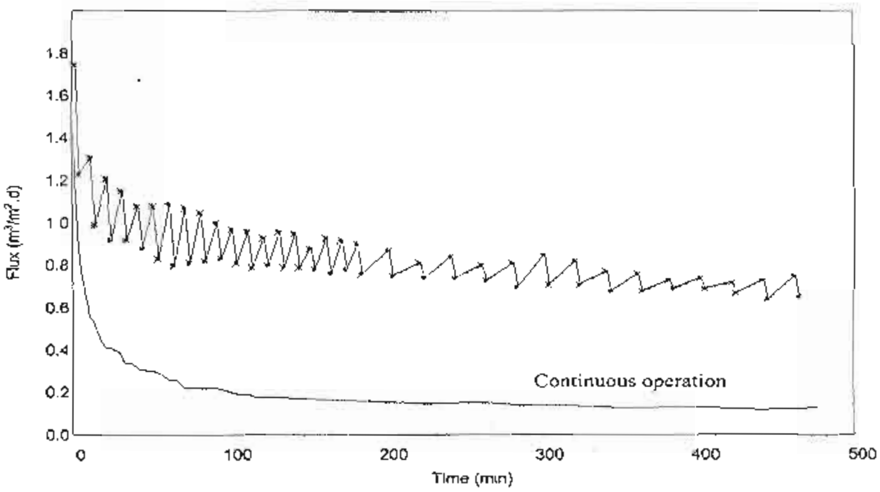

Fig. 2. Permeate flux obtained at continuous operation and 5:5 cycle

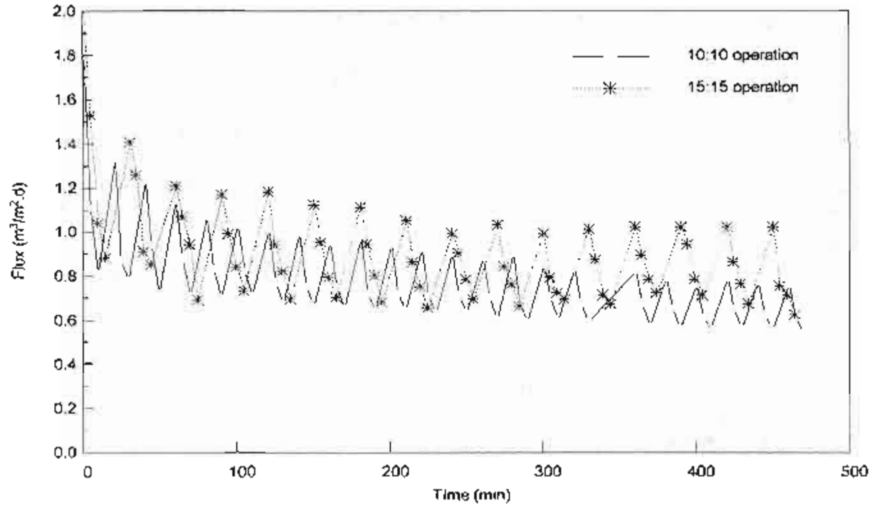

Fig. 3. Permeate flux obtained at 10:10 and 15:15 cyclic operations

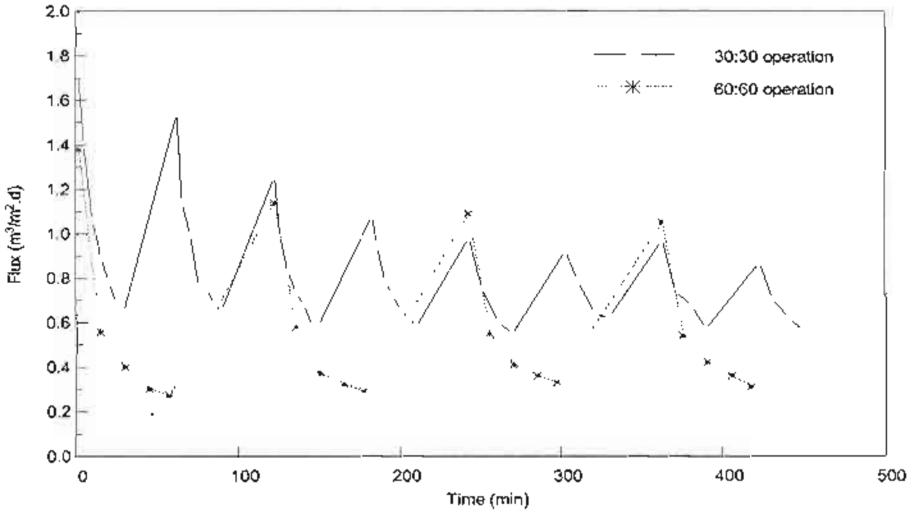

Fig. 4. Permeate Flux obtained at 30:30 and 60:60 cyclic operations

When considering the recovery of permeate flux by air backwash, 60:60 operation gave the highest recovery. This is because it provides for a higher air diffusion period. However there was a big decrease of permeate flux in the 60.60 cycle. On the other hand, in case of 5:5 operation, due to the shorter time of water filtration, the reduction of permeate flux in each cycle is not much, but due to shortest duration of air backwash also, recovery in permeate flux becomes smallest Moreover, 5:5 operation have more cycles per hour, which would lead to higher time lag (time from starting filtration period to time having filtrate). This also affected the net cumulative permeate volume Fig. 5 shows that 15.15 operation gave the maximum cumulative permeate volume. Therefore it can be concluded that duration for air diffusion and for water filtration inversely affect the net cumulative permeate volume By considering all these factors, 15:15 cycle was the optimum operation mode and was used in the long-term experiments.

