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REUSE OF MBR EFFLUENT FROM FRUIT PROCESSING WASTEWATER CONTAINING HIGH DISSOLVED ORGANIC MATTER

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Abstract: Reuse of wastewater is a recognized approach to enhance sustainability of water resources including the related process operations and industrial management. The reuse of wastewater from a fruit processor in Ontario has been challenging due to varied compositions and strength of biodegradable organic matters (BOM) in the wastewater. This ultimately leads to the instability in biological treatment processes by membrane bioreactor (MBR) and subsequent fouling of downstream reverse osmosis (RO) membrane by soluble microbial products (SMP) impacting water reuse operations. Results revealed about 85% of decline in RO flux after only 75 h of continuous operations feeding with the MBR effluent containing 80 ppm dissolved organic matters (DOM). Completed experiments show a reduction of DOM in MBR effluent with enhanced coagulation using high dosed alum and ferric chloride, along with chitosan flocculation coupled with sorption on amorphous and solid phases using granular activated carbon (GAC). On-going work is evaluating long-term continuous operations with treated MBR effluent that include bio-fouling monitoring, membrane cleaning and performance restoration.

1. OVERVIEW

1.1 Background

Industrial partner (IP), is an apple sorting and juicing facility in Ontario. They use a substantial amount of water (± 45 m^3) every day for the growing, hydro-conveying and cleaning of their apples including cider (juicing) processes for apple, pear and sometimes cranberry, along with the pressing and chemical cleaning at the various stages of processing. The facility is facing RO membrane fouling that requires weekly cleaning, reducing plant availability along with a substantial operational budget that has hindered the water reuse program. Examinations of the MBR effluent show high concentrations of low molecular soluble microbial products (SMP). These SMP are causing the observed fouling. Additionally, the IP has fruit change overs during the year, which means the wastewater characteristics vary based on fruits type, which further destabilizes the biological treatment process in the MBR. As a result, the SMP and extracellular polymeric substances (EPS) make their way through the 0.04 µ MBR UF membrane pores to MBR effluent. These materials are subsequently captured on the RO (100 Da) membrane surface during final stage of treatment.

The SMP present in the MBR effluent are group of organic compounds that include carbohydrates, humic acids, and protein type materials along with trace amount of lipids, nucleic acids and some poly saccharides as reported by many researchers (Jarusutthirak and Amy 2006; Haberkamp et al. 2007). These compounds are generated by bacterial metabolism on biodegradable organic matters (BOM) through biomass growth, decay and cell-lysis processes, which also produce soluble EPS. They are hydrophobic, non-reactive to chemical and biological processes and when combined can be considered as total organic compounds (TOC) in effluent. These materials have the potential to adhere onto membrane surface and ultimately block the permeation passages. Fouling caused by SMP materials is irreversible, needing early replacement of membranes, which incur increased operational costs. The present research was targeted to remove/reduce these foulants from the effluent by developing and utilizing a best management practice to treat the effluent prior to filtration by the RO membrane, providing a sustainable operation with water reuse management.

In respect of fruit change impacts assessment, comparative characteristics evaluation of an apple and pear juice reveal remarkable differences of higher contents of dissimilar substances, such as sorbitol and vitamin C in pear juice. In practice this results in a lower pH in case of pear operation. The supernatant pH from apple reactor was 8.9, while that of pear operation was 7.8, which subsequently reduces further due acidogenesis in the process. Lower pH in pear effluent exhibits an acidogenic environment in the reactor, which reasonably shifts or impacts the existing micro-floral activities at higher pH with an apple processing when fruit is changed. Some bacterial growth inhibition has been reported to be enhanced by sorbitol (Liu et al., 2015). Production of more carbohydrates and uronic acid contaminations of EPS may also occur. All those components with low molecular size will be present in the MBR effluent.

