polymers

MDPI

*Supplementary material*

# Fouling Mitigation by Cationic Polymer Addition into a Pilot-Scale Anaerobic Membrane Bioreactor Fed with Blackwater

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## S1. Supporting material: literature review table

**Table S1.** Literature review of flux enhancers (FE) applied to pilot and full-scale MBRs and AnMBRs fed with real wastewater.

| Reactor reference | FE type [a], dosage (mg $L^{-1}$) | Dosing control [b] | Dosing strategy [c] | Reactor type | Membrane surface area ($m^2$) | Reactor volume ($m^3$) | Wastewater (fed) | Operational time with FE (d) | Main effects of FE presence [g] | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| R1 | $FeCl_3$, 26 | FF | Step in influent | AnMBR | 5.4 | 0.55 | Municipal | 90 | ↓fouling, ↑thickness and porosity fouling layer, ↓PR and PS on membrane surface, ↑COD removals, ↓colloidal COD ↓soluble COD, ↑particle size | [1] |
| R2 | $FeCl_3$, 12-21, 43 | FF | Step in influent | AnMBR | 5.4 | 0.55 | Municipal | 70 | ↓reversible fouling, ↓colloidal COD, ↓VSS biodegradability | [2] |
| R3 | PACl, 12.5 mg $gTSS^{-1}$ | FF | Pulse + compensation (W) | MBR | 1 | - | Mixed domestic and textile | 65 | ↓fouling rate, ↓cake resistance, ↑filtration stability, ↕SMP-PR, ↕SMP-PS, ↓extracted EPS-PR and EPS-PS | [3] |
| R4 | Mylbond168, 1,500-2,000 | FF | Pulse + compensation (W) | MBR | 22 | 1 | Municipal | 50 | ↑TMP, washed out with permeate, ↑floc size, ↓CST | [4] |
| R4 | KD452, 70 | FF | Pulse + compensation (W) | MBR | 22 | 1 | Municipal | 63 | ↓TMP, retarded fouling, ↕nutrient removal, ↓SMP, ↑floc size, ↓biopolymers | [4] |
| R4 | MPE50, 500 | FF | Pulse + compensation (W) | MBR | 22 | 1 | Municipal | 74 | ↓TMP, retarded fouling, ↕nutrient removal, ↓SMP, ↑ floc size, ↓CST | [4] |
| R5 | MPE50, 250 | FF; FB | Pulse + compensation (W & B); Pulses | MBR | 0.9 | 0.12 | Refinery effluent | 220 | ↓fouling resistance, ↓TTF, ↑PSD, ↓colloidal TOC, ↓SMP, ↓EPS | [5] |
| R6 | MPE50, 400 | FF | Pulse + compensation (B) | MBR | 60 | 10.2 | Municipal | 20 | ↑flux, ↓TMP, ↓foam | [6] |
| R7 | MPE50, 400 | FF | Pulse + compensation (unspecified) | MBR | 1000 | - | Leachate | 30 | ↓TMP, ↑permeability, ↑flow, ↓permeate COD, ↓chemical cleaning frequency, ↓foam | [7] |
| R8 | MPE50, 600 | FF | Pulse + compensation (unspecified) | MBR | - | 125 | Food Industry | 12 | ↓TMP, ↑permeability, ↓ permeate COD, ↓chemical cleaning frequency, ↓foam | [7] |
| R9 | MPE50, 500 | FF | Pulse + compensation (unspecified) | MBR | 0.5 | 0.2 | Municipal | 14 | ↑critical flux | [8] |
| R10 | MPE50, 400 | FF | Pulse + compensation (unspecified) | MBR | - | 750 [d] | Municipal | >1 [f] | ↑permeability, ↑one-day peak flux | [8] |
| R11 | MPE50, 200 | FF | Pulse | MBR | 6.4 | - | Municipal | 35 | ↑flux, ↓permeate COD | [8] |
| R12 | MPE50, 300 | FF | Pulse + compensation (W) | MBR | - | - [e] | Municipal with hydrophilic waxes | 35 | ↑flux, ↓shuts down triggered by high TMP, ↑one-day peak flux | [8] |
| R13 | PAC, 1,500, 3,000 | FF | Pulse + compensation (unspecified) | MBR | 6 | 0.52 | Tannery Industry | 139 | ↓fouling rate, ↓chemical cleanings, COD removal stabilization | [9] |
| R14 | PAC, 500 | FF | Ramp up until desired concentration | MBR | 0.1 | 0.085 | Municipal | 140 | ↑critical flux, ↑sustainable filtration period, ↓gel-cake deposition, ↑removability of gel-cake, ↑permeate quality | [10] |