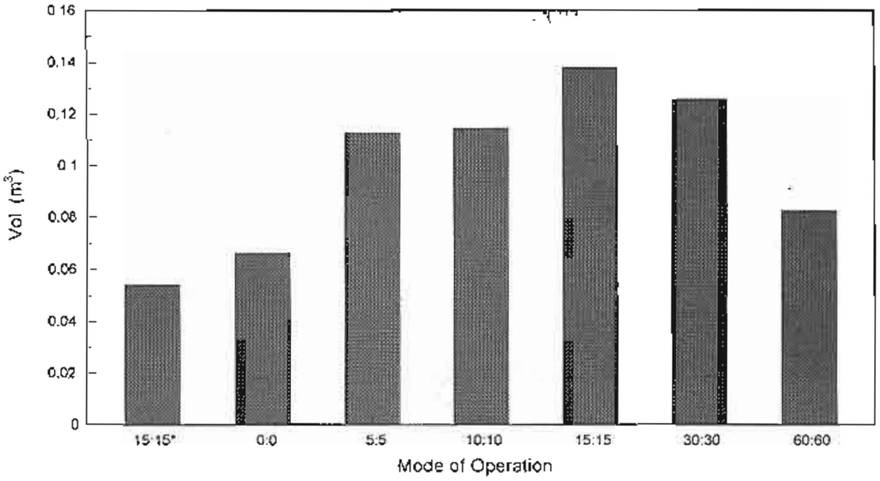

Fig. 5. Comparison of net cumulative permeate volume (after 8 hours) at different modes of operation (15*:- 15 min. without air diffusion)

Transmembrane Pressure

Fig. 6 shows the variation of transmembrane pressure with time for two similar membrane modules in three experimental runs. Transmembrane pressure in Run 1 of both membrane modules was almost constant throughout the period due to the small amount of MLSS (4574 mg/L) in the bioreactor For Run 2, it was found that transmembrane pressure remained constant in the early stage of the run and had an average value about 4.68 and 4.76 kPa for both modules. Then, transmembrane pressure increased rapidly after the 15th day indicating the clogging of membrane. Therefore, the membranes were cleaned in fresh water with continuous air diffusion This cleaning mechanisms helps to remove some of the clogging but not the total removal. During Run 3 wherein the MLSS value was highest at 7476 mg/L, transmembrane pressure increased rapidly within 3 days. This indicated the inefficiency of air back washing to remove the cake layer and that chemical cleaning of the membranes was needed. Thus, after soaking these membranes in sodium hypochlorite solution, transmembrane pressure increased slowly and no drastic clogging was observed in the succeeding experiments.

