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Effects of filtration modes on membrane fouling behavior and treatment in submerged membrane bioreactor

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HIGHLIGHTS

- Longer filtration duration observed for 8 min filtration and 2 min relaxation mode.
- Low specific cake resistance was found in $MBR_{(8+2)}$ and high in $MBR_{(12+3)}$.
- Short filtration and relaxation cycles corresponded to less membrane fouling.
- High microbial activity of MBR sludge is responsible for rapid fouling rate.

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ABSTRACT

Relaxation or backwashing is obligatory for effective operation of membrane module and intermittent aeration is helpful for nutrients removal. This study was performed to investigate effects of different filtration modes on membrane fouling behavior and treatment in membrane bioreactor (MBR) operated at three modes i.e., 12, 10 and 8 min filtration and 3, 2, and 2 min relaxation corresponding to 6, 5 and 4 cycles/hour, respectively. Various parameters including trans-membrane pressure, specific cake resistance, specific oxygen uptake rate, nutrients removal and sludge dewaterability were examined to optimize the filtration mode. TMP profiles showed that $MBR_{(8+2)}$ with 8 min filtration and 2 min relaxation reduced the fouling rate and depicted long filtration time in MBR treating synthetic wastewater. $MBR_{(12+3)}$ was more efficient in organic and nutrients removal while denitrification rate was high in $MBR_{(8+2)}$.

1. Introduction

Water scarcity affects many countries in the world and about 700 million people are under water stress condition. This situation can worsen further if the water resources are not managed properly. So with increasing pressure on fresh water availability, water reclamation and reuse is of utmost importance to cope with this problem (Maton et al., 2010).

Among the wastewater treatment technologies membrane bioreactor (MBR) which is a combination of biological degradation and separation by low pressure driven micro- or ultra-filtration membranes is the most emerging technology over the past two decades (Jahangir et al., 2012; Malaeb et al., 2013). Major advantages of MBR over activated sludge process are: (i) small foot print, (ii) high concentration of mixed liquor, (iii) compact size, and (iv) high quality treated water (Deng et al., 2014; Judd, 2008; Nywening and Zhou, 2009). High quality effluent from MBR, mostly as aerobic type, is suitable for further polishing by nanofiltration and reverse osmosis.

Membrane bioreactor has become a well-established treatment process for both industrial and domestic wastewaters. Membrane filtration in MBR represents a definite barrier for activated sludge flocs which allows the operator to effectively separate hydraulic retention time (HRT) and sludge retention time (SRT) in achieving high quality effluent. Nutrient removal is high in MBR because of high SRT necessary for slow growing nitrifiers and some other microorganisms (Ersu et al., 2010). However, membrane fouling due to deposition of undesired colloidal particles, sludge flocs and cell debris on membrane surface and inside the membrane fibers is the main problem in widespread application of MBR (Guo et al., 2012). Membrane fouling results in high trans-membrane pressure (TMP) and flux decline, which deteriorate

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the membrane performance, requiring frequent membrane chemical cleaning and ultimately replacement of membranes which raises the operational cost of MBR (Akhondi et al., 2014; Flemming, 2002; Kornboonraksa et al., 2009; Nguyen et al., 2013).

It is difficult to develop a relationship between membrane fouling and different environmental parameters, operational conditions and membrane material properties. Fu et al. (2012) examined the effects of aeration rate, aeration position and aeration time and found that aeration time and rate affect positively than aeration position in terms of effluent quality and low fouling. Lim et al. (2007) found that microbial concentration increases in aeration ON time and EPS components increase as OFF time becomes longer. Cake layer contributes more in flux reduction than internal clogging. Cake layer can easily be removed by physical cleaning and classified as reversible fouling while chemical cleaning used for the removal of internal precipitated compounds which causes pore blockage, is classified as irreversible fouling (Chang et al., 2002). Pore blockage and cake layer formation are two main fouling types; in early stages pore blockage resistance is dominant, and in later stage cake layer formation is the major cause of rapid rise in TMP (Lim and Bai, 2003).

Many researchers have studied the control of membrane fouling by varying filtration and backwashing cycles, changing membrane surface structure architecture, adding moving media and adsorbents (Zsirai et al., 2012). However, the efficiency of relaxation in terms of membrane filtration and relaxation cycle of MBR operation is yet to be optimized. Relaxation, also termed as temporary cessation or pausing of membrane production mode, allows back transport of foulants away from the membrane surface through the concentration gradient i.e., diffusion which is further enhanced by maintaining air scour (Wang et al., 2014; WEF, 2012). Intermittent filtration with suitable hydrodynamic conditions is effective technique for maintaining high flux over long term and allow for stable operation even above critical flux having positive effects on membrane fouling (Chua et al., 2002; Wu et al., 2008). As compared to backwashing, relaxation has a positive effect on membrane fouling control since backwashing by the permeate causes blockage of membrane pores (Wu et al., 2008).

