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Operational performance of a submerged membrane bioreactor for reclamation of bath wastewater

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Abstract

Bath wastewater is an ideal wastewater-reclamation source for its large discharge amount, simple pollutant composition and low pollutant content. The feasibility of reclaiming bath wastewater with a membrane bioreactor was investigated in a pilot plant of 10 m^3 per day at an organic load of 0.50–1.85 kg-COD/(m^3 per day). The operation was continued for 216 days without sludge discharge and chemical cleaning of membrane modules. The quality of the effluent obtained met the wastewater reclamation standard of China, with COD < 40 mg/l, NH_4^+−N <0.5 mg/l and anionic surfactant (AS) <0.2 mg/l. Biological treatment removed most pollutants in the influent, degrading 34–85% of COD and 98% of anionic surfactant. The membrane separation balanced the unstable biological treatment of COD but demonstrated no contribution to anionic surfactant removal. Inorganic substances were found to accumulate in the bioreactor. The main reason for membrane fouling was considered to be sludge adhesion and gel layer formation over the outer membrane surface and microbial growth over the inner membrane surface.

Keywords: Membrane bioreactor; Wastewater reuse; Wastewater reclamation; Filtration; Membrane fouling; Membrane cleaning

1. Introduction

Wastewater reclamation has been studied mostly on municipal wastewater so far. Few literature have concentrated on bath wastewater although this is even a better source for wastewater reclamation than municipal wastewater because of its large discharge amount, simple pollutant composition and low pollutant content. Reclaiming bath wastewater separately from the sewage is considered helpful to ensure the quality of the recycled water and consequently to reduce the exposure risk to various unknown hazard substances. However, operational problems may take place when bath wastewater is treated with conventional biological wastewater treatment processes. A high content of surfactants in the bath wastewater exposures the treatment system to a risk of sludge foaming. Moreover, a low content of organics may result in sludge concentrations not high enough to remove surfactants efficiently.

The membrane bioreactor is a promising technology for wastewater treatment and recycling due to its high running performance such as the excellent and stable effluent quality, high organic loading rate, compact structure as well as low excess sludge production [1,2]. By substituting the settling tank in a conventional activated sludge process with a membrane filtration device, all micro-organisms are retained in the bioreactor and the hydraulic retention time (HRT) becomes completely independent on the sludge retention time (SRT) [3]. High sludge concentration can therefore be achieved even in a short HRT. Some macromolecules are also retained in the bioreactor so that the contact time of activated sludge and pollutants is elongated, facilitating efficient removal of slowly biodegradable pollutants [4,5]. The effluent of the membrane bioreactor is normally free of bacteria and has a potential in municipal and industrial reuse [6,7]. The advantages of the membrane bioreactor as mentioned above benefit reclamation of bath wastewater.

In this study, long-term performance was investigated in a membrane bioreactor to treat bath wastewater. The effluent quality was monitored and subsequently compared with the current water reclamation standard of China. Contributions

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of biodegradation and membrane separation to COD and anionic surfactant (AS) removals were examined. The growth of activated sludge and the behaviour of inorganic substances were investigated. Membrane fouling development was monitored and analysed.

2. Materials and methods

2.1. Experimental system

The membrane bioreactor applied in this study was a completely mixed aeration tank (effective capacity of 1.5 m^3) in which were submerged eight hollow fibre membrane modules (total filtration area of 32 m^2) (Fig. 1). The aeration tank was divided into one riser zone (cross-flow area of 0.32 m^2) and two down-comer zones (cross-flow area of 0.23 m^2 each) by two baffle plates. Membrane modules (polyethylene, pore size 0.4 μm, filtration area 4 m^2 each, Mitsubishi Rayon Co. Ltd.) were allocated into two layers by four parallel rows in the riser zone. Air was supplied right below membrane modules for supplying oxygen, mixing and inducing cross flow over the membrane surface. The water level was maintained constant by a floatswitch connected to an electromagnetic valve in the influent pipe. The effluent flow rate and the transmembrane pressure were respectively monitored with sensors.

