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DOMESTIC DIRECT MEMBRANE FILTRATION AND IMPLICATIONS FOR COUPLING WITH ANAEROBIC MEMBRANE BIOREACTOR (DF-ANMBR) FOR WASTEWATER

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ABSTRACT

With the growing use of membranes in the water industry, different methods for using membranes to treat water is still occurring. Enhancing membrane performance is generally performed with extensive pretreatment methods before the feed water is filtered by the membrane. With the utilization of direct membrane filtration (DF), no pretreatment is performed and the membrane is exposed to raw wastewater. While this may suggest that membrane performance and permeate quality would suffer in the process, DF testing with a 0.03µm ultra filtration PVDF membrane showed that relatively high membrane flux was sustained while producing a high quality effluent. Due to the rejection of the membrane, a highly concentrated fraction of the wastewater, which is significantly reduced in volume but high in solids and organic strength, is obtained and can be treated in other ways.

A process is proposed to treat municipal wastewater by coupling a DF system with an anaerobic membrane bioreactor (AnMBR). AnMBRs generally treat industrial strength wastewater, which is high in chemical oxygen demand (COD), and may struggle with domestic wastewater, which is generally considered low strength in terms of COD.

The MFI method was adapted and used to test the fouling propensity of various treatment streams in the DF-AnMBR system, including raw domestic Wastewater, concentrated domestic wastewater (20X by DF), and liquor from an active AnMBR.The effect of powdered activated carbon (PAC) on fouling propensity was also investigated. Raw wastewater had a fouling potential of about 25% of the AnMBR MFI, and with the utilization of PAC the fouling potential was further decreased to nearly 50% of the original fouling potential. The DF concentrated stream had a higher MFI value than liquor from the AnMBR, but presumably some of organics contributing to fouling would be degraded in the AnMBR. This study demonstrated that DF of raw wastewater is feasible, and the combined use of DF and AnMBR is highly promising.

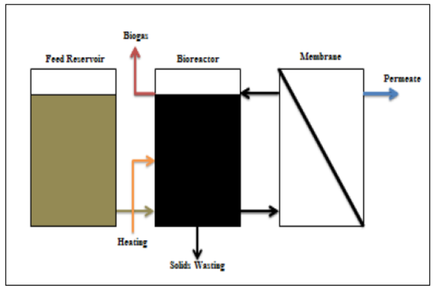
I. INTRODUCTION

WASTEWATER TREATMENT

Conventional wastewater treatment is a well-defined practice with facilities designed to handle small flows of less than a million gallon per day (MGD) to extremely large flow of nearly 1.5 billion gallons per day. To achieve necessary wastewater treatment, these facilities often use many different processes, including physical, chemical, and biological processes (Metcalf and Eddy, 2014).

WASTEWATER TREATMENT

According to Stephenson et al. (2000), the membrane bioreactor is able have high quality effluent within a small footprint. Within this small footprint, the MBRs utilize a bioreactor which houses microbial populations for biological degradation of waste and a membrane system which physically removes contaminants from wastewater. If the system acts as anaerobic membrane bioreactor (AnMBR), energy can be recovered from the system through the recovery of biogas (Prieto et al., 2013) thus offsetting the energy demand of operation. Figure 1.1 shows the generally layout of an AnMBR, where domestic wastewater is the feedwater and solids, energy, and water (permeate) are produced in the system.



Layout of a typical AnMBR

OBJECTIVES

This work is to investigate the potential for utilizing a DF system and the implications of coupling with an AnMBR for the creation of the DF-AnMBR. This work will investigate permeate quality of domestic wastewater produced by a DF system as well as determine the concentration of COD and solids, which are rejected by the DF system. In addition the rejection of various parameters will be monitored and used to propose a model for the DF-AnMBR, which will determine various influents and effluents in the DF-AnMBR. Finally, the fouling potential of various feedwaters (domestic wastewater, DF concentrate, AnMBR reactor liquor, and wastewater with the additive PAC) will be determined to monitor how each feed water interacts with the membrane and fouls the membrane.

SCOPE OF WORK

- Determine the effectiveness of a DF system for domestic wastewater treatment.
- Analyze the water quality of permeate generated through the DF process.
- Determine the concentration of COD, solids, and nutrients produced by the DF system.
- Propose a model for combining a DF and AnMBR.
- Develop a rapid assessment tool for determining fouling propensity of different wastewater streams.
- Analyze the fouling potential of domestic wastewater, DF concentrate, wastewater with PAC addition, and AnMBR sludge and show the reproducibility of this method.