This study was aimed to investigate the effect of different filtration and aeration modes on fouling propensity, fouling rate and cake formation in terms of TMP rise, microbial activity, dewaterability of sludge and treatment performance of MBRs.

2. Methods

2.1. Bench-scale membrane bioreactor

The experimental setup of bench-scale membrane bioreactor is shown in Fig. 1 with a working volume of 35 L and immersed hollow fiber membrane (Memstar, China) having pore size of 0.1 μm with surface area of 0.7 m^2. The permeate flux was maintained at 15 $L/m^2/h$ (LMH) resulting in hydraulic retention time (HRT) of 4 h. The biomass concentration was maintained between 10 and 11 g/L by withdrawing MBR sludge corresponding to solids retention time (SRT) of 20 days. Membrane module had built-in aerator for coarse bubbling; additional stone aerators were also used for complete mixing and to avoid bottom dead zones. For aeration, air compressor (EW-07054-10, Cole Parmer, USA) was used and air flow was controlled through air flow controller. Permeate flow rate was maintained using peristaltic pump (Masterflex, 77200-62, Cole Parmer, USA). Contents of synthetic wastewater were kept well mixed using mechanical mixer (Stir Pak, EW-50007-32, Cole Parmer, USA).

2.2. Wastewater composition

Synthetic wastewater with a medium strength having COD:N:P as 100:10:2 was used as substrate for microbes. Recipe for wastewater included, glucose 514 mg/L (COD 500 mg/L), ammonium chloride (NH_4Cl) 190 mg/L, potassium di-hydrogen phosphate (KH_2PO_4) 55.6 mg/L, calcium chloride ($CaCl_2$) 5.7 mg/L, magnesium sulfate ($MgSO_4 \cdot 7H_2O$) 5.7 mg/L, ferric chloride ($FeCl_3$) 1.5 mg/L and manganese chloride ($MnCl_2 \cdot 4H_2O$) 1 mg/L. pH of wastewater was maintained between 7.0 and 7.5 using sodium bicarbonate ($NaHCO_3$). Seed sludge, taken from full scale Sewage Treatment Plant (Sector I-9, Islamabad, Pakistan), was acclimatized for one month period with synthetic wastewater before transferring to bench-scale MBR. Organic loading rate (OLR) and nitrogen loading rate (NLR) were maintained at 3 $kg/m^3/d$ and 0.3 $kg/m^3/d$.

2.3. Analytical methods

Effluent chemical oxygen demand (COD) were measured according to Standard Methods (APHA et al., 2005). Sludge samples was collected to assess sludge characteristics in terms of mixed liquid suspended solids (MLSS), mixed liquid volatile suspended

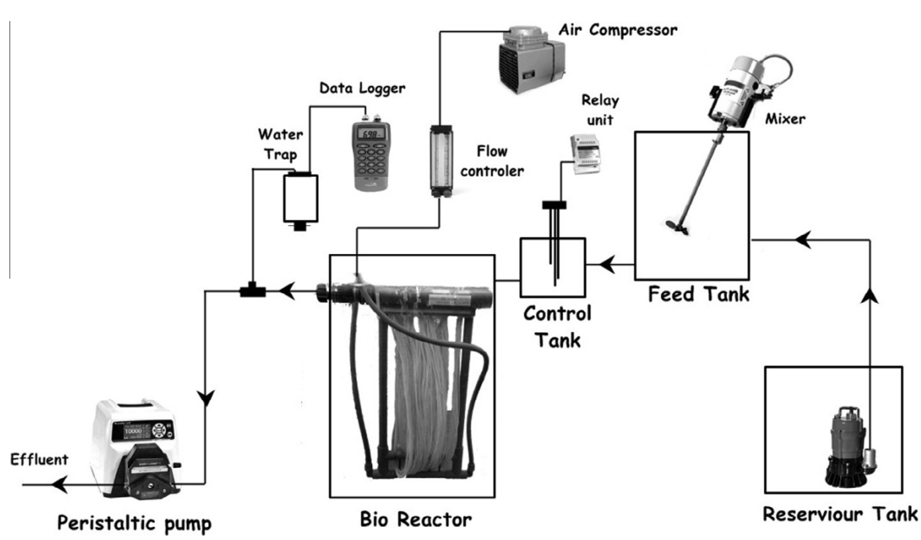

Fig. 1. Process flow diagram for bench-scale MBR.