INTRODUCTION TO VIBRATORY SHEAR ENHANCED MEMBRANE PROCESS AND ITS APPLICATION IN STARCH WASTEWATER RECYCLE

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Abstract

Membrane application in wastewater is gaining significant popularity. Selecting the right membrane and filtration technique is an important consideration to ensure a successful system development and long term performance. A new type of membrane filtration technology known as 'Vibratory Shear Enhanced Process' (VSEP) is introduced in this paper with some test results that has been conducted with VSEP pilot unit to recycle starch wastewater. Conventional cross flow membrane process used in wastewater application always led to rapid fouling. This loss in throughput capacity is primarily due to the formation of a layer that builds up naturally on the membranes surface during the filtration process. In addition to cutting down on the flux performance of the membrane, this boundary or gel layer acts as a secondary membrane reducing the native design selectivity of the membrane in use. This inability to handle the buildup of solids has also limited the use of membranes to low-solids feed streams. In a VSEP system, an additional shear wave produced by the membrane's vibration cause solids and foulants to be lifted off the membrane surface and remixed with the bulk material flowing through the membrane stack. This high shear processing exposes the membrane pores for maximum throughput that is typically between 3 and 10 times the throughput of conventional cross-flow systems. The short term results with raw starch wastewater shows very stable flux rate of 110 lmh using the VSEP system and selecting the PVDF ultrafiltration membrane with no pre-filtration.

Key words: VSEP, Ultrafiltration (UF), membrane flux, transmembrane pressure (TMP), wastewater reuse

1. INTRODUCTION

1.1 Problem of High Solid Wastewater

High solid wastewater has always provided challenge to membrane filtration due to rapid fouling tendency. Membrane module configuration is considered along with cross flow velocity as a primary way to control this problem. This in some instances resulted in very high circulation flowrate especially in capillary and tubular membrane configurations. Introducing air (either during service or during backwash does provide help in some wastewater applications). But introducing vibration is a relatively new approach in case of wastewater with high solid content. As shown in figure 1, conventional cross flow results in formation of a boundary/gel layer on the membrane surface resulting in flux declination that in some cases irrecoverable and shortens the membrane life.

Figure 1

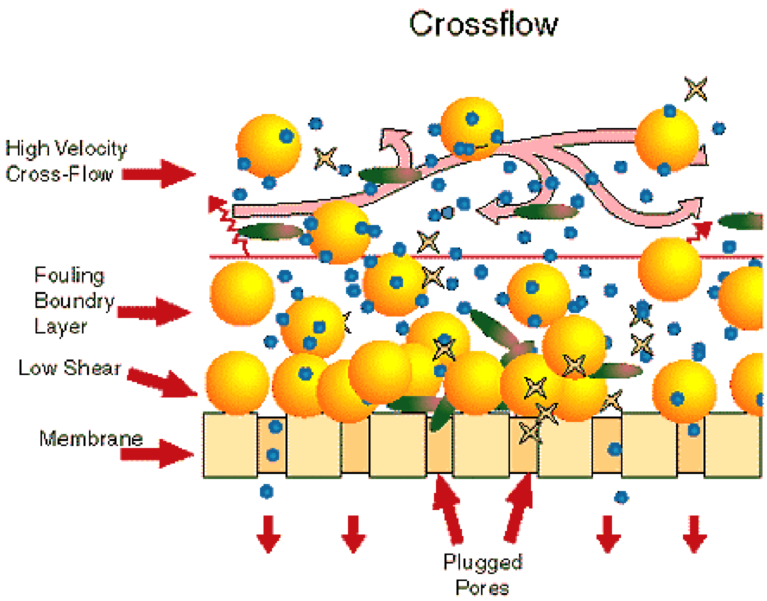
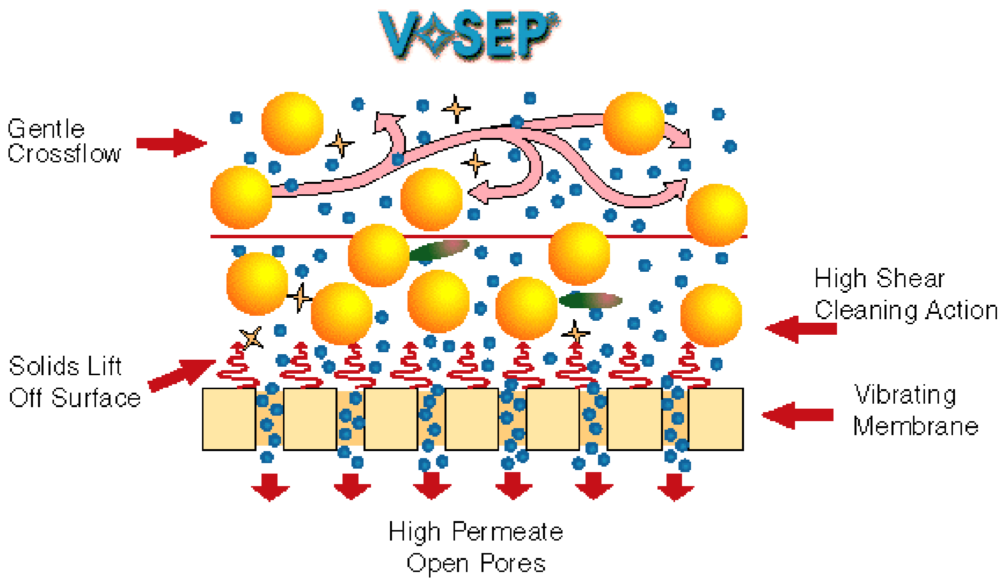