II. LITERATURE REVIEW

Metcalf and Eddy (2014), the term module is used in the membrane field to describe a complete unit comprised of the membrane element (or modules), the pressure support for the feed, permeate and concentrate structure as well as the overall support structure. There are three main configurations used in wastewater treatment including spiral wound, hollow fine fiber and tubular. While other configurations exist such as plate and frame and pleated cartridge filters, these configurations are primarily used for industrial purposes.

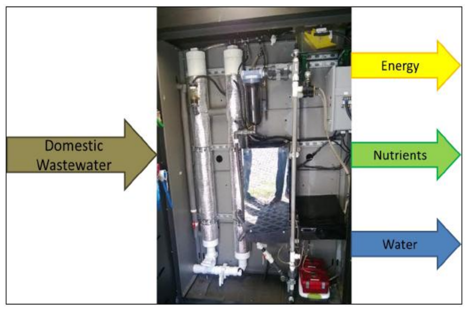
According to **Karabelas (2013)**, for desalination using NF or RO membranes, the spiral wound membrane is the most important part of the desalination system. This type of membrane geometry is not widely used in the MF and UF due to inability to backwash the membrane and extensive pretreatment is required to allow the membrane not to clog and foul.

According to **Vanysacker et al. (2013)** studies have reported that solutes are the main factor in fouling while others claim that suspended solids and another claims that colloidal material is the key issue. While the main reason for membrane fouling may still be debatable, the need for controlling fouling is necessary for a successful membrane system. Three main operating conditions including TMP, feedwater characteristics, and membrane characteristics are the driving factors which can reduce the fouling

III. MATERIALS AND METHODS

Wastewater that would be utilized in the experiments was obtained at a local charter school, Learning Gate Community School (LGCS) in Lutz, FL. At LGCS, a research station known as Biorecycling and Bioenergy Research and Training Station (BBRATS) is established with a unique educational platform to help educate the younger generation to develop a better understanding for sustainability. The BBRATS facility houses four technologies including a food waste digester (FW digester), algae photobioreactor (APBR), a hydroponic/aquaponic system, and an AnMBR.

The AnMBR treats a portion of the wastewater generated by roughly 600 students and 50 staff members via the collection system that disposes wastewater into a septic tank. The system withdraws wastewater from the collection post grinder station to ensure the destruction of sanitary wipes and napkins, as well as any other large particles that may enter the system. The AnMBR is a 20.45 liter; two-stage AnMBR (Figure 3.1) designed to operate at ambient temperature for the treatment of domestic wastewater. Each phase of the sequence holds equal volume (10.23 liters).



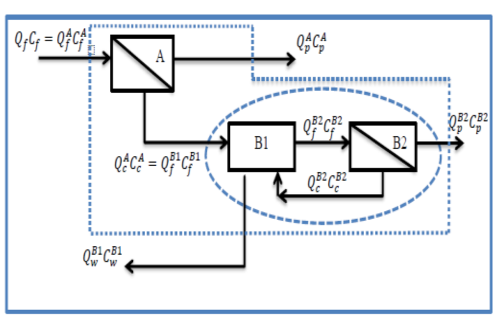
AnMBR established at LGCS for the treatment of domestic wastewater

ANALYTICAL METHODS

Samples from the experiments were measured for some or all of the following parameters depending on each test; COD, total nitrogen (TN), ammonia, total phosphorus (TP), turbidity, total solids (TS), total volatile solids (VS), total suspended solids (TSS), and volatile suspended solids (VSS),pathogens via E. coli testing, color and yellowness. Samples were measured for total concentration (raw) and/or soluble fraction, which was obtained from the supernatant of a centrifuged sample (centrifuged at 3000 rpm for 15 minutes). Hence, soluble sample include both truly dissolved and unsettled colloidal matter.

IV. MODELING THE DF-AnMBR

The AnMBR technology excels for the treatment of industrial wastewater due to the high COD concentrations. The AnMBR which is dependent on the influent concentration, which in field conditions can vary from day to day, may not be able to receive the required organic loading strength found in domestic wastewater.