1.2 Literature Review

In general, the amount of suspended solids (SS), size and ionic properties require a strategy for the proposed treatment. Conventional coagulation-flocculation-sedimentation and filtration, adsorption-sorption, ion exchange, bio-filtration, slow sand filtration, advanced oxidation processes (AOP), dissolved air floatation (DAF), electro coagulation and membrane filtration are all potential treatments. It was reported that aluminum in the form of poly aluminum chloride (PACl) removed about 93%, 56% and 32% of color, COD and NH_3, respectively, from leachate (Aziz et al., 2009). Chitosan aided polymeric bridge was identified by size analysis, that increases floc size in flocculation process resulting with efficient coagulation (Ng et al., 2018). Over 90% of organic (Humic) removal was claimed by applying 20 mg/l dosages of each of Alum or $FeCl_3$, at pH 7 treating pulp wastewater (Hong et al., 2003). DAF has also reported use for lighter colloidal particles reduction (Edzwald, J. 2007, 1995).

In the coagulation of larger TOC compounds, alum together with ferric chloride can be used (Shon et al. 2007; Jarusutthirak and Amy 2006), while activated carbon sorption removes smaller organics as well as pharmaceutical organics (Bonvin et al. 2018, Jarusutthirak and Amy 2006; Snyder et al. 2003). Enhanced coagulation has reported success in reduction of DOC (Edzwald and Tobiason, 1999; Edwards, 1997). Granular activated carbon (GAC) is normally used for drinking water application (USACE, 2001) for high removal of organic contaminants. In the present study, processes removing organics were further evaluated for optimized application.

Foulants on membrane surface are typically polysaccharides, proteins, and amino-sugar, while the intensity of fouling depends on their concentrations in SMP (Juang et al. 2013; Jarusutthirak and Amy 2006; Yao et al. 2011). Protein fouling was observed by municipal wastewater effluent (Juang et al. 2013). Nonpolar hydrophobic organics are the components that attach to the membrane surface, ultimately plug the membrane pores and causing a decline in the permeation power of membrane. Accumulation of dead microbes forms a gelatinous slime of decomposing bacteria on the membrane surface, which inhibits water passage. Foulants accumulated in cake layer of membrane surface revealed mostly the compounds like polysaccharides, proteins, and aminosugar (Jarusutthirak and Amy 2006). Polysaccharides and aminosugars are reported to be the critical membrane foulants.

Therefore, MBR effluent should be free from nonpolar hydrophobic contaminants. In general, the turbidity of feed water should have <0.4NTU, TOC<5 ppm, BOD_5<5 ppm, TSS<10 ppm for long-term steady performance of RO membrane (Davila and Sparks, 2003). Efficient MBR performance is appears to be the vital factor for steady RO performance. After effective removal of hydrophobic and biodegradable organic compounds by MBR, the remaining trace hydrophilic organic compounds were reported to be removeable by RO membrane. Alturki et al. (2010) showed with a lab-scale investigation it is possible to reduce DOM from the MBR effluent, followed by removal via the RO membrane.

Enhanced coagulation (EnC) is a USEPA regulated drinking water treatment strategy to reduce TOC/DOM, turbidity particulates and residual coagulant (Edzwald and Tobiason, 1999). The pH and coagulant dosages are interrelated for the precipitation of amorphous solids from the coagulant hydrolysis reaction (generally, Al-hydroxide or ferrihydrite). The maximum solubility of ferric solid occurs at about pH 8. The solubility of both Al and Fe hydroxide is minimum at pH of 6 at ambient temperature. Iron hydroxide solubility is lower and considered more efficient in sorption coagulation mechanism in enhanced coagulation, while Al works well for semi polar neutralization and coagulation. Stumm and Morgan (1962) noted that coagulation behavior is a function of temperature due to the impact on pH.

The literature reviewed was mostly bench scale concerning municipal wastewater effluent. Minimal information was found for the fruit processing industry using a MBR - RO system to treat the wastewater. As such, any information obtained from this study is unique.

