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自生动态膜生物反应器处理有机废水的工艺及运行参数优化研究

Optimization of process and operation parameters of organic wastewater treatment by self-forming dynamic membrane bioreactor

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摘 要

印染废水与畜禽养殖废水是目前排放量较大且处理难度较高的有机废水。膜生物反应器（MBR）具有占地面积小、固液分离效率高、耐负荷冲击能力强、出水水质稳定等特点，在上述废水处理应用方面取得了较好的效果。但 MBR 法处理有机废水过程中，膜污染难题难以得到有效控制和解决。动态生物膜反应器（DMBR）由于具备造价低、阻力小、易清洗等优点，被广大研究工作者关注并研究。但动态膜工艺在运行过程中存在膜污染问题，因此动态膜污染及调控策略是目前污水处理领域关注的热点和难点。

本文观察了动态膜在形成初、中、末期的形态变化，发现随着动态膜的形成，动态膜表面的凝胶层逐渐增多，动态膜基材的孔隙逐渐缩小，截留能力越来越强。胞外蛋白质变化趋势与动态膜表面形态变化相吻合，说明胞外蛋白质含量是影响动态膜凝胶层形成的主导作用。进一步分析了活性污泥特性、曝气强度、膜通量及出水水头对动态膜的影响，发现增加污泥浓度可缩短动态膜到达稳定的时间，但过高的污泥浓度会加剧膜污染；增加曝气量会减慢动态膜的形成，有利于抑制动态膜的污染，但过高的曝气强度会影响动态膜的形成；增大出水水头可加速动态膜形成，也会增加动态膜的跨膜压差，加速膜污染。采用压力阶梯法测量本实验所用膜组件的临界通量约为 20.8～20.9 L/(m^2 h)。本系统最佳运行参数为：污泥浓度 12.0 g/L，曝气量 2.0 L/min，膜通量小于 20.5 L/(m^2 h)，出水水头 2.5 cm。

在最佳运行参数下采用单独好氧工艺处理实际生活废水，COD 去除率 77.5～81.1%；氨氮去除率 2.0～80.8%。采用单独厌氧工艺处理实际生活废水，COD 去除率 54.6～70.7%；氨氮去除率 30.8～90.2%。采用厌氧-好氧串联工艺处理实际生活废水，COD 去除率 80.0～90.7%；氨氮去除率 73.7～94.8%。采用厌氧-好氧循环工艺处理实际生活废水，COD 去除率 90.3～94.0%；氨氮去除率 54.2%～99.9%。厌氧-好氧循环工艺 COD 及氨氮去除率均优于厌氧-好氧串联工艺。

利用动态膜处理模拟印染废水，分析处理过程中色度、COD 变化情况，得

到以下结果：厌氧-好氧串联工艺处理模拟印染废水，色度去除率为 78.3～94.3%；COD 去除率为 70.4～92.0%。厌氧-好氧循环工艺处理模拟印染废水，色度去除率为 83.8～89.6%；COD 去除率为 80.5～93.8%。厌氧-好氧循环工艺出水的 COD 去除率略优于串联工艺，循环工艺出水水质比串联工艺稳定。

利用动态膜处理模拟养殖废水，分析处理过程中 COD、氨氮变化情况，得到以下结果：厌氧-好氧串联工艺处理模拟养殖废水，COD 去除率 78.8～92.7%；氨氮去除率 82.3～87.2%。厌氧-好氧循环工艺处理模拟养殖废水，COD 去除率 75.2～89.4%，氨氮去除率由最初的 84.8～92.3%。厌氧-好氧循环工艺 COD 去除率与串联工艺相当，但系统出水水质稳定，系统适应期很短；在氨氮去除方面效率更高，但系统适应时间稍长。在运行过程中发现，串联工艺厌氧反应器动态膜比好氧反应器易受到污染；循环工艺厌氧反应器膜污染的速度小于串联工艺，好氧反应器膜堵塞速度大于串联工艺。

关键词：动态膜；有机废水；膜污染

Abstract

Dyeing and livestock breeding wastewater with high amount emission are hard to treatment. Membrane bioreactor (MBR) provides a good effect in the treatment of the wastewaters with less land occupation, high solid liquid separation efficiency, strong load impact resistance, and stable outlet water quality. However, in the process of high concentration organic wastewater treatment by MBR method, the problem of membrane fouling is difficult to be effectively controlled and resolved. So the dynamic membrane bioreactor (DMBR) has been concerned and studied by the majority of researchers because of low cost, low resistance, easy cleaning and recovery. However, in the process of operation, the dynamic membrane has the same membrane fouling problem. Therefore, the dynamic membrane fouling and the control strategy are hot spots in the field of wastewater treatment.

This paper studies the morphological changes of dynamic membrane in the first, middle and late stages. It was found that the gel layer on the surface of the dynamic membrane increased; the porosity of the dynamic film substrate narrowed and the retention ability became stronger during the formation of dynamic membrane. More important, the trend of exogenous protein were also the same with the morphological changes of the dynamic membrane, which indicating that the extracellular protein content is the leading role in the formation of dynamic membrane gel layer. In addition, the effects of activated sludge characteristics, aeration intensity, flux and water head on the dynamic membrane were analyzed. It was found that increasing the sludge concentration could shorten the time of dynamic membrane reaching stable state. However, the excessive sludge concentration would increase the membrane fouling. Moreover, increasing the aeration rate will slow down the formation of the dynamic membrane, which is conducive to the suppression of the pollution of the dynamic membrane. On the other hand, the high aeration intensity will affect the formation of dynamic membrane. Increasing the water head can accelerate the dynamic membrane formation, also facilitate the transmembrane pressure difference of the dynamic membrane, and then accelerate the membrane fouling. The critical flux of the membrane module used in this experiment is about 20.8 ~ 20.9 $L/(m^2 \cdot h)$. The optimal operating parameters for preventing the dynamic membrane fouling were obtained. These parameters were: 12 g/L of sludge concentration, 2 L/min of aeration rate, less than 20.5 $L/(m^2 \cdot h)$ of membrane flux, 2.5 cm of water head.