Raw wastewater was collected from a public bathroom in Tsinghua University, Beijing, China. The bathroom served more than 3000 students daily. Wastewater was mainly produced from a shower bath. Discharge from a small toilet in the bathroom was also combined, but the amount was very small. Fresh wastewater was collected once per day into an elevated tank after filtration with a stainless steel screen of 1.2 mm to remove garbage and hairs. Then after filtration through another stainless steel screen of 0.9 mm, the stored wastewater was supplied into the bioreactor through the electromagnetic valve.

The membrane bioreactor was designed for treating 10 m^3 of wastewater daily. The mixed liquor in the bioreactor was intermittently extracted through membrane modules by suction of a pump at a fixed filtration flux. The corresponding filtration flux and HRT were respectively 13 l/(m^2 h) and 3.6 h. A suction mode of 13 min on and 4 min off was adopted. No sludge was discharged. No chemical cleaning of membrane modules was carried out.

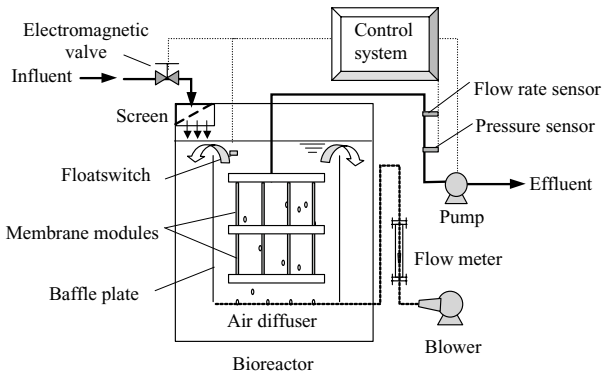

Fig. 1. Schematic flow diagram of experimental apparatus.

2.2. Analytical items and methods

All items on the quality of the influent, supernatant and effluent, together with the mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were measured according to the standard methods [8]. AS was determined as methylene blue active substances (MBAS) with a colorimetric method and the linear alkylbenzene sulphonate (LAS) was taken as the reference substance [8]. Supernatant was obtained by centrifuging the mixed liquor for 15 min at 4000 rpm (LG10-2.4A, Beijing Medical Centrifuge Corporation) then filtering through a membrane of 0.45 μm.

Scanning electron microphotographs (SEMs) of the fouled membrane fiber were taken by a scanning electron microscope (HITACHI S-570) after preparation following the standard procedure.

3. Results and discussion

3.1. Effluent quality

The reactor was continuously operated for 216 days while the quality of the feed water and process effluent was periodically monitored. A stable and excellent effluent quality in terms of COD and AS was obtained all the time despite the fact that the correspondent values of the influent respectively fluctuated in a range of 126–322 and 3.46–8.90 mg/l (Fig. 2). As a whole, effluent COD concentrations were 2–37 mg/l with a mean value of 18 mg/l and AS concentrations were 0.03–0.21 mg/l with a mean value of 0.08 mg/l.

Other items on quality of the influent and effluent were also determined when the operation went to pseudo-steady state (Table 1). All suspended solids (SS) and most of the biological oxygen demand (BOD_5) in the influent were removed after being treated with the membrane bioreactor. Compared with the French grey, turbid, shampoo-odoured influent, the effluent appeared clear, transparent and odourless. The effluent quality met the water reuse standard of China (CJ25.1–89) (Table 1), thus the effluent could be used for car washing, land watering and toilet flushing.

Sludge foaming often occurred in the reactor owing to the high content of anionic surfactant in the feed. Brown foam sometimes was as thick as 15 cm over the activated sludge surface and some of the foam flowed out of reactor from the overflow pipe. The effluent quality, however, was not negatively influenced, showing advantage over the conventional activated sludge system in which the foam would