2 METHODS

The premise moving forward was that the bacterial metabolism would be similar to whatever is the source of BOM. With this idea, baseline information from municipal biological processes were assessed. As SS and turbidity of the IP's effluent are very low, the only challenge was the removal of dissolved organic matters (DOM). Parallel to the evaluation of other technologies, advanced sorption on an amorphous water phase followed by solid phase sorption were considered for the tertiary treatment for the IP effluent.

2.1 Enhanced Coagulation and Amorphous Sorption

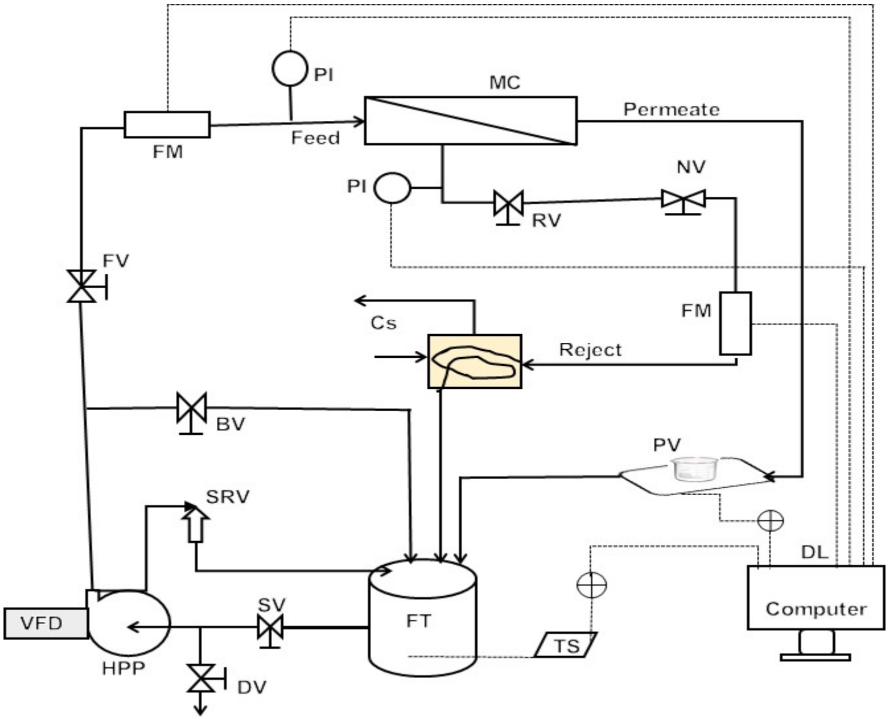
Eight different coagulants and coagulant aids including Chitosan, Poly Aluminum Chloride (PACL), Aluminum Sulphate (AS), Ferric Chloride (FC), Poly DADMAC (diallyl dimethyl ammonium chloride) (PDM), Poly-glu (PG), ULTRION 8187 (aluminum chloride hydroxide) (UL) and Core Shell (polymeric latex flocculant) (CS) were evaluated. Seasonal variations and wastewater applications of chemicals were considered. To predict the interrelation between coagulation with amorphous sorption onto the oxide surface, and to optimize performance of DOM removal by EnC, Jar testing was used to identify best conditions for actual and synthetic effluent (prepared at lab mimicking characteristics of actual effluent). Following coagulant addition that was 1 min rapid mixing at 100 rpm, 30 min slow mixing at 20-25 rpm and 60 min settling sequence. To determine coagulant dosages and DOM removal efficiencies, DOM/TOC is measured after each coagulation sequence. To determine alum solubility at equilibrium, gibbsite and amorphous solubility diagrams was followed (Faust and Aly, 1998).