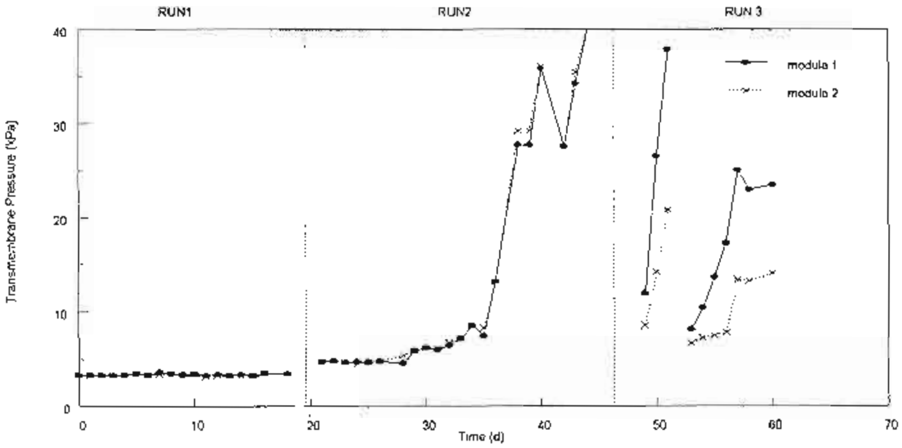

Fig. 6. Variation of transembrane pressure for different runs

COD Removal

Fig 7 shows the influent and effluent COD of Runs 1, 2 and 3 The influent COD was maintained in the range 200-300 mg/L. The removal efficiency in all runs was maximum from the beginning which was greater than 90%.

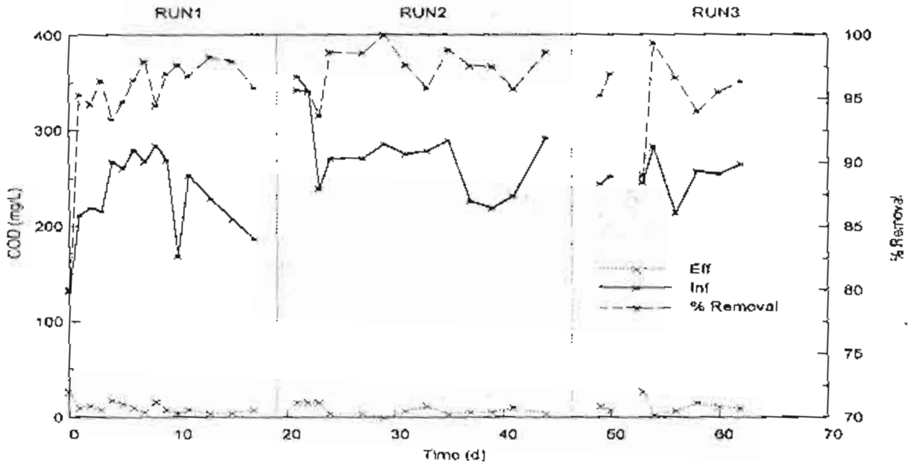

Fig. 7. Variation of COD for different runs

MLSS

The variation of biomass concentration at different HRT is presented in Fig 8 For Run 1 which had a volumetric organic loading of 0.4-0 6 kgCOD/m^3 d, the MLVSS/MLSS ratio was constant in the range of 28-31% For Run 2 which had a volumetric organic loading of 0.9-1 2 kgCOD/m^3 d, MLSS rapidly increased from 3370 mg/L to 6356 mg/L while MLVSS only increased slightly. MLVSS/MLSS ratio was in the range of 23-29%. For Run 3, MLVSS/MLSS ratio was in the range of 21-25 %.