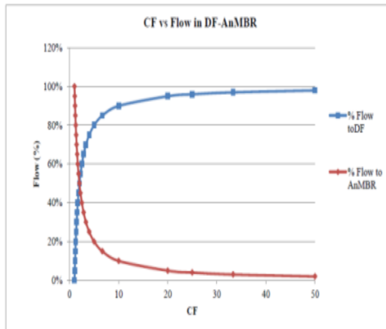


Mass balance diagram for the DF-AnMBR (A represents DF stage, B represents AnMBR stage, where B1 is the bioreactor and B2 is the membrane)

Table: Variables, superscripts, and subscripts used in DF-AnMBR

Parameter		Superscripts		Subscripts	
Variable	Meaning	Variable	Meaning	Variable	Meaning
Q	Flow	A	Stage A, DF	f	Feed
C	Concentrate	B	Stage B, AnMBR	c	Concentrate
		B1	Bioreactor	p	Permeate
		B2	Membrane	w	Waste

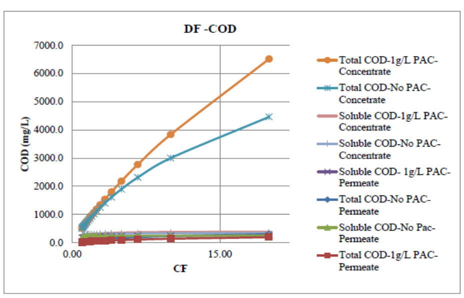
CONCENTRATION FACTOR

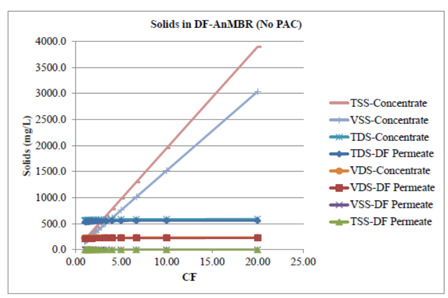


Flow rate in various parts of the DF-AnMBR with different CF

ANALYSIS

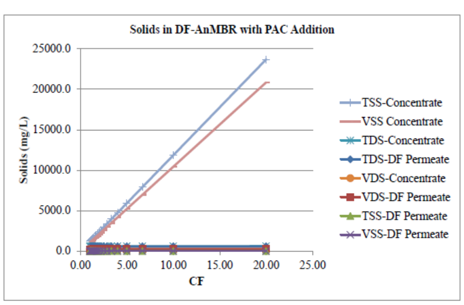
Since the membrane performance will change with various CFs it is important that each parameter is modeled according along various CF.

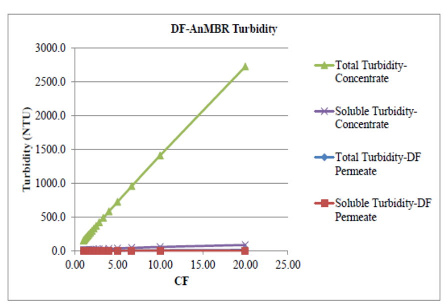




Expected COD concentrations of the DF-AnMBR

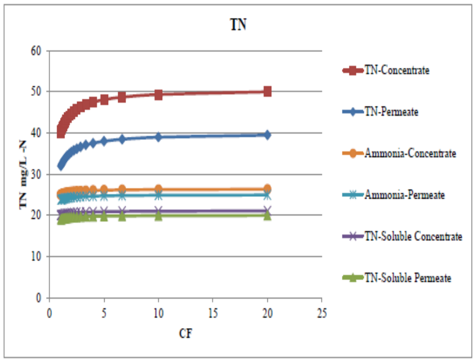
Expected solids in DF-AnMBR with no PAC addition



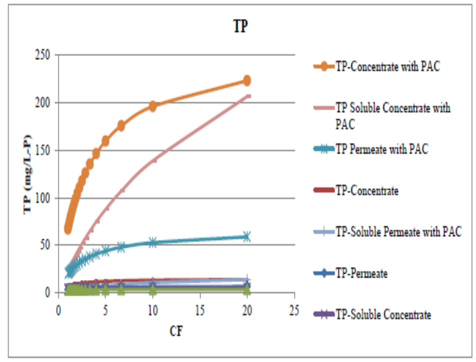


Expected solids in DF-AnMBR with 1g/L PAC addition

Expected turbidity in the DF-AnMBR



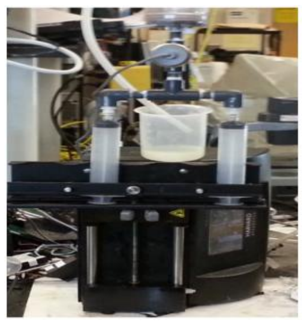
Expected TN and ammonia concentrations in DF-AnMBR



