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Performance of an anaerobic membrane bioreactor for pharmaceutical wastewater treatment

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HIGHLIGHTS

- Wastewater from pharmaceutical industry can be treated by anaerobic MBR technology.
- Varying wastewater composition had negative influence on the treatment efficiency.
- Addition of waste organic solvents caused inhibition of the anaerobic degradation.
- Dichloromethane exhibited the strongest inhibitory effect on anaerobic degradation.
- Changes in the biocenosis reflected the substrate pattern and inhibition events.

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ABSTRACT

Anaerobic treatment of wastewater and waste organic solvents originating from the pharmaceutical and chemical industries was tested in a pilot anaerobic membrane bioreactor, which was operated for 580 days under different operational conditions. The goal was to test the long-term treatment efficiency and identify inhibitory factors. The highest COD removal of up to 97% was observed when the influent concentration was increased by the addition of methanol (up to 25 g L^{-1} as COD). Varying and generally lower COD removal efficiency (around 78%) was observed when the anaerobic membrane bioreactor was operated with incoming pharmaceutical wastewater as sole carbon source. The addition of waste organic solvents (>2.5 g L^{-1} as COD) to the influent led to low COD removal efficiency or even to the breakdown of anaerobic digestion. Changes in the anaerobic population (e.g., proliferation of the genus *Methanosarcina*) resulting from the composition of influent were observed.

1. Introduction

Industrial wastewater treatment by anaerobic biological processes is a proven technology with several advantages compared to aerobic treatment, such as production of biogas, lower energy costs and low excess sludge production (Lew et al., 2009). Although modern high-rate anaerobic reactors such as Up-flow Anaerobic Sludge Blanket (UASB) can achieve chemical oxygen demand (COD) removal efficiencies over 90% (Choi et al., 2013; Delforno et al., 2014), a more widespread use of anaerobic wastewater treatment is hampered by higher residual effluent pollution (Chen et al., 2008) and poor retention of biomass in the reactor (Lin et al., 2013). Furthermore, the granular biomass in high-rate anaerobic reactors can be negatively affected by the characteristics of various industrial wastewaters.

Anaerobic membrane bioreactors (AnMBRs) present an attractive approach for the treatment of wastewater with a high content of COD and suspended solids, high salinity and large variations of flow and composition, even in the presence of fat, oil and grease or inhibitory compounds (Dereli et al., 2012; Diez et al., 2012; Lin et al., 2013). Moreover, the membrane in an AnMBR represents a barrier for slow-growing microorganisms with specialized degradation pathways, resulting in an increase in their activity. For instance, Tao et al. (2012) used an AnMBR for the retention of slow-growing Anammox microorganisms; installing a membrane in the system increased their activity 19 times.

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Despite the aforementioned advantages, there are still several drawbacks associated with AnMBR, especially the lower filterability of the biomass leading to lower filtration fluxes compared to aerobic MBRs (Lin et al., 2013).

AnMBRs have been successfully applied for the treatment of various industrial wastewaters at both pilot and full scale. Most applications targeted wastewater from food processing (e.g., Spagni et al., 2010; Wijekoon et al., 2011) since this is in general highly biodegradable, contains high concentrations of organic matter and often high amounts of suspended solids (Liao et al., 2006; Lin et al., 2013). AnMBRs have been further used for treatment of pulp and paper industry wastewater (Gao et al., 2010; Savant et al., 2006), textile industry wastewater (dos Santos et al., 2007) or polymer synthesis effluents (Araya et al., 1999). However, there have been few studies dealing with the treatment of pharmaceutical wastewater in AnMBRs to date, particularly in pilot plants treating real wastewater or full scale installations (Dvořák et al., 2015). Most studies focusing on the treatment of real pharmaceutical wastewaters have been conducted either in aerobic MBRs or in lab-scale AnMBRs. For instance, Ng et al. (2014) tested the treatment of pharmaceutical wastewater in a lab-scale AnMBR and achieved COD removal of 14.7–47.2%. The low organic removal efficiencies were caused by high salinity and complex nature of the organics in the wastewater. In another study Ng et al. (2015) evaluated microbial communities and AnMBR performance treating wastewater from a pharmaceutical factory in a lab scale AnMBR and demonstrated a positive influence of halophilic organisms on the treatment efficiency.

The present study focused on the performance of an AnMBR pilot plant, which was fed by real wastewater originating from pharmaceutical and chemical production. The treatment feasibility and efficiency of the industrial wastewater under anaerobic conditions, biogas production and process stability under highly varying composition was assessed. Furthermore, concentrated waste organic solvents from the production were tested as a co-substrate for the anaerobic process with regard to their degradability and possible inhibition properties. The goal of the study was to evaluate whether anaerobic treatment can be a reliable and economical addition or alternative to current aerobic wastewater treatment.