Figure 2



1.2 VSEP Principle

Introducing vibration at the membrane surface exactly where it is needed, reduces the tendency to form any layer that results consistent flux. In combination with the appropriate type of membrane and material selection VSEP can provide an effective solution. In a typical VSEP system, membranes are arranged in a plate and frame configuration (figure 3). Different types of membrane (Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis) can be used in a VSEP module to achieve the required product quality. The VSEP system requires a careful pilot test protocol to obtain a right membrane material in combination with vibration to provide a very stable flux.

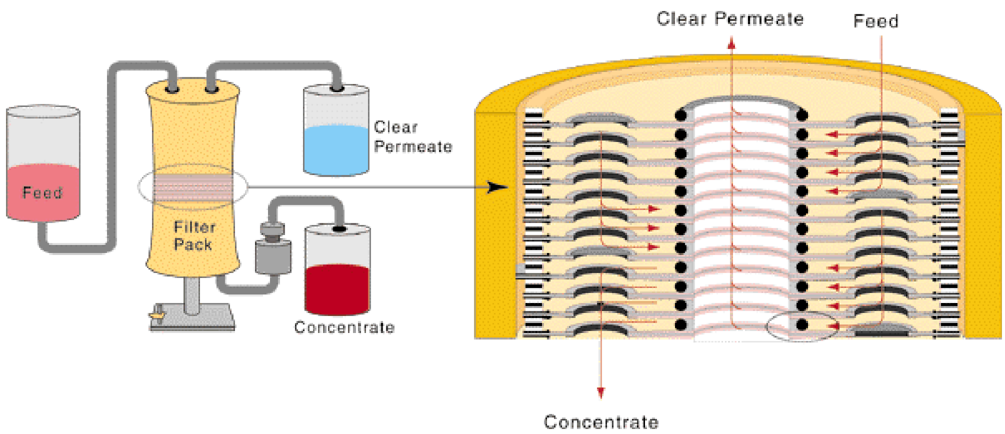


Figure 3: Inside look at the VSEP plate and frame assembly

At the core of VSEP's highly efficient operation is a patented resonating drive system (figure 4). This system achieves high energy efficiency by applying shear into a thin zone near the filter surface. This precise application of shear results in efficient energy conversion and very low power consumption.

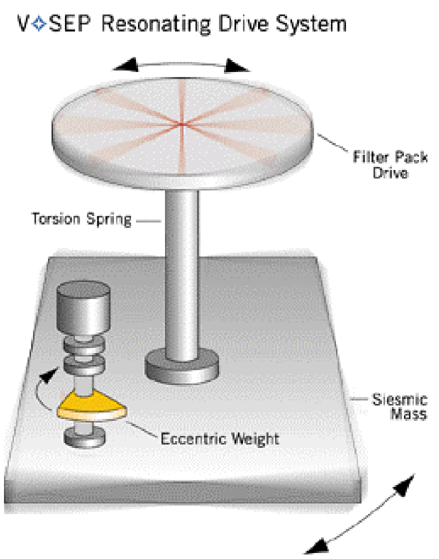


Figure 4: Principle to generate vibration for typical VSEP system

VSEP allows nearly 99% of the total energy utilized to be converted to shear at the membrane surface (*Culkin et.al. 1998*). Compare this to a typical crossflow filtration system where as little as 10% of the energy is converted to shear on the membranes.

The disk stack of a VSEP unit is oscillated above a torsion spring that moves the stack back and forth approximately 7/8 inches The oscillation produces a shear at the membrane surface of about 150,000 inverse seconds, which is much higher than conventional cross-flow systems The shear waves produced by the membrane's vibration cause solids and foulants to be lifted off the membrane surface and remixed with the bulk material flowing through the membrane stack.

1.3 VSEP Engineering Advantage

VSEP is a simple, compact, closed system. Under normal operating conditions, VSEP will require the same level of attention as a pump. It will perform the instant power is applied, and the resulting separation is a pure physical occurrence.

VSEP only has two moving parts: the torsion spring — which is tested to assure infinite life; and the bearings — which are lubricated automatically. Additionally, the patented redundant membrane system, which automatically self-repairs in case of membrane element failure, guarantees uninterrupted performance.

Figure 5: Typical VSEP Setup

A VSEP system occupying only 1.85 square meter of floor space can support up to 185 square feet of membrane area and do the work of a system 10 to 100 times larger. The system is also modular for easy expansion. Installation of a Series I system is no more complicated than the installation of a pump.

