MBBR Produced Solids: Particle Characteristics, Settling Behaviour and Investigation of Influencing Factors

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Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Environmental Engineering

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Abstract

The separation of solids from biological wastewater treatment is an important step in the treatment process, as it has a significant impact on effluent water quality. The moving bed biofilm reactor (MBBR) technology is a proven upgrade or replacement wastewater treatment system for carbon and nitrogen removal. However, a challenge of this technology is the characteristics of the effluent solids that results in their poor settlement; with settling being the common method of solids removal. The main objective of this research is to understand and expand the current knowledge on the settling characteristics of MBBR produced solids and the parameters that influence them. In particular, in this dissertation, the impacts are studied of carrier types, biofilm thickness restraint design of carriers, and varying carbonaceous loading rates on MBBR performance, biofilm morphology, biofilm thickness, biofilm mass, biofilm density, biofilm detachment rate, solids production, particle size distribution (PSD) and particle settling velocity distribution (PSVD).

With this aim, three MBBR reactors housing three different carrier types were operated with varying loading rates. In order to investigate the effect of carrier geometrical properties on the MBBR system, the conventional, cylindrically-shaped, flat AnoxK™ K5 carrier with protected voids was compared to two newly-designed, saddle-shaped Z-carriers with the fully exposed surface area. Moreover, the AnoxK™ Z-200 carrier was compared to the AnoxK™ Z-400 carrier to evaluate the biofilm thickness restraint design of these carriers, where the Z-200 carrier is designed for greater biofilm thickness-restraint. The Z-200 carrier is designed to limit the biofilm thickness to the level of 200 µm as opposed to 400 µm for the Z-400 carrier. Finally, to investigate the effects of varying carbonaceous loading rates on system removal performance, biofilm characteristics and solids characteristics, further analyses were performed at three different loading

rates of 1.5 to 2.5 and 6.0 g-sBOD/m^2·d in steady-state conditions. The PSD and the PSVD analyses were combined to relate these two properties. A settling velocity distribution analytical method, the ViCAs, was applied in combination with microscopy imaging and micro-flow imaging to investigate the relation of PSD and settling behaviour of MBBR produced particles.

The obtained results have indicated that the carrier type significantly impacted the MBBR performance, biofilm, and particle characteristics. As such, the K5 carrier MBBR system demonstrated a statistically significantly higher carbonaceous removal rate and efficiency (3.8 ± 0.3 g-sBOD/m^2·d and 59.9 ± 3.0% sBOD removal), higher biofilm thickness (281.1 ± 8.7 μm), higher biofilm mass per carrier (43.9 ± 1.0 mg), lower biofilm density (65.0 ± 1.5 kg/m^3), lower biofilm detachment rate (1.7 ± 0.7 g-TSS/ m^2·d) and hence lower solids production (0.7 ± 0.3 g-TSS/d) compared to the two Z-carriers. The Z-carriers' different shape exposes the biofilm to additional shear stress, which could explain why the Z-carriers have thinner and denser biofilm, resulting in higher solids production and lower system performance in comparison with K5. Moreover, the carrier type was also observed to impact the particle characteristics significantly. PSD analysis demonstrated a higher percentage of small particles in the Z-carrier system effluent and hence a significantly lower solids settling efficiency. Therefore, the solids produced in the K5 reactor have shown enhanced settling behaviour, consisting of larger particles with faster settling velocities compared to Z-carriers.

This dissertation also investigated the effects of restraint biofilm thickness on MBBR performance by comparing the Z-200 biofilm thickness-restraint carrier to the Z-400 carrier. No significant difference was observed in removal efficiency, biofilm morphology, biofilm density, biofilm detachment rate, and solids production between the Z-200 to the Z-400 carriers. The PSD and the PSVD analyses did not illustrate any significant difference in the particles' settling behaviour for these two biofilm thickness restraint carriers, indicating that the biofilm thickness-restraint carrier design was not a controlling factor in the settling potential of MBBR produced solids.

Finally, this research studied the effect of varying loading rates and demonstrated a positive, strong linear correlation between the measured sBOD loading rate and the removal rate, indicating first-order BOD removal kinetics. The biofilm thickness, biofilm density and biofilm mass decreased when the surface area loading rate (SALR) was increased from 2.5 to 6.0 g-sBOD/m^2·d. The solids retention time (SRT) was also shown to decrease by increasing the SALR, where the lowest SRT (1.7 ± 0.1 days) was observed at the highest SALR, with the highest cell viability (81.8 ± 1.7%). Significantly higher biofilm detachment rate and yield were observed at SALR 2.5, with the thickest biofilm and a higher percentage of dead cells. Consequently, a higher fraction of larger and rapidly settling particles was observed at SALR of 2.5 g-sBOD/m^2·d, which leads to a significantly better settling behaviour of the MBBR effluent solids.

This study expands the current knowledge of MBBR-produced particle characteristics and settling behaviour. A comprehensive understanding of the MBBR system performance and the potential influencing factors on the MBBR produced solids, particle characteristics, and their settleability will lead to optimized MBBR design for future pilot- and full-scale applications of the MBBR.