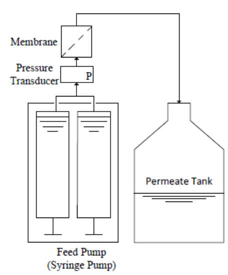
Expected TP concentrations in DF-AnMBR

V. FOULING POTENTIAL

EXPERIMENTAL SETUP FOR MFI SYSTEM

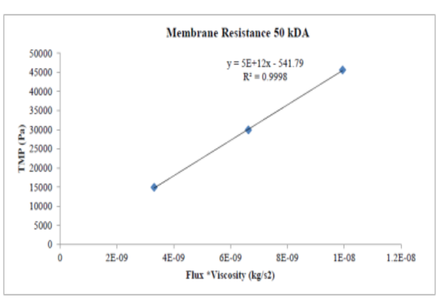


Syringe pump setup for the Modified Fouling Index testing

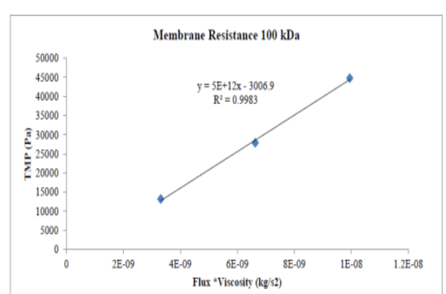


Schematic of the MFI system

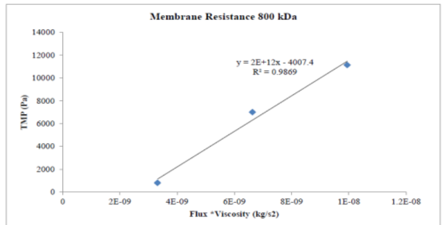
MEMBRANE RESISTANCE



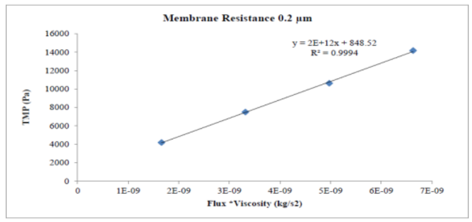
Membrane resistance curve of an UF membrane with a MWCO of 50 Kda



