IWA World Water Congress & Exhibition
11-15 AUGUST 2024 | TORONTO, CANADA | www.worldwatercongress.org

Direct membrane filtration of municipal wastewater assisted by a tannin-based coagulant for an energy-efficient water resource recovery facility

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Abstract: The study explores the innovative use of tannin-based coagulants in direct membrane filtration (DMF) to reduce fouling and enhance energy efficiency in water resource facilities. Experiments with different tannin dosages (10 – 50 mg/L) show a significant improvement in filterability and reduction of fouling resistance, particularly notable at concentrations of 30 and 50 $mg \cdot L^{-1}$. This coagulant application led to a substantial decrease in fouling, and a rise in threshold flux by promoting the formation of larger aggregates and decreasing the presence of smaller particles and biopolymers in wastewater. The study indicates that tannin-based coagulants offer a promising strategy to minimize fouling and optimize energy efficiency in DMF processes, demonstrating the potential for broader implementation in large-scale water treatment facilities.
Keywords: fouling; plant-based coagulants; ultrafiltration

In the last years, direct membrane filtration (DMF) assisted by metal-base coagulation emerged as an innovative approach for enhancing energy recovery in self-sustaining water resource recovery facilities (WRRF). In this setup, organic matter of raw wastewater is concentrated for further anaerobic degradation, while coagulants are used to mitigate fouling. Natural coagulants, such as tannin-based coagulants (TAN), can be used in DMF to avoid the environmental drawbacks of metal-based coagulants and their toxicity to anaerobic microorganisms. Tannin is a plant-derived coagulant that has not yet been used in association with DMF for fouling control. Therefore, in this study, a holistic investigation was conducted with a TAN coagulant to reduce fouling in a DMF.

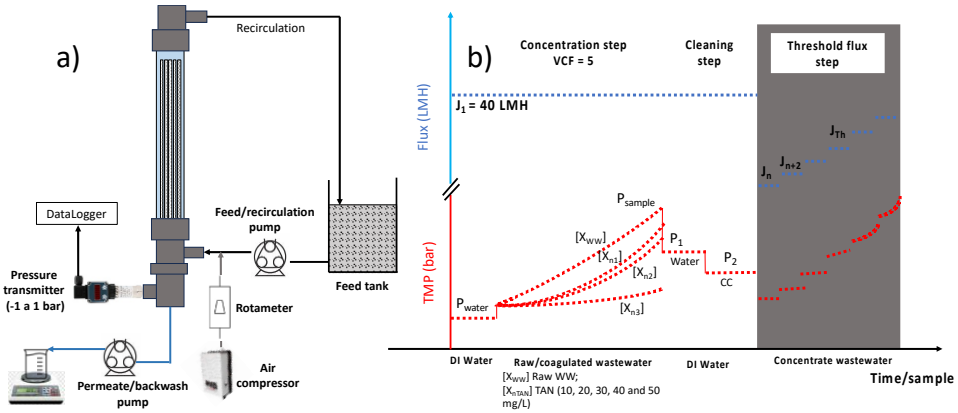

Figure 1: Schematic diagram of the lab-scale HF-UF membrane cell test (a) and filtration approach.

A hollow fiber ultrafiltration membrane system was used to carry out the filtration experiments (Fig. 1a). Wastewater after a preliminary treatment with rotary drum screening and grit removal was used as a sample and 5 dosages of TAN was tested. Details of the filtration tests are shown in Figure 1b. Darcy's law was used for hydraulic characterization of fouling, which was divided into external (removed by water) and internal fouling (chemical

removed). Organic foulants extracted from the surface and membrane pores were characterized as total biopolymers (protein and carbohydrates), while the dissolved fraction using Liquid chromatography with organic carbon detection (LC-OCD) (Subhi et al., 2012).

The results demonstrate that adding tannin, in all concentrations evaluated, enhanced the wastewater filterability. In this way, after adding both 30 and 50 mg·L^{-1} of TAN (Fig. 2a), the transmembrane pressure (TMP) increase was very low. As a result, the total fouling resistance was drastically reduced from 39·10^{11} m^{-1} to 2·10^{11} m^{-1} with 30 mg·L^{-1} of TAN. Furthermore, threshold flux progressively increased with the addition of TAN, being 50% higher (24 L/m^2.h) than estimated for wastewater (16 L/m^2.h).

