Moving bed biofilm reactors (MBBRs) for removal of pharmaceuticals in biological wastewater treatment

Torresi, Elena; Polesel, Fabio; Smets, Barth F.; Andersen, Henrik Rasmus; Plósz, Benedek G.; Christensson, Magnus

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

MOVING BED BIOFILM REACTORS (MBBRs) FOR REMOVAL OF PHARMACEUTICALS IN BIOLOGICAL WASTEWATER TREATMENT

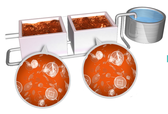
Elena Torresi[1,2], Fabio Polesel[1], Barth F. Smets[1], Henrik R. Andersen[1], Benedek Gy. Plósz[1], Magnus Christensson[2]

[1] DTU Environment, Technical University of Denmark (DTU), Kongens Lyngby, Denmark
[2] Veolia Water Technologies AB, AnoxKaldnes, Lund, Sweden

MBBR for removal of micropollutants

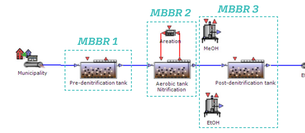
Micropollutants (MPs) are recalcitrant chemicals (i.e., pharmaceuticals, illicit drugs, hormones and personal care products) that are found in wastewater effluent at ng/L to µg/L concentration range.

Moving Bed Biofilm Reactors (MBBRs) have been recently proposed as a valid alternative to conventional activated sludge (CAS) to enhance the elimination of pharmaceuticals during biological wastewater treatment (Escolà Casas et al., 2015; Falås et al., 2016, 2012; Hapeshi et al., 2013; Torresi et al., 2016).



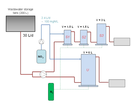
How can we operate strategically MBBRs to enhance removal of micropollutants?

Three different operations of MBBR

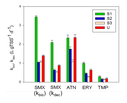


- Pre-denitrifying MBBR (MBBR 1): how MBBR staging and tiered substrate availability influences denitrification and removal of MPs
- Nitrifying MBBR (MBBR 2): how biofilm thickness influences nitrification and removal of MPs
- Post-denitrifying MBBR (MBBR 3): how external carbon source (methanol and ethanol) influences denitrification and removal of MPs

MBBR 1: Pre-denitrification



Two pre-denitrifying MBBR configurations, with **single-stage** (U) and **three-stage** (S1, S2, S3) bioreactors were operated in parallel for 1.5 years. Due to staging, S1, S2 and S3 were exposed to a decreasing trend of organic carbon degradability.

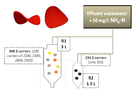


Batch experiment showed that several compounds (i.e atenolol, sulfamethoxazole, trimethoprim) were effectively removed in anoxic MBBRs with biotransformation rate constants k_{bio} (as well as denitrification rate) enhanced in S1.

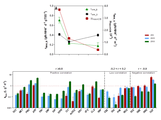
Positively correlation was found between MP biotransformation rate constants and denitrification rates, possibly indicating **co-metabolism of MPs** in the 4 pre-denitrifying MBBRs.

Removal of pharmaceuticals in pre-denitrifying MBBR—Influence of organic substrate availability in single- and three-stage configuration. *Water Research (2017), 123, 408,419*

MBBR 2: Nitrification



AnoxKaldnes Z-carriers with grids of defined heights were used to control maximum biofilm thickness.
Two nitrifying reactors with Z-carriers of biofilm thickness ranging from 50 µm (Z50) to 500 (Z500) were operated in parallel for approximately 200 days.



The nitrification rate ($r_{NH4,\,g}$) was found significantly higher for Z50 MBBR compared to the other Z-carriers. k_{bio} were positively correlated with biofilm thickness for 14 out of 22 compounds, not correlated for four compounds, negatively correlated for three sulfonamide antibiotics and diclofenac (DCF).

Thin biofilm (~50 µm) could achieve complete nitrification and increase the removal of some key compounds (sulfonamides and diclofenac)

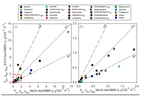
Biofilm technologies based on thicker biofilms could enhance the removal of a major number of micropollutants.

Biofilm thickness influences biodiversity in nitrifying MBBRs - Implications on micropollutant removal. *Environmental Science & Technology (2016), 50, 9279-9288.*

MBBR 3: Post-denitrification

Two laboratory-scale MBBRs, containing AnoxKaldnes K1 carriers with acclimated biofilm from full-scale systems, were operated in continuous-flow using wastewater dosed with methanol and ethanol.

The methanol-dosed MBBR showed higher (e.g., 1.5 to 2.5-fold) or comparable k_{bio} to the ethanol-dosed MBBR for 15 out of 22 targeted compounds.

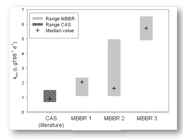


Conversely, denitrification was enhanced in the MBBR dosed with ethanol.

During continuous-flow operation at conditions representative of full-scale systems (hydraulic residence time = 2 h), the removal efficiencies of micropollutants were below 35% in both MBBRs, with the exception of atenolol and trimethoprim (>80%)

Impact of external carbon dose on the removal of micropollutants using methanol and ethanol in post-denitrifying Moving Bed Biofilm Reactors. *Water Research (2017), 108, 95-105*

Comparison with CAS



The three MBBR systems presented **improved k_{bio} as compared to CAS for atenolol** (in figure) **and for a number of pharmaceuticals** (e.g., diclofenac, sulfamethoxazole, erythromycin)

- The post-denitrifying MBBR 3, that was supplemented with more readily degradable carbon sources (ethanol, methanol) compared to MBBR 1, exhibited the highest k_{bio}.
- The **availability of primary substrates** (carbon and nitrogen) was found crucial for the biotransformation of pharmaceuticals in the three MBBR systems, suggesting removal via cometabolism.
- **Overall, our results suggest that MBBR can be a valuable alternative to CAS in enhancing the removal of several micropollutants both under aerobic and anoxic conditions**.

References

Escolà Casas, M.E., Chhetri, R.K., Ooi, G., Hansen, K.M.S., Litty, K., Christensson, M., Kragelund, C., Andersen, H.R., Bester, K., 2015. Biodegradation of pharmaceuticals in hospital wastewater by staged Moving Bed Biofilm Reactors (MBBR). Water Res. 83, 293-302.

Falås, P., Baillon-Dhumez, a, Andersen, H.R., Ledin, a, la Cour Jansen, J., 2012. Suspended biofilm carrier and activated sludge removal of acidic pharmaceuticals. Water Res. 46, 1167-75.

Hapeshi, E., Lambrianides, a, Koutsoftas, P., Kastanos, E., Michael, C., Fatta-Kassinos, D., 2013. Investigating the fate of iodinated X-ray contrast media iohexol and diatrizoate during microbial degradation in an MBBR system treating urban wastewater. Environ. Sci. Pollut. Res. Int. 20, 3592-606.

Contact information

Elena Torresi
Email: elena.torresi@anoxkaldnes.com

Technical University of Denmark DTU

MERMAID

WATER TECHNOLOGIES