2. Material and methods

2.1. Anaerobic membrane bioreactor

The AnMBR consisted of a bioreactor (50 L) and external cross-flow membrane unit (Fig. 1). Before entering the bioreactor, the incoming raw wastewater was pumped into a buffer tank (20 L) in order to equilibrate concentration and flow peaks as well as to adjust the pH to 7.0–7.5. In some phases of operation (specified in Chapter 2.3) an additional substrate, i.e., methanol or waste organic solvents, was added to the incoming wastewater. The daily influent into the bioreactor was between 10 and 30 L.

The AnMBR was operated under mesophilic conditions (35–37 °C). Continuous recirculation between the bioreactor and filtration step facilitated mixing of the reactor and pressurization of two tubular membranes (TAMI Industries; Nyons, France). The membranes were 1-inch ceramic (ZrO_2–TiO_2) tubes with 8 channels (MWCO 50 kDa) and had a total area of 0.25 m^2. Filtration was operated at a flux of 8.4 $L{\cdot}m^{-2}{\cdot}h^{-1}$. Since the permeate flow exceeded the desired inflow rate, part of the permeate was periodically recycled back to the bioreactor in order to reach the targeted hydraulic retention time (HRT). The excess sludge was removed discontinuously three times per week. The volume of excess sludge was adjusted to the incoming organic load, so that the concentration of total solids in the bioreactor was kept above 10 $g{\cdot}L^{-1}$. The solids retention time (SRT) was calculated as the ratio between the bioreactor volume and the sum of sludge volume extracted weekly; the resulting value was between 120 and 450 d.

2.2. Industrial wastewater and waste organic solvents

The AnMBR was placed indoors at the industrial wastewater treatment plant (WWTP) ProRheno AG in Basel (Switzerland), so

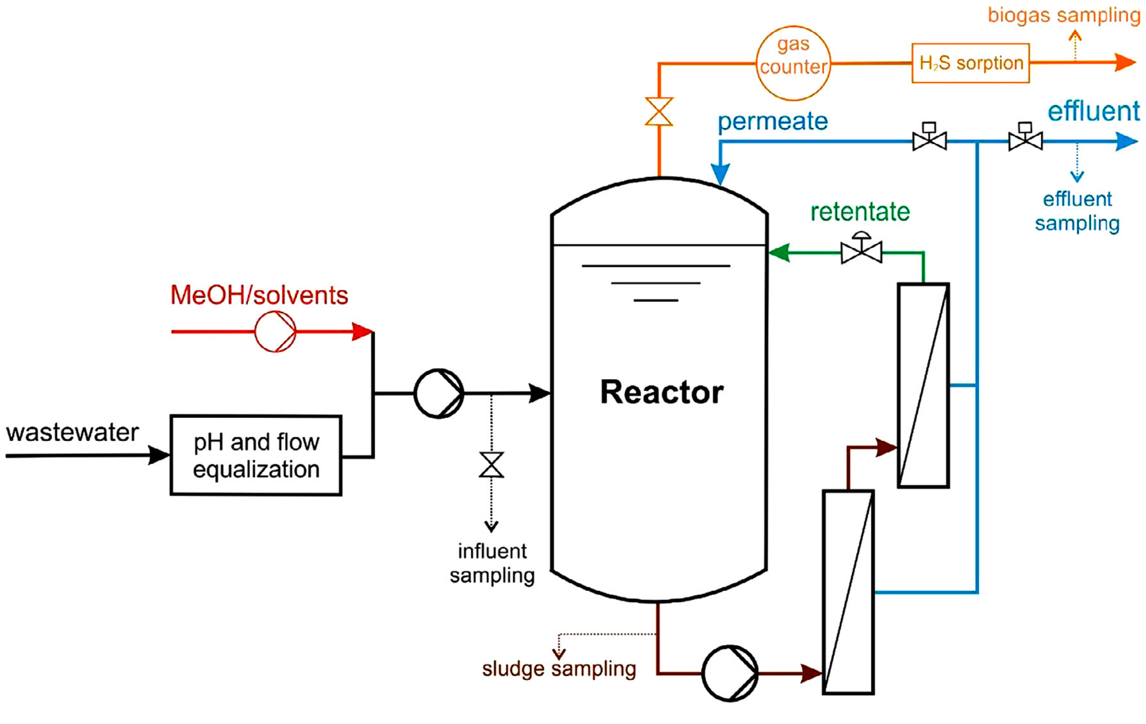

Fig. 1. Flow scheme of the pilot AnMBR.