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Coupling powdered activated carbon (PAC) adsorption with membrane bioreactor (MBR) treatment for enhanced removal of trace organics

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Coupling powdered activated carbon (PAC) adsorption with membrane bioreactor (MBR) treatment for enhanced removal of trace organics

Abstract

the occurrence of trace organics such as pesticides, pharmaceutically active compounds, natural and synthetic hormones as well as various industrial compounds in the aquatic environment is of great concern due to their potential adverse effects on human health and those of other biota. Therefore, the removal of these compounds from wastewater is an important consideration to ensure safe drinking water and better protection of the environment. In the literature, several techniques have been explored for trace organics removal, namely, conventional activated sludge, membrane bioreactors (MBRs), and adsorption. However it has been found that neither MBR nor activated carbon on its own can adequately remove all trace organics of concern.

Keywords

removal, carbon, pac, adsorption, trace, activated, organics, membrane, powdered, bioreactor, mbr, coupling, treatment, enhanced

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Keywords: Membrane bioreactor (MBR); Powdered activate carbon (PAC); Fouling; Trace organics.

The occurrence of trace organics such as pesticides, pharmaceutically active compounds, natural and synthetic hormones as well as various industrial compounds in the aquatic environment is of great concern due to their potential adverse effects on human health and those of other biota. Therefore, the removal of these compounds from wastewater is an important consideration to ensure safe drinking water and better protection of the environment. In the literature, several techniques have been explored for trace organics removal, namely, conventional activated sludge, membrane bioreactors (MBRs), and adsorption. However, it has been found that neither MBR [1] nor activated carbon [2] on its own can adequately remove all trace organics of concern.

This study has investigated the effect of direct addition of PAC into a laboratory scale MBR system on the removal efficiencies of 22 selected trace organic contaminants comprising 11 pharmaceutical and personal care products, 2 pesticides, 4 industrial chemicals and their metabolites and 5 steroid hormones. These trace organics were continuously introduced to a synthetic wastewater solution each at a concentration of up to 5 µg/L. The MBR system consisted of a single compartment glass reactor, an air pump, influent and effluent pumps, a 0.4 µm PVDF hollow fiber membrane module, supplied by Mitsubishi Rayon Engineering, Japan and a Neslab RTE 7 temperature control unit. Samples were collected twice a week for TOC/TN, turbidity, EPS and SMP, DO, MLSS, MLVSS, and SOUR analysis. Feed and permeate samples of 500 mL were also collected weekly for immediate solid phase extraction. The trace organics were analyzed using a previously developed GC/MS method [1]. The MBR was first operated for 205 days without any PAC addition. PAC (Activated carbon Pty Ltd., Australia) was added into the reactor on day 206 and subsequently on day 243 of continuous operation to obtain a PAC concentration of 0.1 and 0.5 g/L, respectively. Operating conditions (temperature, HRT, pH and DO concentration) were kept the same before and after the addition of PAC.

TOC/TN removal: The results confirmed that the TOC removal was already 98 ± 2 % before the addition of PAC. On the other hand, as expected, in the absence of a denitrification zone within the MBR, the removal of TN in this study was only around 40%. Only a slight increase in the removal of TOC and TN by MBR was observed after addition of PAC.

Trace organics removal: MBR treatment can effectively remove hydrophobic ($\log D > 3.2$) and readily biodegradable trace organic compounds (**Figure 1**). However, our data highlighted the limitation of MBR in removing hydrophilic and persistent compounds such as metronidazole, fenoprop, naproxen, ketoprofen, diclofenac, and carbamazepine. The removal of the above-mentioned persistent trace organic contaminants by MBR treatment was enhanced after direct addition of PAC into it. The high degree of removal (95%) of the hydrophobic and readily biodegradable compounds continued to be achieved in the PAC – MBR system. In addition an immediate increase in removal efficiency of the biologically persistent hydrophilic compounds, was observed in the PAC – MBR system., in contrast to the low removal by MBR- only treatment, In order to assess the long-term performance of the combined PAC– MBR system, the removal of carbamazepine—a widely reported highly persistent pharmaceutical compound [1]— was monitored for 110 days. Within approximately three weeks of the first addition of PAC (0.1 g PAC/ L), the removal efficiency of carbamazepine dropped to the level achieved before the addition of PAC (**Figure 2**). The removal efficiency of this compound could be recovered by adding a second dose of PAC, raising the PAC concentration in the MBR to 0.5 g/L. Following this, the removal of carbamazepine did not drop below 87% for the rest of the observation period (2 months). Based on the current study, a PAC-MBR MBR can be used

to achieve better trace organics removal over MBR-only treatment. However, dosage and periodic replenishment of activated carbon would be critical for maintaining excellent removal.