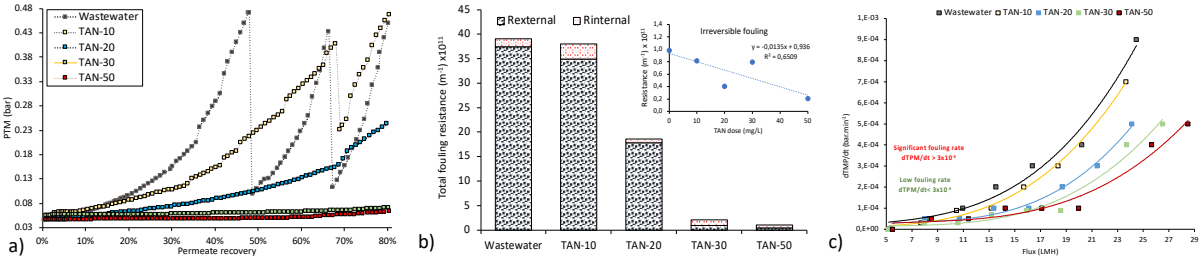

Figure 2: TMP under constant flux (a), fouling resistance (b) and threshold flux (c).

Particle size plays a crucial role in the dynamics of coagulation and fouling processes. As can be seen in Figure 3a, the addition of the tannin-based coagulant resulted in larger aggregates and a reduction in small particles, especially when using 50 mg·L^{-1} of coagulant. Larger particles were easier to remove and reduced fouling potential. Furthermore, this aggregate formation significantly reduced the presence of biopolymers (proteins and carbohydrates), which are more prone to fouling membranes. With an addition of 30 mg·L^{-1} of TAN the concentration of dissolved biopolymers reduced from 3.3 mg·L^{-1} to 0.6 mg·L^{-1} in the supernatant. Similar behavior occurred with the concentration of biopolymers in the external (Fig. 3c) and internal fouling layers.

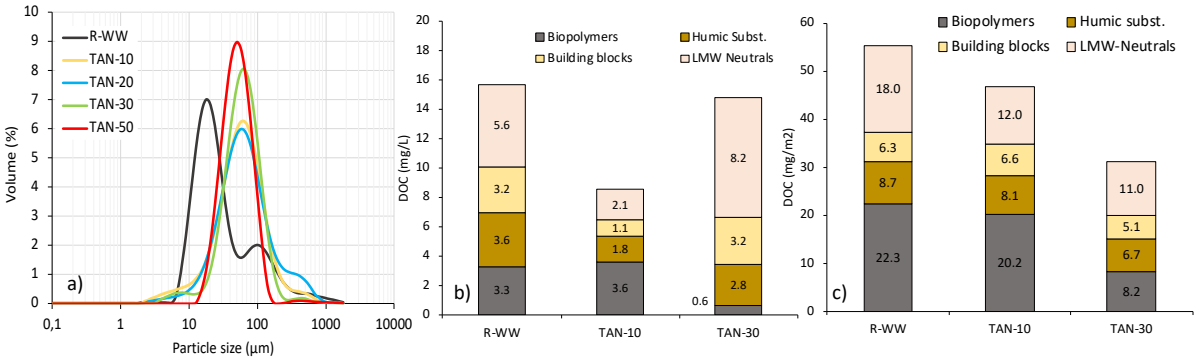

Figure 3: Particle size distribution (a) and dissolved organic components with different molecular weights in raw and coagulated wastewater (a), external (b), and internal fouling layer (c).

In conclusion, the application of a tannin-based coagulant has proven to be highly effective in mitigating fouling during DMF, primarily attributed to the ability to facilitate aggregate formation and significantly reduce the presence of biopolymers. The dosage optimization of tannin-based coagulants represents a promising strategy for potential full-scale implementation in DMF systems, offering an efficient means to reduce fouling and enhance the energy efficiency of the role process.

REFERENCES

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