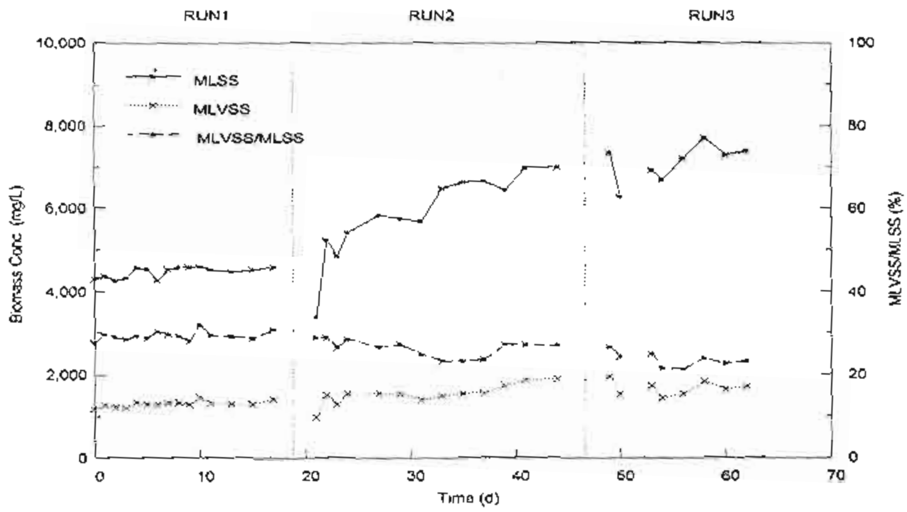

Fig. 8. Variation of biomass concentration for different runs

The general decreasing trend of MLVSS/MLSS in the bioreactor could be explained by the constant accumulation of inorganic matter within the reactor while the organic matter (MLVSS) concentration is quasi constant at 1600-1700 mg/L. Therefore, longer experimental runs will theoretically lead to relatively low MLVSS/MLSS ratio Such situation may hinder the biomass growth, possibly reduce MLVSS and the reactor organic removal performance. In order to avoid such phenomenon in long runs, it is always advisable to drain periodically the sludge from the reactor to maintain significant MLVSS/MLSS ratio

Microorganism in the Reactor

Samples were taken from the bioreactor and observed in the microscope to identify the various types of microorganisms present. *Stalked Protozoa* was found in the reactor while *Paramecium* and *Ciliates* were predominant in the first run. *Rotifer* and *Nematodes* were found greater in the last experimental runs. The presence of *Nematodes* indicates that the reactor has low F/M ratio, high SRT and biomass which tend to form as pin flocs making it difficult for microorganisms to attach to the membrane surface.

CONCLUSIONS

This study proved that membrane air diffusion/aeration process plays an important role in the improvement of permeate flux by removing external deposits on the membrane, preventing the compaction of cake layer and removing internal pore clogging of the membranes. Although cyclic operation with air diffusion could not completely remove the clogging, air backflush technique could improve the flux by up to 371% compared to the continuous operation. By considering the recovery of permeate flux and net cumulative permeate volume, 15 15 (15 minutes of filtration and 15 minutes of air diffusion) cycle was found to be the optimum operation mode

COD removal in all runs were greater than 90% with effluent concentration below 20 mg/L. Due to extremely high solids retention time (SRT) in the bioreactor, there was no significant COD removal for various volumetric organic loading The effluent quality in terms of SS, TKN and total phosphate was extremely good. The MLVSS/MLSS in the bioreactor was in the order of 20-30% Inorganic mass balance calculation indicated a steady accumulation within the reactor. The lower fraction of active microorganisms in the bioreactor, did not show any significant effect on the process efficiency Nevertheless, it is anticipated that in longer run it might affect the process, thus it is advisable to have periodical sludge draining.

The membrane cleaning process adopted in this study was found to be adequate in removing mainly the external membrane resistance. Nevertheless, it is necessary to have chemical cleaning procedure for complete elimination of internal and external resistances caused by macromolecular adsorption. From the process efficiency point of view, the membrane bioreactor produced extremely better quality effluent than the conventional activated sludge process and could totally eliminate the common operational problem of sludge bulking. However use if 0.1 μm need a huge suction pressure and due to the membrane's inability to bear more than 100 kPa pressure, air backwash pressure was limited to 100 kPa. Use of large pore size (>0 2μm) membrane can produce similar quality effluent at low suction pressure. Also use of structurally stable membrane module which can withstand higher air backflushing pressure can remove cloggings effectively

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