Influence of biofilm thickness on micropollutants removal in nitrifying MBBRs

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Influence of biofilm thickness on micropollutants removal in nitrifying MBBRs
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Summary:
The removal of pharmaceuticals was investigated in nitrifying Moving Bed Biofilm Reactors (MBBRs) containing carriers with different biofilm thicknesses. The biofilm with the thinnest thickness was found to have the highest nitrification and biotransformation rate for some key pharmaceuticals. Microbial analysis revealed a different relative abundance of nitrifying guilds in the different carriers, suggesting the importance of nitrite oxidizing bacteria in removal of micropollutants.

Keywords: pharmaceuticals removal, MBBR, nitrification

Introduction
The presence of micropollutants in receiving waters and sewage effluent has received increased attention due to the potential threat that they may pose to the recipient environment. Moving bed biofilm reactors (MBBR) have been recognized to have considerably higher micropollutants removal potential compared to activated sludge, potentially due to their higher solid retention time and thus the capability to enrich the microbial community of nitrifiers (Falås et al., 2013). Diffusion processes and metabolic activities of the cells result in concentrations gradients of substrates through the biofilm, resulting in unique ecological niches for microorganisms (Stewart and Franklin, 2008). With increasing biofilm thickness, the gradients and metabolic processes will be emphasized, potentially leading to higher diversity. Thus, questions arise on how biofilm thickness can impact microbial diversity with microbial community members more or less specialized in micropollutants biotransformation. This study aims to investigate the impact of biofilm thicknesses on the removal of micropollutants (considered as secondary and cometabolic substrates) as well as on the nitrogen removal (primary metabolism) in nitrifying MBBRs using real effluent wastewater, containing only indigenous micropollutants. AnoxKaldnes™ Z-carriers with grids of defined heights were used to control maximum biofilm thickness.

Material and Methods
Continuous operation. Two laboratory-scale MBBRs were operated in parallel, where the first reactor (R1, 3 L) contained a mixture of Z-carriers (Z500, Z400, Z300, Z200) with 500, 400, 300, 200 µm thickness (200 carriers of each) and the second reactor (R2, 1.5 L) contained a modified version of Z-carriers (Z50) with 50 µm thickness (260 carriers). The enrichment of nitrifying biofilm was performed under similar conditions in both reactors by feeding the reactors with effluent wastewater from a local municipal treatment plant (Källby, Lund, Sweden) spiked with additional 50 mg/L of ammonium.

Batch experiments. Batch experiments for each carrier type were performed in 5 different reactors under 24 hours using the same feed composition and similar operational condition as used during the continuous operation. Pseudo first-order biotransformation rate constants (k_bio, Lg⁻¹d⁻¹) were calculated for different pharmaceuticals (only two compounds are presented in the abstract) and for three biofilm thicknesses, 50 µm (Z50), 200 µm (Z200), 500 µm (Z500).
Results and conclusion

The cases of diclofenac and atenolol. After 200 days of continuous operation, a stable nitrification removal rate of 1.7 gNd m⁻² and 2 gNd m⁻² was reached in R1 and R2 respectively. Batch experiments showed that: (i) the carriers with thinnest biofilm of 50 µm thickness (Z50) presented the highest nitrification rate (gN gTSS⁻¹ d⁻¹) (Figure 1a); (ii) the removal of the analgesic diclofenac (DCF) predominantly occurred with Z50 and Z200, while the removal was negligible for Z500 (Figure 1b); (iii) the beta-blocker atenolol (ATN) was removed with all three Z-carriers, with Z-50 showing the highest biotransformation rate \( k_{bio} \) of 10.90 gTSS⁻¹ d⁻¹ (Figure 1c).

Normalized on biomass (gTSS), the \( k_{bio} \) obtained for DCF with Z500 and Z200 (<0.6 gTSS⁻¹ d⁻¹) were in agreement with literature (Falås et al., 2012; Casas et al., 2015) whereas the rate obtained for Z50 (2.1 gTSS⁻¹ d⁻¹) was significantly higher than that obtained with other MBBR systems. A similar trend was obtained for ATN with significantly higher biotransformation rate for the thinnest biofilm compared to the other thicknesses (2.6 and 7 gTSS⁻¹ d⁻¹) and to literature data (Maurer et al., 2009; Falås et al., 2013). The microbial community structure, analyzed with qPCR, showed an average of more 31% of nitrifying community for all Z-carriers but a different relative abundance of ammonia oxidizing bacteria (AOB) and nitrite oxidizing bacteria (NOB as Nitrobacter and Nitrospira) in the three biofilms (data not shown). More specifically, the biofilm with 50 µm thickness presented the highest abundance of NOB (15% of Nitrospira) and the lowest fraction of AOB (16%) compared to the others biofilm thicknesses. The results indicated a more important role of NOB compared to the AOB for the degradation of some key pharmaceuticals and harboring species with functionality relative to micropollutants biotransformation. In conclusion, this study showed that different biofilm thickness had an important impact on the primary and secondary metabolism, and results from further microbial characterization investigating the role of the microbial diversity related to the biofilm thickness will be presented.

References