2.2 Solid Phase Sorption

Solid phase sorption onto various activated carbons (AC) surfaces including Norith RB40M AC (M1), Char House-BoneChar with Granular Charcoal 20x 60 (M2), Calgon Carbon WHP powder activated carbon PAC (M3), CEI-8x30 (M4), Filtra Sorb 300- 8X30 (M5), CEI-12x40 (M6), Norith GAC 12x40 (M7), Filtra Sorb 400 -12X 40 (M8), and Anthra-Filter-BC-12X40 (M9) were evaluated. Evaluation was carried out both at bench and semi-pilot scale using mini columns maintaining 10 min contact time. Performance of AC was assessed based on reduction of DOM, turbidity, color, and inorganics content in treated water, both at bench scale and mini columns tests. DOM was determined using filtered water to avoid suspended part. Out of nine activated carbons tested, 5 ACs (M3-M6, M8) were procured from USA, and the rest from local vendors.

2.3 Evaluation by RO Test Unit

To mimic the membrane performances with the IP site, a DOW Filmtec polyamide thin film composite (PA-TFC) extra low energy (XLE) for brackish water RO membrane model (BW30XLE) was tested. It had an effective surface area of 2.3" x 2.95" with a design flux (gfd/psig) of 33-41/125 and a salt rejection 98.7% (NaCl). The pore size/MWCO was 100 Da. It was installed and evaluated in the experimental set-up shown in Figure 1.



FT = Feed tank
SV = Suction valve
DV = Drain valve
HPP= High pressure pump
VFD= Variable frequency drive
SRV= safety relieve valve

BV = Bypass valve
FV = Feed valve
FM = Flow meter
PI = Pressure indicator
RV = Reject valve
ND = Needle valve

CS = Cooling system
PB = Precision balance
DL = Data logger
TS = Temperature sensor
AI = Automatic logging

Figure 1: Schematic flow diagram of RO experimental unit set-up

2.4 Analysis of Foulants on RO Membrane Surface

Foulants accumulated on the RO membrane surface were dried and examined using a dissecting microscope. Initial physical observations were noted, and simple laboratory tests were conducted such as addition of hydrochloric acid to dry and crushed materials from membrane surface to see any bubbling reactions leading to prediction of carbonate materials. Foulant materials elemental analysis was conducted using a scanning electron microscope (SEM) with an X-ray microanalysis system to determine elemental compositions. To predict organic functionality providing subsequent structural information, Fourier Transform Infrared (FTIR) spectrometer and associated infrared microscopy was conducted to obtain comparable reasonable match to a compound in laboratory database. Both the SEM EDX and FTIR analyses were facilitated at the UofG Central Laboratory.

3. RESULTS

3.1 Characterization of MBR effluent

Analyses of the MBR effluent revealed remarkably variable characteristics. Turbidity, a prime parameter for RO operation, was very low, which makes sense considering that the effluent passes through a 0.04µ UF membrane. Among the SMP and EPS components, carbohydrates, humic substances and protein type materials were detected with varied concentrations, where humic substances had the highest level at 50-

70 ppm. Table 1 shows concentration ranges of the various constituents found in the MBR effluent. Including COD, BOD, TOC, conductivity, TDS, EPS, turbidity and pH, almost all parameters varied substantially. Variability in operating conditions, short (7 days) SRT (sludge retention time) and pulse feeding (10 min/h) to the MBR impact the effluent, producing variable SMP. In addition, EPS hydrolysis was impacted by pH and temperature variations during the fruit change, as discussed earlier, which also added to the variability.

Table 1: Characteristics of MBR effluent

Components	*Concentrations*	*Components*	*Concentrations*
Chemical oxygen demand (COD)	60 -110 ppm	pH	8.0-9.0
Biological oxygen demand (BOD)	40 – 90 ppm	Turbidity	0.1-0.5 NTU
TOC	17 – 125 ppm	TP	0.67-1.63 ppm
UVA	0.17–0.48	TKN	0.20-0.45 ppm
Conductivity	800-3000 µs/cm	NH3 - N	0.01 -0.02 ppm
TDS	500-1500 ppm	Color	14 – 38 Co-Pt
Protein type materials	1-15 ppm	Carbohydrates	30-55 ppm
Humic substances	40-70 ppm		

The MBR effluent also varied due to storage in the lab. Comparison of analysis results as a function of sampling date showed variability and an substantial increase in subsequent days of storing. Fluctuations varied 80 to 103 ppm, 12 to 129 ppm and 25 to 51 ppm in the three samples. Such behavior could attribute to the high biopotential in the effluent. In addition, BOD and COD values in the BMR effluent were high when compared with typical municipal wastewater quality.