[a] MPE50 and KD452 are cationic polymers; PACl is polyaluminum chloride; and Mylbond168 is a starch.
[b] FF: feedforward dosing, where FE is dosed to achieve a target concentration. FB: feedback dosing, where FE is added based on the value of an input variable.
[c] Pulse: reactor spiked with FE. Pulse + compensation: initial pulse-dosage followed by periodic additions to compensate loss of FE with sludge withdrawal (W) and 1% biodegradable fraction (B).
[d] Total bioreactor volume calculated based on total MPE50 added (300 kg) and target concentration (400 mg $L^{-1}$).
[e] Design operational volume 50 $m^3$ $d^{-1}$.
[f] Reported results for 1 day, but MPE50 remained in the system.
[g] Nomenclature:↑, increase; ↓, decrease; ↕, no significant change. Abbreviations: COD, chemical oxygen demand; CST, capillary suction time; EPS, extracellular polymeric substances; PR, proteins; PS, polysaccharides; PSD, particle size distribution; SMP, soluble microbial products; TMP, transmembrane pressure; TTF, time-to-filter; VSS, volatile suspended solids.

## S2. Supporting material: pilot AnMBR plant monitoring

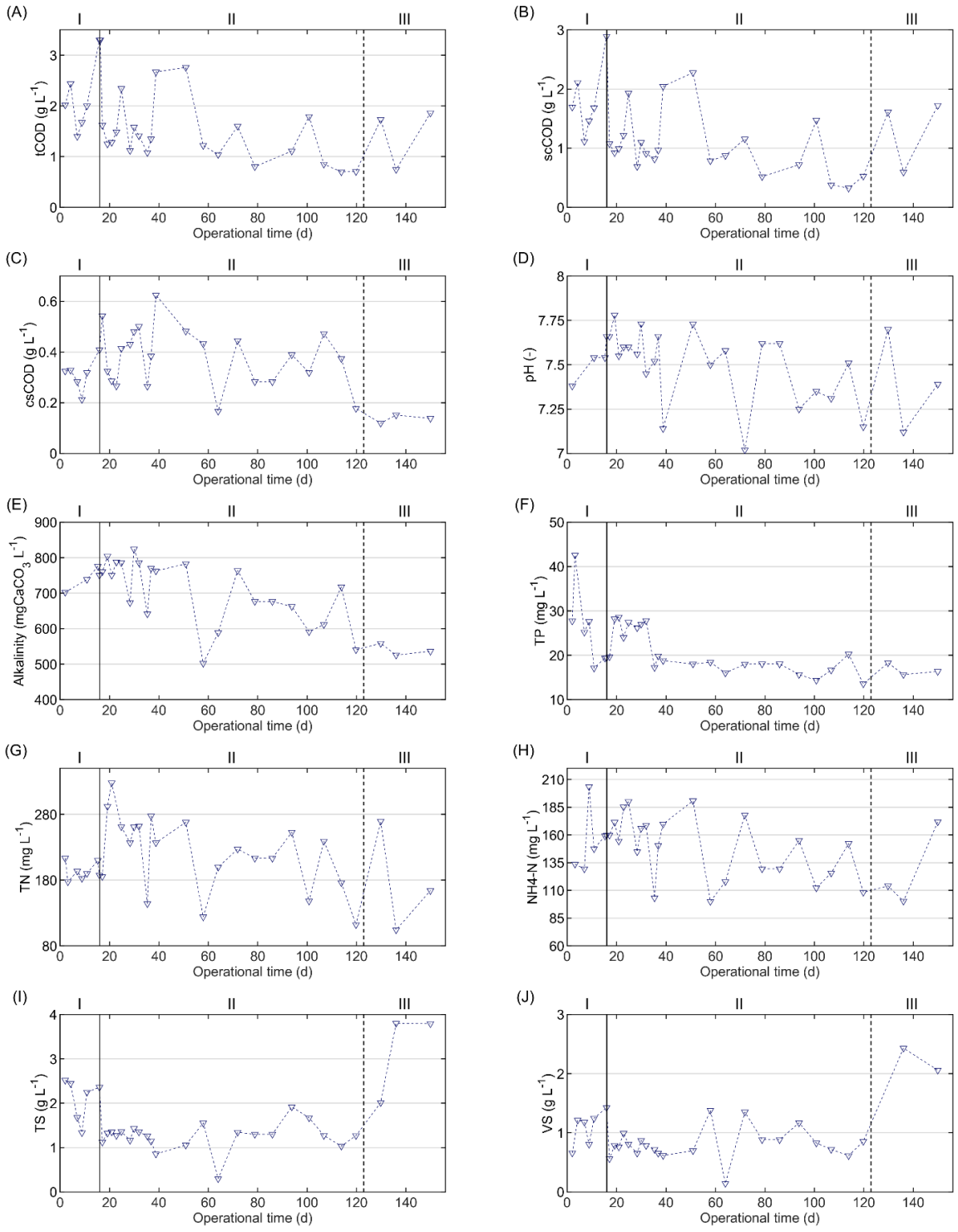


**Figure S1**. Blackwater characteristics during operational period of pilot AnMBR plant dosed with flux enhancer: (A) total COD, (B) supracolloidal COD, (C) submicron COD, (D) pH, (E) alkalinity, (F) total phosphorous, (G) total nitrogen, (H) ammonium-nitrogen, (I) total solids, and (F) volatile solids.

