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Removal of organic pollutants and analysis of MLSS–COD removal relationship at different HRTs in a submerged membrane bioreactor

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Abstract

In order to investigate the influence of hydraulic retention time (HRT) on organic pollutant removal in a submerged membrane bioreactor (SMBR), a laboratory-scale experiment was conducted using domestic sewage as influent. The dissolved oxygen (DO) concentration was controlled at 2.0–3.0 mg L^{-1} during the experimental period. The experiments demonstrated that when HRT was 3, 2 and 1 h, the reduction of chemical oxygen demand (COD) was 89.3–97.2, 88.5–97.3 and 80–91.1%, and the effluent COD was 38.9–11.2, 41.6–10.8 and 63.4–35.8 mg L^{-1}, respectively. It is suggested that an HRT of 1 h could meet the normal standard of discharged domestic sewage, and an HRT of 2 h could meet that of water reclamation. In addition, we use mathematical software MATLAB to analyse the relation of mixed liquor suspended solids (MLSS) and COD removal. The results showed that the optimum MLSS concentration should be maintained at around 6000 mg L^{-1} in the SMBR. The results also showed that the COD removal was related to HRT (τ), influent concentration (S_0) and sludge loading rate for COD removal (N_S). Moreover, the high COD removal could be achieved through adjusting τ, S_0 and N_S.

Keywords: Submerged membrane bioreactor (SMBR); Domestic sewage; HRT; MLSS; COD removal

1. Introduction

It is well known that submerged membrane bioreactors (SMBRs) have the following advantages for wastewater treatment: high sludge concentration (Halil Hasara et al., 2002), high quality of effluent, long contact time between activated sludge and organic pollutants (Brindle and Stephenson, 1996), and complete separation of the hydraulic retention time (HRT) and sludge retention time (SRT) (Ueda et al., 1996; Devies et al., 1998; Guender and Krauth, 1998). Moreover, highly treated water in an SMBR is free from bacteria and has potential for municipal and industrial reuse (Xing et al., 1998). Although there are shortcomings of high-cost and high-energy consumption, SMBR technology has been applied to wastewater treatment and reclamation previously (Chiemchaisri et al., 1993; Knoblock et al., 1994; Trouve et al., 1994). In Europe, America and Japan, SMBRs are used to rebuild sewage treatment plants and to reclaim wastewater.

It is accepted that HRT is the key to further improving the capacity of an SMBR. At present, when an SMBR is used for domestic sewage treatment, the HRT is set at 1.5–7.5 h in laboratory-scale tests and at 2.7–34.2 h in the pilot-scale tests (Makoto et al., 1998; Urbain et al., 1998; Defrance and Jaffrin, 1999; Huang et al., 2000; Gu and He, 2002; Shim et al., 2002). When Rosenberger et al. (2002) used a membrane bioreactor to treat municipal wastewater at HRTs varying from 10.4 and 15.6 h, the concentration of mixed liquor suspended solids (MLSS) gradually increased and the chemical oxygen demand (COD) was reduced by 95%. Until now, the lowest HRT, 1.5 h, has been designed by Stefan and Walter (2001) to treat synthetic wastewater. The organic loading rate (OLR) in their study was in the

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range 6.0–13.0 kg m^{-3} day^{-1}, and COD reduction was >95%. However, little has been reported on the optimum HRT needed to meet reused water quality standard, and how to control the operational conditions of SMBRs in order to reach different water quality standards.

The purpose of this study was to investigate the shortest HRT needed in SMBRs in order to reach different water quality standards and the effect of HRT on COD removal. A laboratory-scale experiment was conducted using artificial domestic sewage as influent in an SMBR. The dissolved oxygen (DO) concentration was controlled at 2.0–3.0 mg L^{-1} for the duration of the experimental period, and the HRT at 3, 2 and 1 h. The effect of MLSS on COD removal at different HRTs is examined.

