Integrated Process towards the Elimination of Micropollutants and Toxicity for Water Reuse

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ABSTRACT

Water scarcity is aggravating due to climate change and a global rise in freshwater demand, essentially linked to the increased human consumption as well as the overuse and wastage of water. One of the recently proposed strategies by the European Commission to overcome this conundrum is the reuse of treated wastewater (https://environment.ec.europa.eu/topics/water/water-reuse_en). Nevertheless, the perpetual increase in human activities has resulted in recurrent detections of various organic micropollutants (MPs) particularly at the outlet of wastewater treatment plants (WWTPs). Their eventual presence and discharge (e.g., pharmaceutically active compounds, endocrine disrupting chemicals, pesticides) into environment via the treated wastewater remain a worrying issue due to their potential cumulative and toxic effects. Despite their presence at relatively low concentrations (< 1µg/L), the release of these molecules into the environment has been indeed associated with multiple significant risks to human health and aquatic ecosystems (Ajala et al. 2022).

The secondary treatments presently used in most WWTPs display noteworthy removal efficiencies of carbon- and nitrogen-based pollutants but the operating conditions applied in such treatments are not always well adapted for the elimination of MPs. This therefore leads to the implementation of tertiary processes to enhance their removal. Among those processes, the Moving Bed Biofilm Reactor (MBBR) is deemed promising not only for its economic and environmental advantages, but also for its robustness. In fact, biofilm formed on the fluidized plastic carriers has better resistance to constant variations in characteristics of the influent, e.g., organic load, pH, temperature (di Biase et al. 2019); It also contributes substantially to the biodegradation of certain MPs (Abtahi et al. 2018).

Currently, on top of quantifying the removal efficiencies of diverse MPs, numerous studies were also conducted to characterize the link between the microbial populations' diversity and the degradation of MPs in MBBR processes (Guo et al. 2019). In spite of the persistent progress in research on the characterization of the optimal degradation conditions of MPs, their removal mechanisms, revealed to be very complex and no longer elucidated. Furthermore, the ecotoxicological assessment of the treated effluent has to be systematically performed in order to evaluate potential risks to humans and the environment.

In this study, the removal efficiency of 19 MPs and the diversity of microbial community in a hybrid semi-pilot scale system coupling MBBR and membrane processes (figure 1) were evaluated. The hybrid system was operated to treat different natures of non-conventional pre-treated wastewaters (i.e., domestic (**C1**) and hospital (**C2**)). The particularity of these wastewaters is their low carbon content, resulting in C/N ratio in the range of 0.9 to 5.4. Besides, a comparative study of the microbial populations of biomass present in the system (attached (AB) and suspended (SB)) with those of activated sludge from a WWTP (inoculum (IN)) at phylum (figure 2) and class (data not shown) level demonstrated significant modifications in the population dynamics. Indeed, the microbial community abundances on the IN are notably different from those identified on the biomass (AB, SB) of the

aerobic MBBR. Moreover, Proteobacteria was the most abundant phylum on the majority of the MBBR biomass samples except on SB3 and AB2 where Bacteroidetes and *Nitrospirae* were the most abundant phylum respectively. *Nitrospirae* was mainly detected on AB samples due to the longer contact time between the biomass and carriers, which greatly favoured its proliferation (Eshamuddin et al. 2024). In addition, principal conventional pollution parameters namely soluble Chemical Oxygen Demand (sCOD), nitrogen based-compounds, mixed liquor suspended solids (MLSS) and mass of attached biofilm showed reuse-friendly outcomes in terms of general process performance.