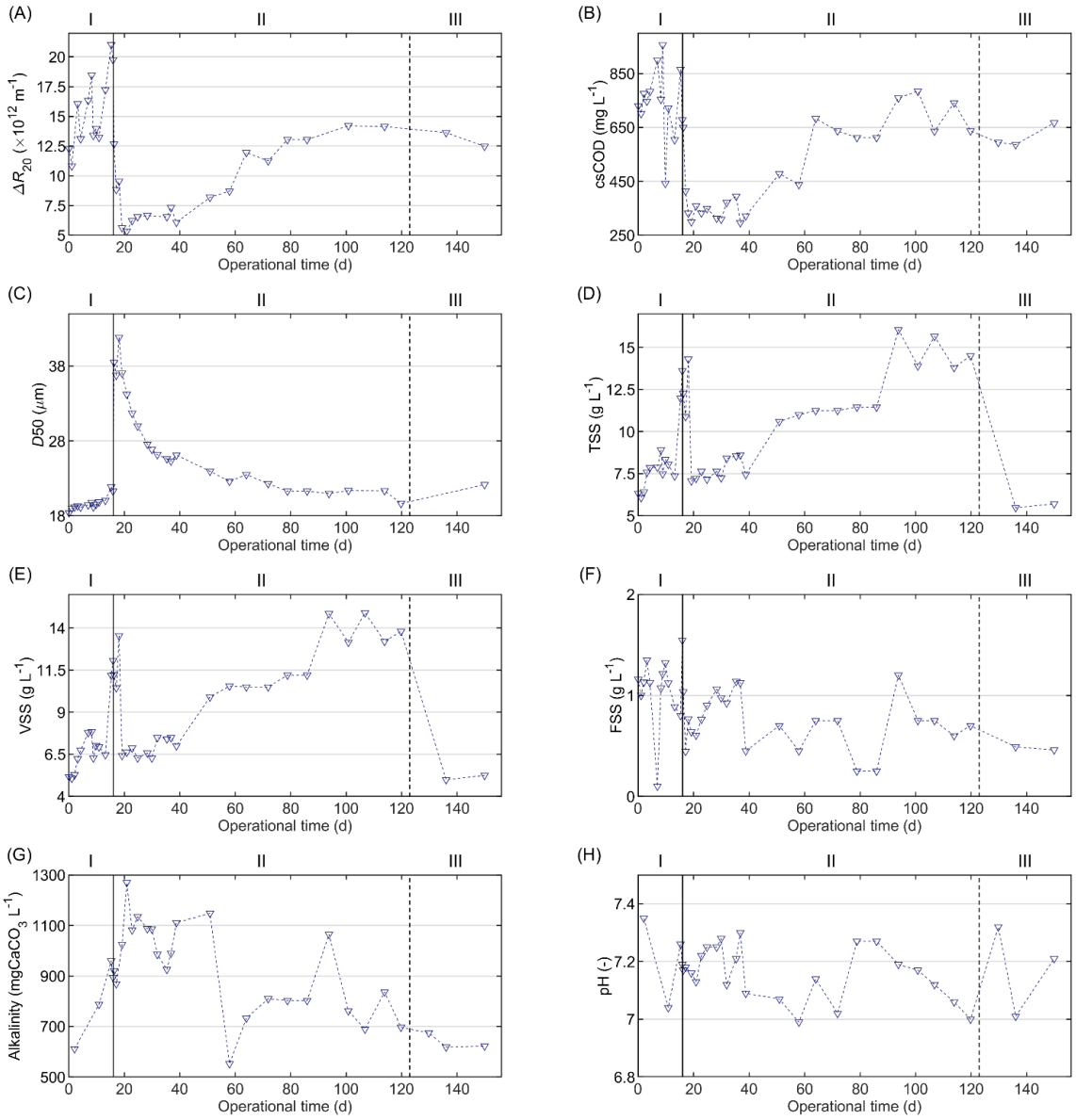


**Figure S2**. Sludge characteristics during operational period of pilot AnMBR plant dosed with flux enhancer: (A) sludge filterability expressed as $\Delta R_{20}$ (which is inversely related with filterability), (B) submicron COD, (C) floc size expressed as 50$^{th}$ percentiles of volume-based particle size distribution, (D) total suspended solids, (E) volatile suspended solids, (F) fixed suspended solids, (G) alkalinity, and (H) pH.