Membrane resistance curve of an UF membrane with a MWCO of 100 kDA

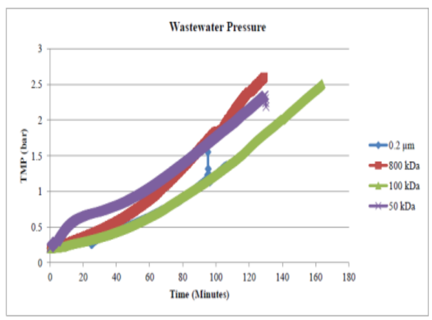


Membrane resistance curve of a MF membrane with a MWCO of 800 kDA

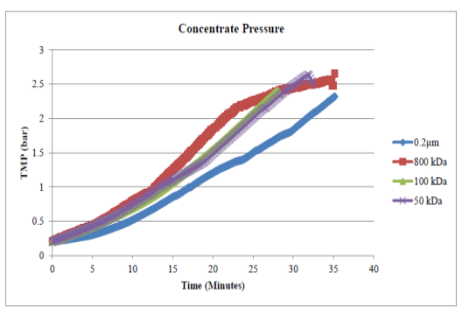


Membrane resistance curve of a MF membrane with average pore size of 0.2 µm

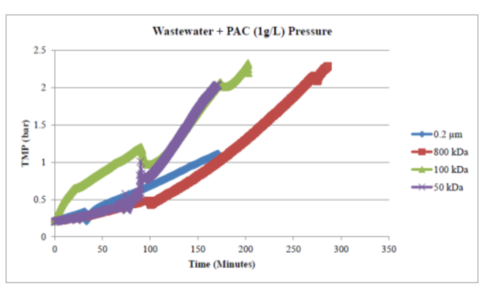
PRESSURE CURVES



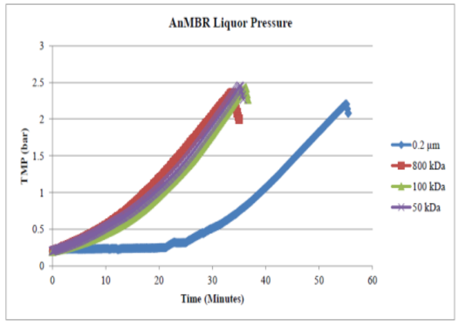
Pressure curves for the feedwater, wastewater, with four different membranes



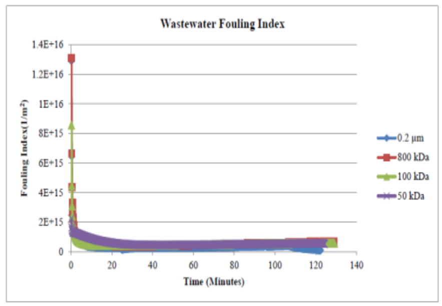
Pressure curves for the feedwater, concentrate, with four different membranes



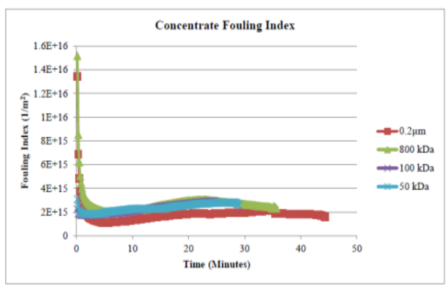
Pressure curves for the feedwater, wastewater with PAC addition, with four different Membranes



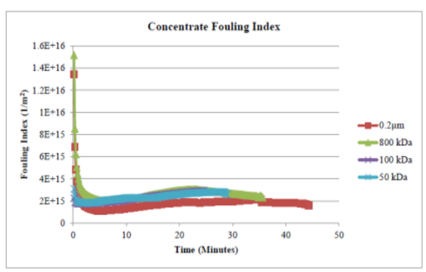
Pressure curves for the feedwater, AnMBR liquor with four different membranes



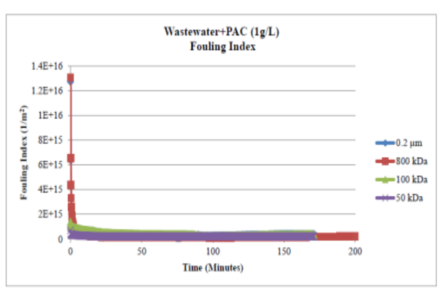
Fouling index for wastewater tested on four different membranes



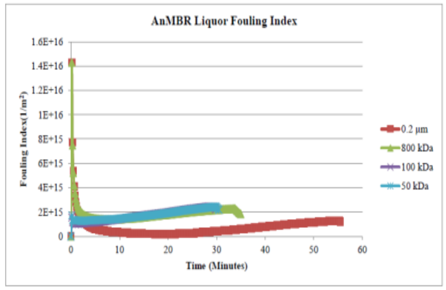
Fouling index for wastewater tested on four different membranes



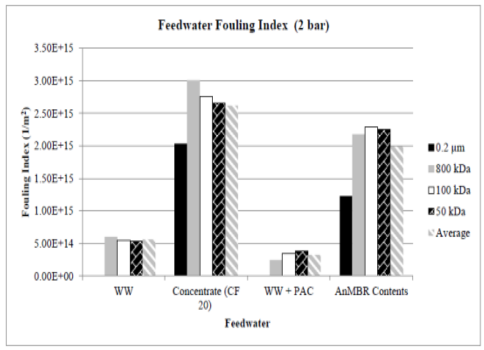
Fouling index for concentrate tested on four different membranes



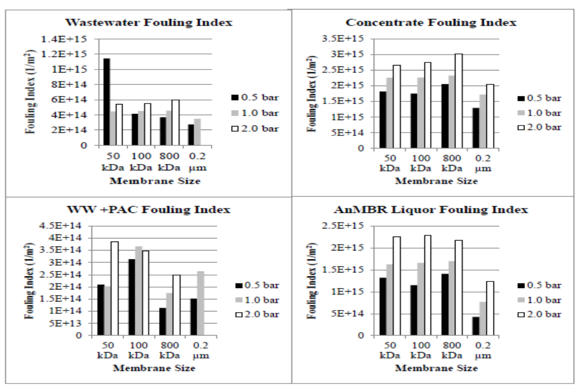
Fouling index for wastewater with 1 g/L PAC addition tested on four different membranes