The dynamic membrane process was applied to treat actual living wastewater under the optimum operating parameters. The results indicated that the removal rate of COD was 77.5 ~ 81.1% and the removal rate of ammonia nitrogen was 2.0 ~ 80.8% with only aerobic process. The removal rate of COD was 54.6 ~ 70.7% and the removal rate of ammonia nitrogen was 30.8 ~ 90.2% with only anaerobic process. The removal rate of COD was 80.0 ~ 90.7%, and the removal rate of ammonia nitrogen was 73.7 ~ 94.8% with anaerobic-aerobic series process. The removal rate of COD was 90.3 ~ 94.0%, and the removal rate of ammonia nitrogen was 54.2% ~ 99.9% with anaerobic-aerobic recycling process. The removal rate of COD and ammonia nitrogen in anaerobic-aerobic recyclingprocess was better than that of anaerobic-aerobic series process.

Under the optimum operating parameters, the dynamic membrane process was applied to treat simulated dyeing wastewater. The changes of chroma and COD in the process were analyzed. The chroma removal rate was 78.3 ~ 94.3% and the COD removal ratewas 70.4 ~92.0% in anaerobic-aerobic series process. The chroma removal rate is 83.8 ~ 89.6% and the COD removal rate is 80.5 ~ 93.8% in anaerobic-aerobic recycling process. The COD removal rate of the effluent of anaerobic aerobic recycling process was slightly better than that in series process. The effluent quality of circulating process is also more stable than that of the series process.

When treating simulated livestock wastewater under the optimum operating parameters with anaerobic-aerobic series process, the removal rate of COD was 78.8 ~ 92.7%, and the removal rate of ammonia nitrogen was 82.3 ~ 87.2%. The removal rate of COD was 75.2 ~ 89.4%, and the removal rate of ammonia nitrogen was 84.8 ~ 92.3%

when treating simulated breed wastewater with anaerobic-aerobic recycling process. The COD removal rate of the anaerobic-aerobic recycling process is similar to that of the series process, but the water quality of the system is more stable and the system adaptation period is shorter. The ammonia nitrogen removal rate of the anaerobic-aerobic recycling process is higher than that of the series process, but the system adaptation period is a little longer. In the process of operation, anaerobic reactor dynamic membrane is more susceptible to be polluted than that of aerobic reactor. In the recycling process, the speed of membrane fouling of anaerobic reactor was quicker than that in series process, and the membrane blockage rate of aerobic reactor was greater than that in series process.

Key Words: Dynamic membrane; Organic wastewater; Membrane fouling

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第一章 绪论

1.1 印染废水现状及特点

我国是世界上纺织印染的最大国家，这和我国人口众多有关，据统计我国每天要排放的印染污水超过 300 万吨。而且印染废水的排放量占总工业废水的三成以上，已经成为废水排放的最大领域。根据实际生产得出每印染 100 米的材料就会有 3-5 吨的废水排出，因此如果不及时有效地处理这些废水，就会给我们的生态环境造成严重破坏。由于印染废水中含有多种不易处理的成分如助剂、染料、无机盐以及其它杂质等，并且含量较高，使得印染废水很难进行处理[1]。想要合理持久地发展印染行业，就必须要解决印染废水造成的环境污染问题。

在印染过程中的每一道工序（包括预处理、染色、印花以及整理）都会有废水产生。在预处理工序中因为涉及很多操作流程比如退浆、漂白等，会产生很多种类的废水像退浆、漂白废水等，染色工序会有染色废水产生，而在印花工序不仅会产生印花废水，还会产生皂液废水。最后的整理工序会有整理废水产出。这些类型的废水综合在一起我们称之为印染废水。

印染废水的成分会随着使用材料以及加工程序的不同而发生变化，而且会有很大的差别。据统计，一般的印染废水参数是 SS：100～200 mg/L，pH：6-10，BOD_5：100-400 mg/L，COD_{Cr}：400-1000 mg/L，色度为正常水的 100-400 倍。但是如果印染时采用的材料和加工程序发生改变时，这些参数也会发生相应的巨大变化。比如把原材料换成含有涤纶纺丝时所产生废水的 COD 就会由原数据增加几倍甚至几十倍达到 2000-3000 mg/L，BOD 增加了 2-8 倍，pH 也会直接变为 12 左右，而且还发现随着涤纶纺丝量的增加废水水质会变得更差。一旦改变后的废水中 COD 的量超过原始数据的 20%时，就会更加难处理。印染各个阶段的排水情况是：

（1）退浆废水：排出量不多，但废水中所含污染物的浓度非常高，包括几种主要的成分，有纤维屑、浆料、各种分解物以及多种助剂等，pH 约为 12。如果上浆时所用材料中含有的淀粉较多，会造成排出的废水其 BOD 和 COD 值偏