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Impact of carbon-dosing on micro-pollutants removal in MBBR post-denitrification systems

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Summary:

Dosing of methanol or ethanol is a common practice in post-denitrification steps during wastewater treatment by MBBR technology. The carbon-dosage impact on micro-pollutants removal, in terms of type (methanol or ethanol) and concentration was investigated. First, with continuous operation and indigenous micro-pollutants concentrations, different methanol and ethanol dosages were used to manipulate the carbon-to-nitrate ratio in two MBBRs. Atenolol, citalopram and trimethoprim were efficiently removed in both reactors. However, type or concentration of carbon did not correlate to micro-pollutant removal rates. Second, an anoxic-batch test with spiked micro-pollutants was conducted. The batch test showed that acetyl-sulfadiazine, atenolol, citalopram, propranolol and trimethoprim were easily removed in both reactors. Ibuprofen, clarithromycin, iopromide, metoprolol, iohexol, iomeprol, venlafaxine, erythromycin and sotalol were moderately removed while diatrizoic acid, iopamidol, carbamazepine and diclofenac showed to be hardly biodegradable. The fact that both reactors gave similar removal rate constants for easily degradable compounds, could suggest that diffusion through the biofilm determined the removal of such compounds. In contrast, for moderately degraded micro-pollutants, the biofilm developed under methanol dosing presented the highest removal rate constants. This might mean that the primary metabolism of methanol improved the metabolism of these micro-pollutants. In general, post-denitrification with methanol or ethanol gave high and consistent removals of micro-pollutants.

Keywords: MBBR, denitrification rate, pharmaceutical removal

Introduction

Moving Bed Biofilm Reactor (MBBR) is a cost-effective solution for upgrading wastewater treatment systems (Mases et al., 2010, Jardin et al., 2000). Methanol and ethanol are common additional carbon sources used in post-denitrification systems as electron donors for the reduction of nitrate to nitrogen gas under anoxic conditions. The carbon-to-nitrate ratio (COD/NO_3^--N ratio) is an important parameter for denitrification and, generally, it is optimal around 4 (Metcalf & Eddy, 2003). Although methanol is the most used carbon source for denitrification, ethanol can result is a more readily available carbon source than methanol, leading to higher denitrification rates (Foresti et al., 2004; Christensson et al., 1994). Pre-denitrification MBBRs showed comparable or higher removal of micro-pollutants than aerobic activated sludge (Polesel et al., in preparation). We hypothesized that due to different type of the carbon sources (methanol and ethanol) microbial community can specialize its primary metabolism (i.e. denitrification) and, as a consequence, the metabolism of micro-pollutants. Also, the metabolism of micro-pollutants could be influenced by the carbon concentration. Therefore, the present study investigated the post-denitrification dynamics for nitrogen, carbon and micro-pollutants removal.

Materials and Methods

Two laboratory-scale MBBRs (1L) were operated in parallel simulating the post-denitrification stages of two wastewater treatment plants (WWTPs) where methanol (WWTP 1) or ethanol (WWTP 2) is used as carbon source. Both MBBRs had a filling rate of 40%. The reactors were fed

with trickling-filter effluent from WWTP 1 and methanol or ethanol were dosed as a dilution in distilled water. Both systems operated with a hydraulic retention time of 2 hours and using indigenous concentration of nitrate and micro-pollutants. The COD/NO_3^--N ratio was manipulated by changing methanol or ethanol dilution. The MBBRs were always flushed with nitrogen and stirred to mix and to ensure an anoxic system. After 4 months operation, a batch test with spiked micro-pollutants was performed to determine the degradation kinetics of micro-pollutants in the reactors.

Results and Conclusions

The denitrification rates increased proportionally to the COD/NO_3^--N ratio as expected. In continuous operation atenolol, citalopram and trimethoprim were efficiently removed in both reactors, with removal percentages from 56 to 98%, 17 to 53% and 30 to 100 % respectively. The removal rate of micro-pollutants did not correlate to the COD/NO_3^--N ratio or the carbon type, indicating that the removal mechanism of such compounds might not be dependent on the primary substrate availability.

The batch test assessed the biodegradation potential of selected micro-pollutants in the MBBRs. The data was fitted to first order kinetics and the removal rate constants normalized to the amount of biomass (k_{bio}) (Figure 1). WWTP 1 and WWTP 2 biomasses appeared to degrade acetyl-sulfadiazine, atenolol, citalopram, propranolol with similar and high removal rate constants, indicating that these reactions may be limited by diffusion through biofilm surface. The compounds removed with lower k_{bio} were degraded more efficiently by the WWTP 1 biomass, indicating that methanol shaped a more efficient biofilm community in that reactor. In conclusion, this study demonstrates that wastewater treatment plants could be potentially optimized to enhance micro-pollutants removal by modifying or adding the post-denitrification stage.

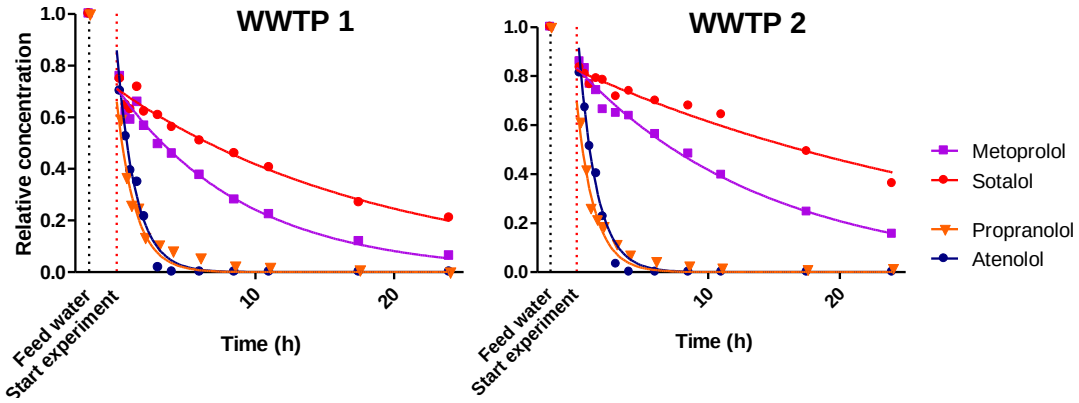

Figure 1: Batch data from four pharmaceuticals (beta-blockers). The curves correspond to first order kinetics fitting

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