3.2 Assessment of Trace Elements on Membrane Surface Operated with MBR effluent

When the RO was operated with untreated MBR effluent, the membrane lost its initial permeation within less than 75 hours of operations. During this time, the initial temperature corrected flow declined to about 70%, from about 0.98 mL/min flow to 0.30 mL/min. The amber colour of the liquid had an amorphous appearance, which could be attributed to humic and protein materials, respectively. SEM-EDX analysis showed predominate elements of oxygen, iron, zinc, silicon, aluminum and sodium along with smaller proportions of calcium, magnesium, phosphorous, Sulphur, potassium and copper. The majority of these elements could be attributed to corrosion product from system pipes/tanks. However, the high peaks of oxygen, associated hydrogen and carbon suggest presence of alcoholic, acidic and amine functionality of organic compounds.

3.3: Assessment of SMP and DOM Foulants on Membrane surface

Foulant analysis was completed using Fourier Transform Infrared (FTIR) spectrometer and infrared microscopy as shown in Figure 2. The spectra show functional groups of foulants over the membrane surface. The peaks at wavenumbers of 1040 and 2940 cm^{-1} indicate the presence of polysaccharide like materials. A very broad peak in the region between 3100 and 3600 cm^{-1} indicates presence of exchangeable protons, typically from alcohol, amine, amide, or carboxylic acid having -OH, -NH2, -CONH, or -COOH functionality, respectively (Marlic et al., 2001). Peaks at 1550 and 1640 cm^{-1} are evidences of presence of protein like materials (Jarusutthirak and Amy, 2006), which reasonably correspond to the building block of bacteria cell walls. The FTIR analyses are consistent with DOC levels of 80-90 ppm and the amber color, showing the presence of humic substances.

3.4: Enhanced Coagulations and Sorption

The effectiveness of EnC depends on type and concentration of organics, corresponding coagulant dosage and pH (5.8-7.0) along with related alkalinity (0-240 ppm). Most of the collected MBR effluent pH varied from 8-9, consistent with no OH alkalinity, with only M alkalinity present at the lower range (0-120). Interestingly, after the addition of coagulants, effluent pH reduced substantially, requiring the addition of

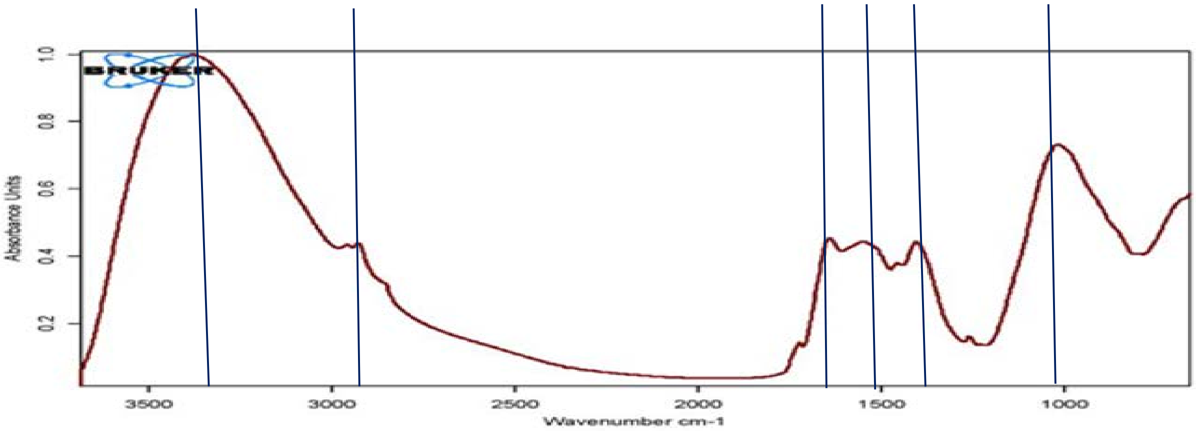


Figure 2: FTIR Spectra of Fouled Membrane Operated with Untreated MBR Effluent

alkali to increase alkalinity to a pH range of around 6, the desired lowest solubility condition for Al and Fe oxide coagulation.