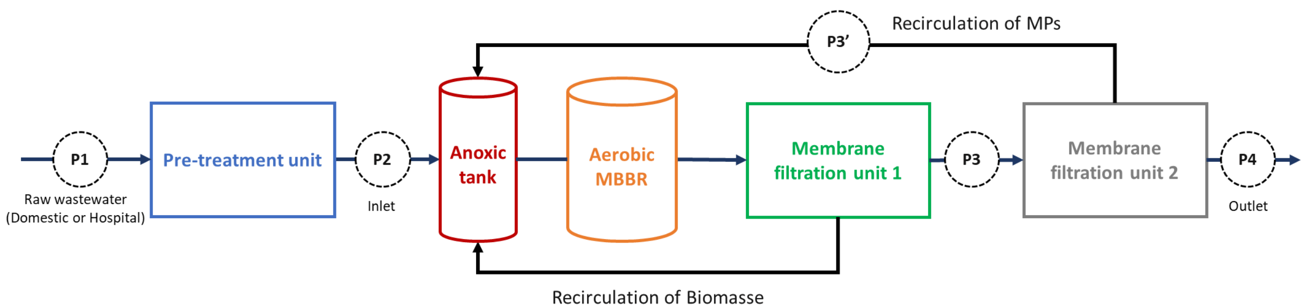


Figure 1: The hybrid semi-pilot scale system (MBBR + membrane processes) and the different sampling points (P)

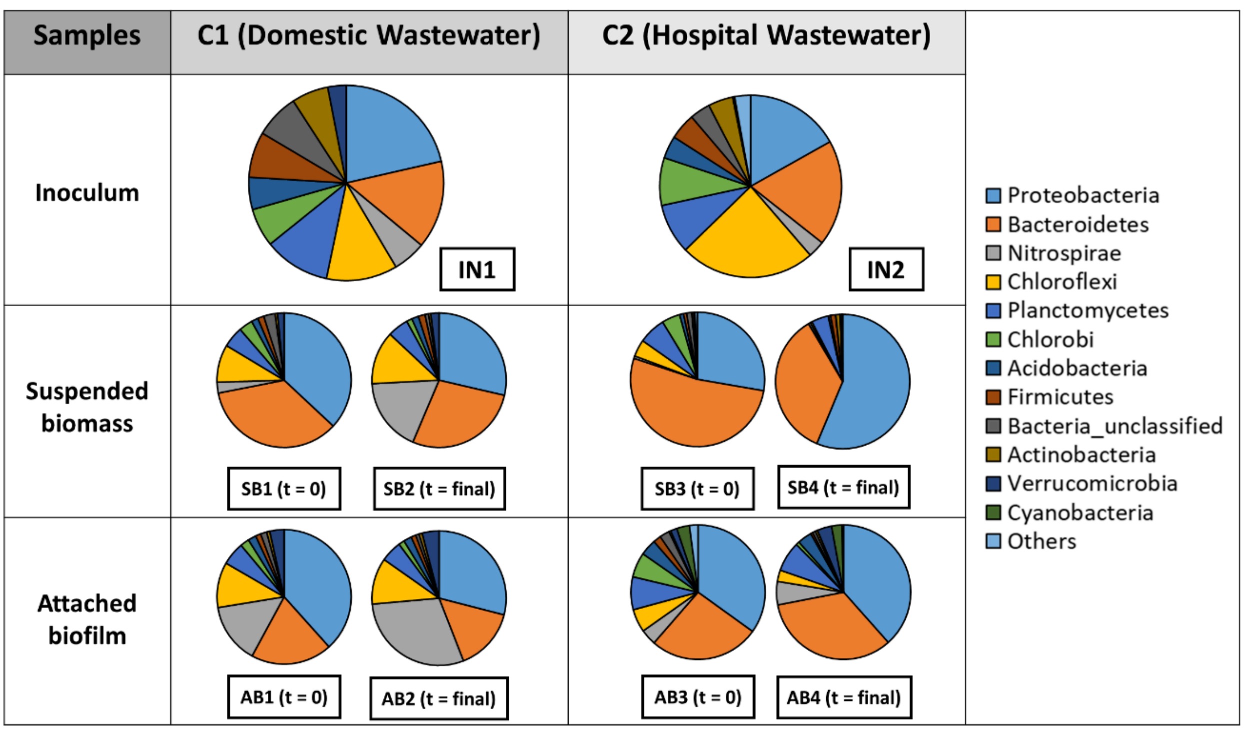
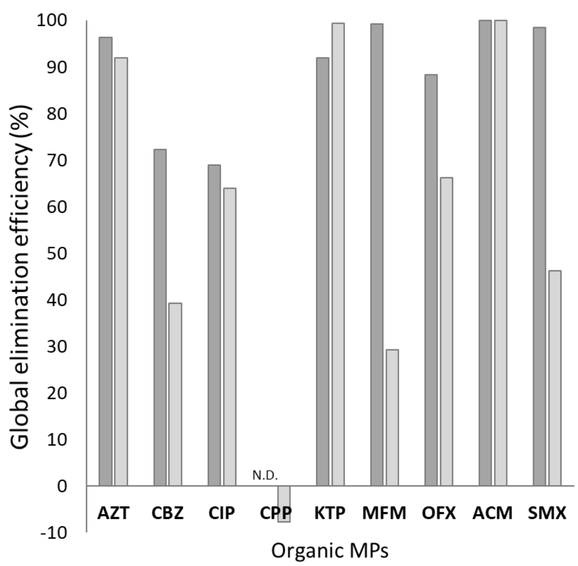