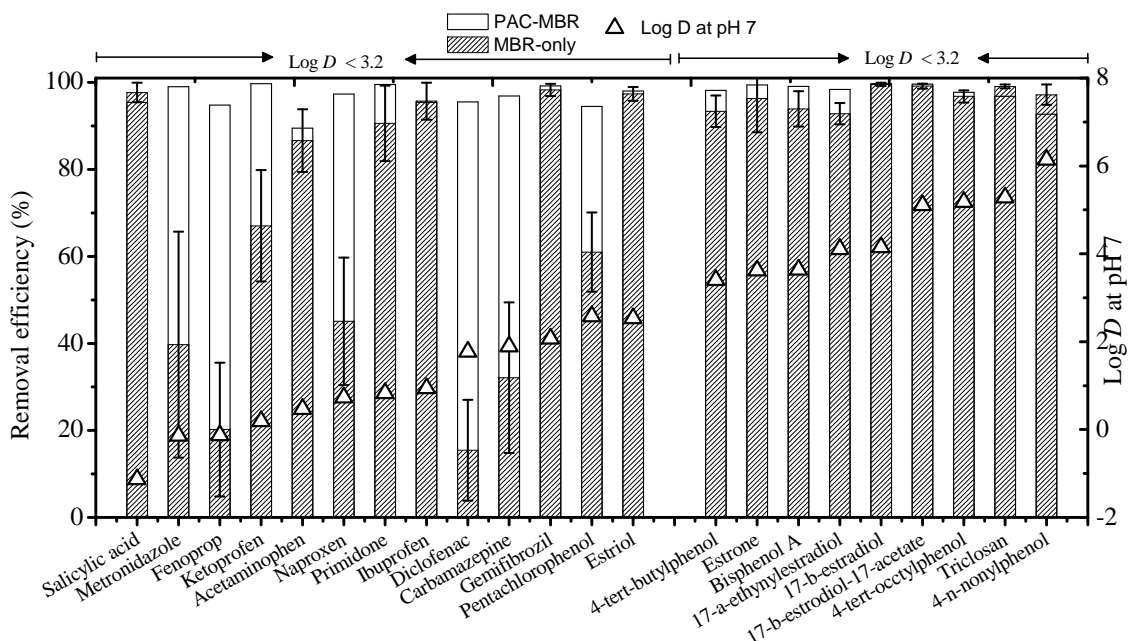


Figure 1: Comparison of overall removal efficiency of trace organics by MBR-only (n=58, over 29 weeks) and PAC - MBR hybrid system (2 days after addition of PAC).

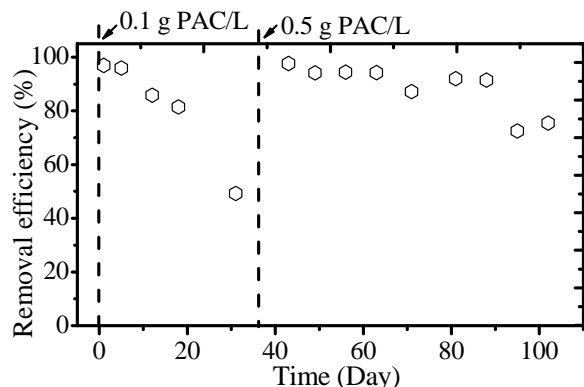


Figure 2: Long-term removal of carbamazepine in the PAC-MBR.

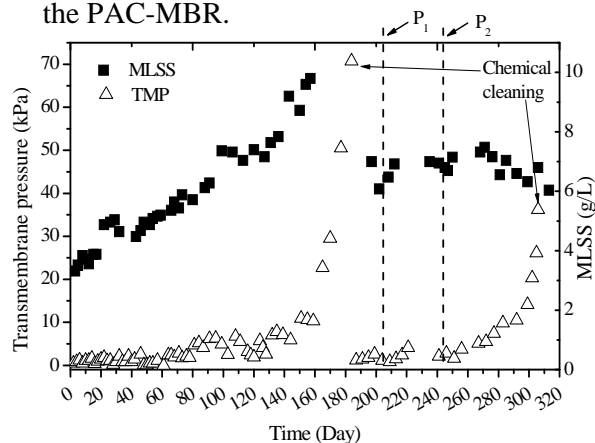


Figure 3: Variation of transmembrane pressure (TMP). “P₁” and “P₂” indicate the points of PAC addition to achieve final PAC concentrations of 0.1 g/L and 0.5 g/L, respectively.

Membrane fouling: The membrane was operated under a low average flux (0.07 m/d) with periodic relaxation, (operation in a 14 min on and 1 min off mode), but without any periodic cleaning. The focus of this study was on the removal performance of the MBR and as such the MBR system in this study was not hydraulically optimized. Therefore a precise comment about the role of PAC on mitigation of membrane fouling cannot be made based on the observations in this study. However, the rate of TMP-increase appeared slower for the operation with PAC (**Figure 3**).

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