2. Materials and methods

2.1. SMBR

The plexiglass SMBR (Fig. 1) had a working volume of 7.0 L. The hollow polypropylene fibre membrane module employed in this study was 0.5 m long and had a pore size of 0.1 μm and surface area of 2.0 m^2. The process was maintained at 20–25 °C. The height was from liquid surface in the bioreactor to effluent port. The mixed liquor in the bioreactor was driven under the height by gravitation and passed through the hollow fibre membrane module. Aeration was employed to maintain an aerobic environment for the normal growth of activated sludge. The amount of air was adjusted using a gas flow meter and controlled at 0.3–0.5 m^3 h^{-1}. The water level in the SMBR was controlled by a ballcock in the water balance tank, which balanced the flux of effluent and influent.

2.2. Substrate

The artificial domestic sewage containing (mg L^{-1}) glucose (300–400), beef grease (20–40), peptone (20–40), NH_4Cl (5–10), Na_2HPO_4 (5–10) and NaH_2PO_4 (5–10) was used as influent. The influent was maintained at pH 7.0 by adding NaOH. Influent COD concentration was 350–500 mg L^{-1}.

2.3. Inoculation and acclimation of activated sludge

Activated sludge was taken from the aeration pool in Harbin Refinery and was incubated in batch culture. After 7 days, MLSS reached 1858 mg L^{-1}. An old membrane module (operated for 1 year in the same bioreactor) was added to the bioreactor to operate the SMBR continuously. Seven days later, MLSS reached 2820 mg L^{-1}. The old membrane module was taken from the bioreactor and a new membrane module was added to the bioreactor to operate the SMBR. With incubation and acclimation for 14 days, the colour of the flocs changed to a brown colour. The amount of

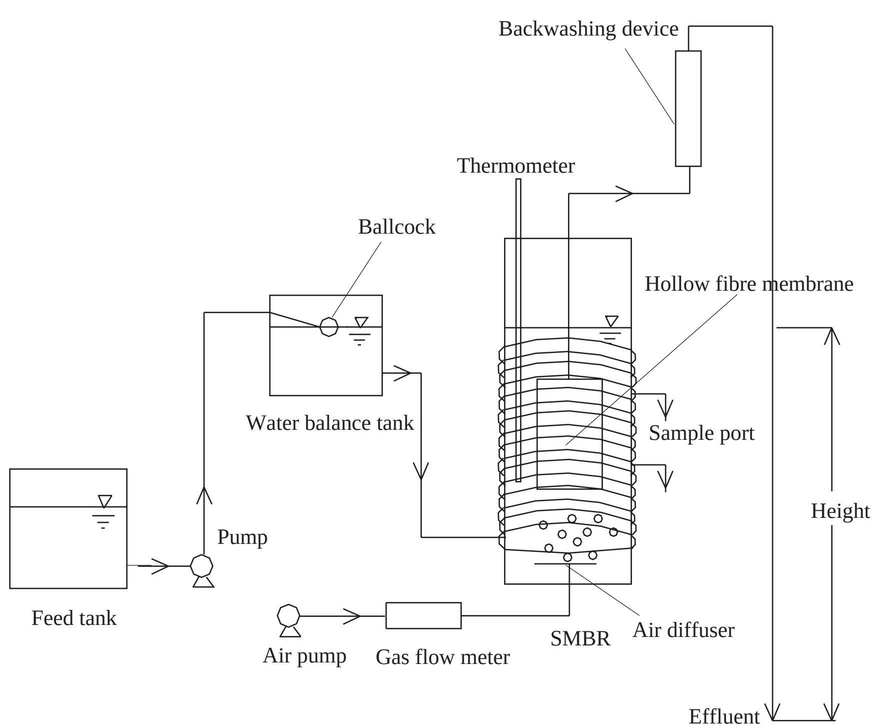

Fig. 1. Schematic diagram of the SMBR.