沉浸式生物薄膜反應器之積垢特性探討

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摘　要

生物薄膜反應器 (membrane bioreactor, MBR)之特點在於以薄膜單元取代傳統沉澱池，達到有效之固液分離。目前 MBR 無法被廣泛應用的原因為薄膜積垢 (membrane fouling)。薄膜積垢的發生會使得薄膜通量衰減或透膜壓力 (transmembrane pressure, TMP)增加，導致清洗薄膜的次數增多而縮短薄膜壽命，提高操作及維護成本。本研究欲對 MBR 進行薄膜積垢影響因子及其阻塞成因之探討。

MBR 於次臨界通量下 (sub-critical flux)操作，積垢速率極為緩慢，但隨著系統中絲狀細菌的增加，積垢速率急遽增加，推測與污泥黏滯性及胞外聚合物 (extracellular polymeric substances, EPS)中多醣類濃度有關。薄膜過濾阻抗以濾餅阻抗 (R_c)為主，隨著薄膜滲透率(permeability)的增加，R_c 及總阻抗 (R_t)會變大，但孔洞阻塞阻抗 (R_f)則會變小，可能原因為濾餅的形成可做為薄膜表面之屏障，避免小分子物質的進入。水流剪力的增加雖能有效降低 R_c 及 R_t，卻無法改善 R_f，反而會因 R_c 的減少而使其增加。懸浮顆粒 (R_{ss})、膠體物質 (R_{col})及溶解性物質 (R_{sol})分別貢獻了 62 %、31 %與 7 %之過濾阻抗。水流剪力的提升對於降低污泥阻抗 (R_{AS})最為有效，$R_{col+sol}$ 其次，R_{sol} 則無效。由於膠體或溶解性物質不易受系統水力條件影響，因此即使 MBR 於次臨界通量下操作，仍會有薄膜積垢的產生。

關鍵字：生物薄膜反應器、薄膜積垢、透膜壓力、次臨界通量、胞外聚合物、薄膜滲透率、水流剪力

Fouling Characteristics of MF Membrane in Submerged Membrane Bioreactor

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Abstract

By replacing a secondary clarifier with a membrane unit in an activated sludge process (ASP), membrane bioreactors (MBRs) have emerged as one of the innovative solutions for wastewater treatment and reclamation. The application of MBR is constrained by membrane fouling. Fouling leads to permeate flux decline and transmembrane pressure (TMP) increase, resulting in more frequent membrane cleaning and replacement which increase the operating cost. This study is to investigate the mechanism of membrane fouling.

The lab-scale MBR was operated under sub-critical flux. The fouling rate of the MBR was very low. However, with the increase in filamentous bacteria, an abrupt rise in fouling rate was observed along with the increased sludge viscosity and polysaccharides in extracellular polymeric substances (EPS) suggesting their close relationship. Cake resistance (R_c) was the dominant resistance in batch filtration tests. The increase in total resistance (R_t) and R_c and the decrease in pore resistance (R_f) with increasing membrane permeability suggested that the cake formed on the membrane surface hindered the penetration of smaller particulates inside the membrane pores. Although increasing hydraulic shear stress could effectively reduce the R_t and R_c, the R_f increased due to the reduced cake barrier. The relative contributions of SS (R_{ss}), colloid (R_{col}) and solutes (R_{sol}) toward total resistance were 62 %, 31 % and 7 %, respectively. Hydrodynamic control was a powerful method to mitigate macroscopic fouling (R_{AS}), but it could not prevent the deposition of soluble macromolecules (R_{ss}). Despite the choice of filtration at sub-critical flux, fouling was experienced due to the effect of soluble macromolecules.

Keywords: Membrane bioreactor; Membrane fouling; Transmembrane pressure (TMP); Sub-critical flux; Extracellular polymeric substances (EPS); Permeability; Shear stress