Through the assessment of different coagulants, enhanced coagulation at higher dosage of aluminum sulfate (90 ppm) and ferric chloride (55 ppm) aided by Chitosan (35 ppm), reduced the DOM to about 12% from an initial concentration of 90 ppm. The color was also reduced substantially. It was observed that, the dosing rates of coagulants depended on the DOM concentration. For example, at a lower DOM concentration (15-30 ppm) about 60 ppm aluminum sulfate and 40 ppm ferric chloride worked well. Adjustment of pH and coagulant concentrations was essential to keep the operation line within the region of solid/amorphous phase in solubility product diagrams of Al and Fe as outlined in Faust and Aly (1998). Dissimilar to conventional coagulation, flocculation and precipitation, amorphous phase precipitation occurred along with organic sorption onto amorphous phase and flocculation, as promoted by controlled Chitosan dosage. Sizing analysis (Ng et al., 2018) also suggested that chitosan helped with polymer bridging, which leads to an increase in size of floc, thereby improving the removal.

Optimum dosage and pH were tracked for experimental temperature to achieve maximum reduction of particulates, turbidity and DOM. A minimum level of residual coagulant (Al) ions in solution was also maintained. All those parameters are analyzed for comparative evaluation of trials. As an average, at an effluent temperature of 15 °C, a pH of 6.3 worked well for efficient removal. Table 2 shows summarized results of coagulation for an effluent with 88 ppm DOM.

Table 2: Results from a Coagulation Experiment

	Coagulation and sorption results				Coagulants		
	NTU	TOC ppm	TC ppm	IC ppm	AS ppm	Fe ppm	CS ppm
Effluent		88.05	221.45	137.5			
Coagulated effluent	2	79.03	122.92	43.88	60	40	30
M8 sorbed	0.28	1.57	66.4	64.86			
Ref. DI water	0.2	0.418	0.647	0.23			

Notes: TC = total carbon; IC=inorganic carbon; CS = Chitosan

Coagulation of contaminants from the apple effluent generated at bench scale MBR operations was conducted with a combined dosing of aluminum sulfate (AS), and ferric chloride (FC) as coagulants, while chitosan (CS) as an aid at the rates of 60, 60 and 40 ppm, respectively, at pH 5.8. A reduction of COD, TOC, IC (inorganic carbon), TC (total carbon) were about 55, 32, 54, 57 %, respectively. Further reduction of IC, about 53%, could be achieved by DAF. It is worthy to mention here that no improvements were observed at higher pH 7-8, and lower coagulant dosage (20 ppm). Visible suspended floc justified a filtration requirement after coagulation. In parallel, for the treatment of synthetic effluent, only AS was required without FC. This was most probably, due to the absence of phosphate in synthetic effluent, as phosphorous compound requires ferric chloride for removal. Compared to carbohydrate, coagulation removed humic acid remarkably as indicated by corresponding TOC measurement after coagulation. Coagulation was found to be optimum at pH 6, while about 85±% of DOC/TOC (as humic) removed from synthetic effluent.

In comparison, EnC was excellent in the treatment of bench scale MBR effluent and synthetic effluent. In case of synthetic effluent as all the constituents are known, their treatments could be formulated from experience and theories. Preparation of bench scale apple effluent from fresh and washed apple as well as controlled MBR conditions provided more clear effluent. On the contrary, the IP's effluent has variable characters, as discussed earlier, make it challenging for their treatment.