We calculated the mean TMP (TMP$_{ave}$, Pa) as the average of the TMP values recorded by the SCADA system during one filtration cycle (TMP$_i$), as follows:

$$TMP_{ave} = \frac{\sum TMP_i}{n} \quad (S1)$$

, where n is the number of observations.

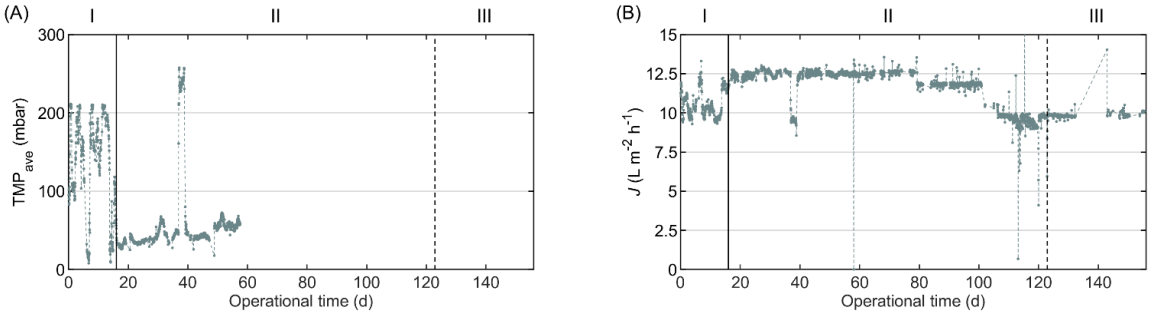


**Figure S3.** Pilot AnMBR mean hourly membrane performance state variables during operational period of pilot AnMBR plant dosed with flux enhancer: (A) mean TMP during one filtration cycle, and (B) transmembrane flux.

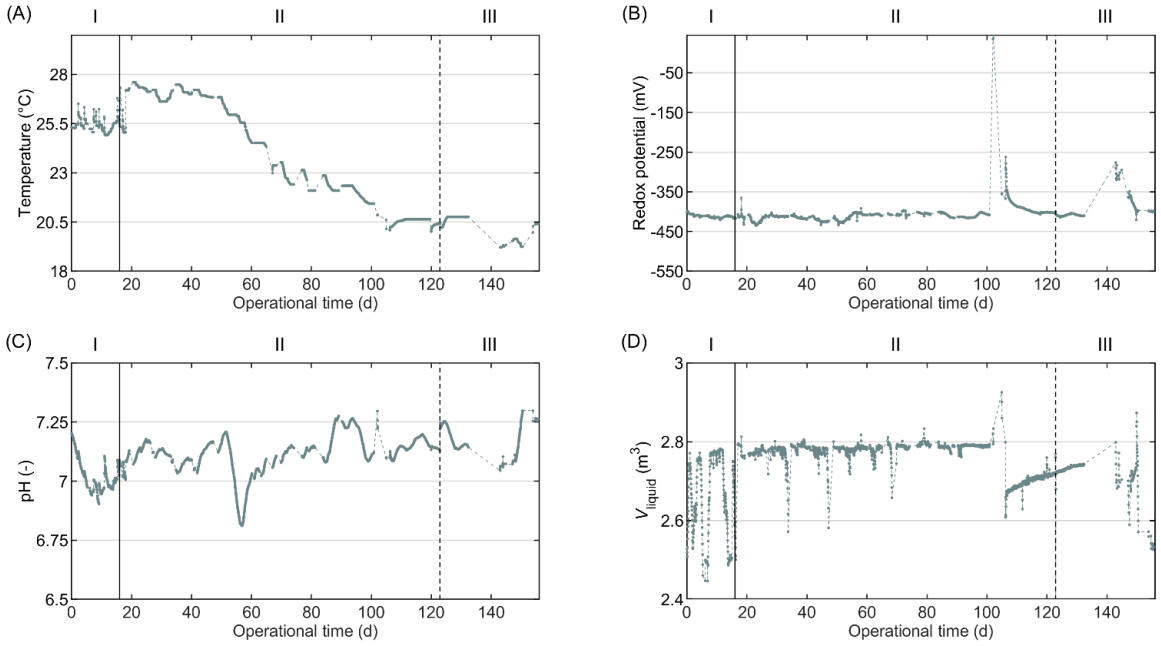


**Figure S4.** AnMBR mean hourly mixed liquor state variables during operational period of pilot AnMBR plant dosed with flux enhancer: (A) temperature, (B) redox potential, (C) pH, (D) total liquid volume (membrane tank + anaerobic reactor).

## S3. References


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