Figure 2: Microbial community profiles of different biomass (inoculum (IN), attached (AB), suspended (SB)) at phylum level according to sampling campaigns

The 19 targeted MPs were analyzed using an in-house developed method, coupling QuEChERS extraction and ultra-high-performance liquid chromatography with tandem mass spectrometry (UHPLC-MS-MS) (Cavaillé et al. 2021). Different removal efficiencies (figure 3) were obtained depending on the molecules and the operating conditions, among which the quality and nature of the initial influent. Out of the eight detected MPs in C1, six molecules (AZT, KTP, MFM, OFX, ACM, SMX) were excellently removed (>75%) by the hybrid system while two compounds (CBZ, CIP) achieved good elimination rates (51 - 75%). Besides, based on the nine quantified MPs in C2, three (AZT, KTP, ACM) were significantly eliminated (>75%), two molecules (CIP, OFX) presented good elimination rates (51 - 75%), three compounds (CBZ, MFM, SMX) attained low removal rates (26 - 50%) while one cytostatic agent (CPP) was poorly eliminated (<25%) by the integrated process. Finally, the ecotoxicological assessment of selected samples was executed using the adapted OECD202 immobilization bioassay for *Daphnia magna* (OECD 2004). Results from the toxicity assays (figure 4) on the final effluent as well as the effluents produced by each treatment unit of the integrated system exhibited notable abatement of acute toxicity. This last result is a positive preliminary indicator for considering the reuse of these effluents, provided that a more specific risk assessment is carried out according to the considered use.



Molecule	Abbreviation
Azithromycin	**AZT**
Carbamazepine	**CBZ**
Ciprofloxacin	**CIP**
Cyclophosphamide	**CPP**
Ketoprofen	**KTP**
Metformin	**MFM**
Ofloxacin	**OFX**
Paracetamol	**ACM**
Sulfamethoxazole	**SMX**

Figure 3: Global elimination rates of organic MPs in the hybrid system according to sampling campaigns (N.D.: not detected)

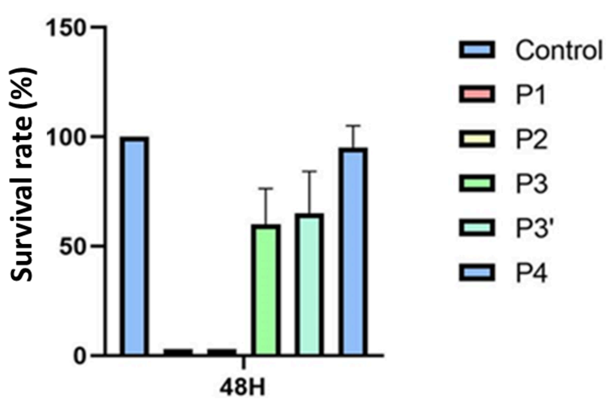


Figure 4: Survival rate of Daphnia magna after 48 hours in different sampling points of C2 effluents (according to the OECD 202 test)

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