3.5 Solid Phase Activated Carbon Sorption

Evaluation of nine different granular activated carbons (GACs) was conducted based on their capacity and intensity of DOM removal. Results of DOM removal by sorption revealed that granular AC (GAC) with granule size of 12X40 are good performers in removal of DOM from the MBR effluent. The observations are in agreement with USACE (2001). Granular activated carbon is designed by sizes, and the most popular aqueous phase GAC are the 12x40 and 8x30 sizes as they have very good balance of size, surface area, and head loss characteristics (USACE, 2001). The 12x40 size is normally recommended for drinking water application as it shows good SS removal, as well turbidity. Based on DOM removal efficiency, four of the good performing GACs were identified (M6-M9) for subsequent evaluation.

Results of further assessment tests through 8 hours contact are shown in Table 3. Based on comparative efficiencies they are ranked as M8> M6>M9>M7. The maximum DOM removal (99.9%) was achieved from M8 type GAC. Accordingly, the M8 GAC was selected for a larger volume test of treated effluent on a mini column experiments maintaining 10 min. residence time. Table 5 also shows final results on this column test, a remarkable reduction of turbidity to 0.25 NTU and DOM to about 97.63 was achieved. Ultimately, for the proposed BMP (best management practices), M8 was used for production of pre-treated water to feed RO membrane in subsequent operations.

Table 3: Summary Table on GAC Sorption

Contact= 8 hr	GAC Types						Best
100g/L	M4	M5	M6	M7	M8	M9	GAC
% TOC removal	89.86	94.17	97.52	85.23	99.91	90.77	M8
NTU	3.91	5.17	2.97	9.91	1.50	9.91	M8
Column test, 10 min. residence							
% TOC removal					97.63		
NTU					0.25		

3.6 Water Quality Comparison

A summarized comparison of water quality at different stages, starting from MBR effluent followed by coagulation product and subsequent GAC sorption operation prior to RO feed are shown in Table 4. The final product after GAC sorption was fed to the RO unit for continuous operation of RO and comparative evaluation with untreated MBR effluent feed. The feed turbidity 0.28 NTU was well below the RO operation feed quality limit. A similar trend was seen with the TOC concentration, about 98 % reduction, a significant achievement.

3.7 RO performance Evaluation

The reverse osmosis unit was run continuously, feeding the above (GAC) treated water having TOC 1.57 ppm and turbidity 0.28 NTU. Figure 3 shows the comparison of RO performances with and without the BMP treated effluent feed. A sharp decline was seen in the case of untreated effluent, compared to almost steady flux with the treated effluent. A mild decline after about 80 hours of operation was restored to nearly initial flow conditions (0.97 mL/min) utilizing an online management of forward flushing. This was done for a short time, 5-10 minutes at lower pressure with higher than normal flow without stopping the operation. The high flow with high velocity cleans the loosely bound materials from the surface, showing that the accumulation was loosely bound. In the case of untreated effluent, a temporary improvement was observed with an online management (high flow low pressure flushing), but there was an immediately flux decline to below <70%. This comparative performance proved the success of BMP treated effluent as suitable RO feed ensuring sustainable recycle and reuse process.

Table 4: Comparison of water quality at different stages of BMP operationTreatment steps			Property parameters		
	TOC ppm	TC ppm (total carbon)	IC ppm (inorganic carbon)	Turbidity (NTU)	Color Pt Co
Effluent	88	221	138	-	32
Coagulation product	78	123	79	2.0	9.0
M8 sorption	1.5	66	65	0.28	<1.00
Reference DI water	0.42	0.65	0.23	0.20	1.00