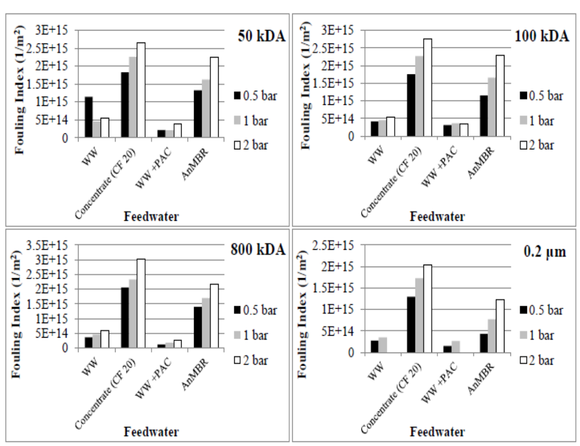
Fouling index for AnMBR liquor contents tested on four different membranes



Fouling index of each feedwater on each membrane at 2 bar



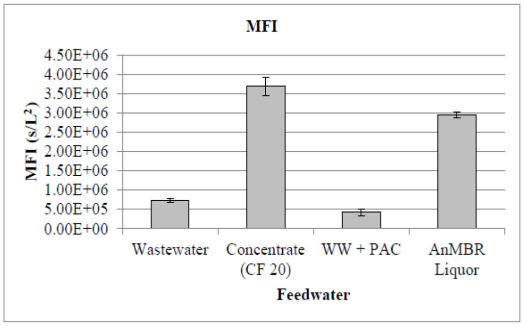
Fouling index generated at pressures of 0.5, 1.0, and 2.0 bar for the four feedwaters on the four membranes



Comparison of the fouling index produced on each membrane by the feedwaters

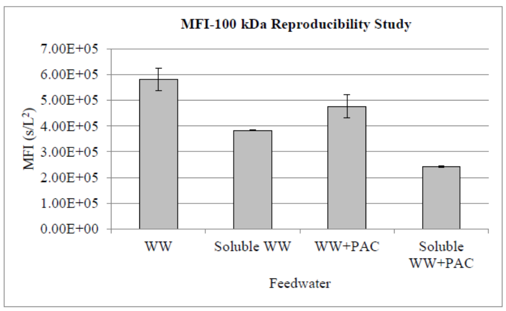
MODIFIED FOULING INDEX

Parameter	WW	Concentrate (CF 20)	WW + PAC	AnMBR Liquor
Fouling Index ($1/m^2$)	5.6E+14	2.8E+15	3.2E+14	2.2E+15
Standard Deviation	3.4E+13	1.8E+14	7.0E+13	5.7E+13
Percent Deviation	6%	6%	22%	3%



MFI for wastewater, concentrate, wastewater with PAC, and AnMBR contents

REPRODUCIBILITY



MFI reproducibility study

CONCLUSION

From this above study the following conclusions were made

1. Concentration of the feedwater (domestic wastewater) in the DF module is possible to generate higher strength wastewater at over 1500 mg/L of COD. Higher CFs were able to produce COD concentrations between 2000 and 2500 mg/L.
2. Utilizing the model, high concentration of COD and solids will be present within the concentrate while permeate remains relatively stable, making the concentrate an ideal feedwater for the AnMBR.
3. With PAC, the solids buildup in the concentrate is much higher, which could result in lower SRT or the need for a larger bioreactor to reduce solids buildup.
4. Nutrients in the DF-AnMBR remain relatively stable in all phases of system, except for TP when the PAC is added to the system, due to phosphate leaching.
5. The MFI system constructed produced highly reproducible results with the deviation of the MFI ranging from less than 1% in the soluble fraction to less than 10% when PAC was added
6. Domestic wastewater fouling potential was improved with a PAC of dose of 1 g/L, in dead-end filtration, with a MFI value 60% with PAC than without PAC.
7. Concentrate (CF of 20) and AnMBR liquor produced MFI values of 5 and 4 times higher than domestic wastewater, respectively.

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