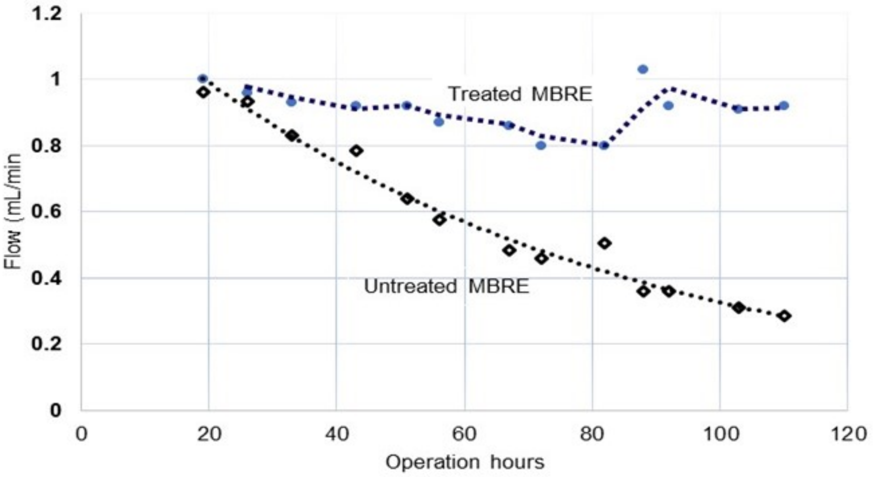


Figure 3: Performances Comparison of RO feeding with untreated and BMP treated MBR effluents

Analysis of the permeate quality was conducted for the required parameters. The permeate quality was excellent in terms of TDS (25 ppm), color (zero), Mn (nil), Zn (nil) and iron (0.03 ppm) content. Table 5 shows a quality comparison of RO feed and permeate, as final product. The proposed operations of feeding the RO with enhanced coagulation followed by GAS feeding (EnC-GAC) provides for negligible flux decline in comparison to about 70% decline in case of untreated MBR effluent during the same period (about 100 hours) of operations. It should be mentioned that the initial 20-24 hours of RO operation is membrane compaction period, are not included in the comparison.

Table 5: Specification of RO Feed and Permeate

	Feed	Permeate		Feed	Permeate
Conductivity µs/cm	3015	49	Aluminum ppm	0.01	nil
TDS ppm	1635	25	Magnesium ppm	0.00	nil
pH	9.3	8.2	NH_3 ppm	0.00	nil
Turbidity	1.1	0.0	NO_3 ppm	0.00	nil
Color pt co	3	0.0	TH ppm $CaCO_3$	0.00	nil
Calcium ppm	0.02	Nil	SiO_2 ppm	0.00	Nil

4. INNOVATION AND LESSONS LEARN

The completed study provides an innovative BMP that involves enhanced coagulation and GAC treatment. This system will help the industrial partner manage the treatment of the MBR effluent, providing a sustainable recycling process for water reuse, which will save the environment and minimize the operational budget. The following summary highlights the significance of the studied issues in fruit and vegetable industries (FVI).

- Enhanced coagulation process, although applied elsewhere, was previously never used in MBR effluent treatment. This is an additional supportive technology reducing DOM load on solid GAC sorbent
- Development of the BMP will support recycling of water after RO filtration, allowing in reduction of fresh water needed by the process as well as amount of discharges. This ultimately reduces the discharge surcharge costs contributing to profitability and environmental sustainability.
- Lessons learned from this project can safely be applied to other fresh fruit producers, leading to allowable discharge quality or recycle process.
- RO unit functions smoothly as foulants in the form of SMP DOM were almost removed from effluent by the BMP, which was not the case in presence of DOM where RO flux declined substantially.
- Detailed knowledge on accurate detection of EPS is still a deficient area. More knowledge on interfering radicals and accurate EPS detection is a call supporting treatment strategy
- Trained HQP working on the project will mitigate deficient skills, presently observing by the sector, discharge know-how of treatment across the food sector
- In support of water scarcity issues, the processor can maintain and expand their market share at reduced water costs along with creating more job opportunities

A pilot process set-up integrating BMP pre-treatment with the online MBR effluent at IP site to treat the effluent as well as feed to the RO system is highly recommended. A mini-module tester, capable of evaluating 40x40 membrane module as used at the IP site, would be instrumental to avail design information for a commercial application.

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