Because VSEP does not depend on feed flow to induce shearing forces, the feed slurry can become extremely viscous and still be successfully dewatered. The concentrate is essentially extruded between the vibrating disc elements and exits the machine once it reaches the desired concentration level. Thus, VSEP Systems can be run in a single pass through the system, eliminating the need for costly working tanks, ancillary equipment and associated valving.

The disc pack holdup volume of a system with 130 sq. meters of membrane area, is less than 190 liters. As a result, product recovery in batch processes can be extremely high. Waste after draining the stack is less than 11 liters. At startup, the VSEP system is fed with a slurry and the concentrate valve is closed. Permeate is produced and suspended solids in the feed are collected inside the VSEP filter pack. After a programmed the time interval, concentrate valve is opened to release the concentrated solids. The valve is then closed to allow the concentration of additional feed material. This cycle repeats indefinitely.

1.4 VSEP Operating Parameters

Membrane selection is the single most important parameter that affects the quality of the separation. Other important parameters that affect system performance are pressure, temperature, vibration amplitude, and residence time. All of these elements are optimized during testing and entered into the programmable logic controller (PLC) that controls the system.

The operating pressure is created by the feed pump. VSEP machines can routinely operate at pressures as high as 68 bar. While higher pressures often produce increased permeate flow rates, they also use more energy. Therefore, an operating pressure is used that optimizes the balance between flow rates and energy consumption. In most cases, the filtration rate can be further improved by increasing the operating temperature. The temperature limit on a standard VSEP system depends on the membrane selected and can be as high as 90°C. This is significantly higher than competitive membrane technology. Even higher temperature constructions are available to treat streams up to 130°C. The vibration amplitude and corresponding shear rate can also be varied which directly affects filtration rates. Shearing is produced by the torsion oscillation of the filter stack. Typically the stack oscillates with amplitude of 1.9 to 3.2 cm peak-to-peak displacement at the rim of the stack.

Feed residence time is set by the frequency of the opening and closing of the exit valve (valve one). The solids level in the feed increases as the feed material remains in the machine. Occasionally, a cleaner is added to the membrane stack and continued oscillation helps clean the membrane in minutes. This process can be automated and only consumes approximately 190 liters of cleaning solution thus reducing cleaner disposal problems inherent with other membrane systems.

1.5 VSEP Application

VSEP has been tried in many applications, details of which can be found on the VSEP website (www.vsep.com). Some most established applications are;

- Pulp and Paper wastewater
- PVC latex concentration
- Clay and mining applications
- Carbon black
- Laundry-water recycling
- Landfill leachate
- Chemical processing
- Various industrial wastewater effluents.

2. MATERIALS AND METHODS

2.1 Starch Waste Water

A VSEP pilot test has been conducted on starch wastewater for the first time in Thailand. For this particular customer, the objective is to reuse as much water as possible. Topographically located in a dry region, the customer was exploring a solution that can reduce both the water consumption as well as to achieve a zero discharge.

Initial pilot test runs were conducted in tubular membrane module but it required frequent cleaning. In order to overcome this draw back pilot scale trial runs were conducted with the VSEP system. The initial objective was to produce a clarified wastewater using the VSEP system with maximum obtainable flux.

Table 1: Feed wastewater characteristics

Parameter	Unit	Starch Wastewater
1. pH	-	5-6
2. Temperature	°C	42
3. Conductivity	ms/cm	~2.9
4. TSS	%	~10

Membrane Selection

Based on the process objectives given, the following membranes were chosen for study:

Table 2: Selected test membranes

Membrane	% NaCl Rejection	pH Tolerance	Temp Tolerance	Water Flux*	Chlorine Tolerance
NANOFILTRATION					
NTR-7410	10.0%	2 to 11	90°C	196	100 ppm.
ULTRAFILTRATION					
Membrane	Pore size/ Rejection	pH Tolerance	Temp Tolerance	Water Flux*	Chlorine Tol.
C-100F	100,000 da	1 to 12	60°C	457	20 ppm
AF-5	2,000 da	2 to 11	90°C	-----	1000 ppm
NANOFILTRATION					
NTR-7450	50.0%	2 to 11	90°C	43	100 ppm.

* Average Batch Cell Test Results in lmh on new membrane @ 4 bar & 20°C

AF 5 is a PVDF membrane, C-100F is Regenerated Cellulose, NTR-7410 and NTR-7450 is sulfonated polyethersulfone membranes. The NTR-7450 was tried on the second day for longer time interval mostly to see the flux performance and typical cleaning efficiency.

2.2 Pilot Test Set-Up

The series L test is designed to test the relative performance of membranes (selected for test) and select the best one for further study. The technician begins the test by placing sample material into the feed tank and configuring the system in “Recirculation Mode” (Figure 6 a). The unit is run on the first membrane for 5 minutes to stabilize the system and then the unit is operated in ‘Batch mode’ (figure 6 b) for 2 hours. Some portion of permeate was collected as sample for analysis and rest was collected in a permeate tank. After end of 2 hours of operation for each membrane, the permeate remaining in the tank is put back to the feed tank to start with the new membrane type.

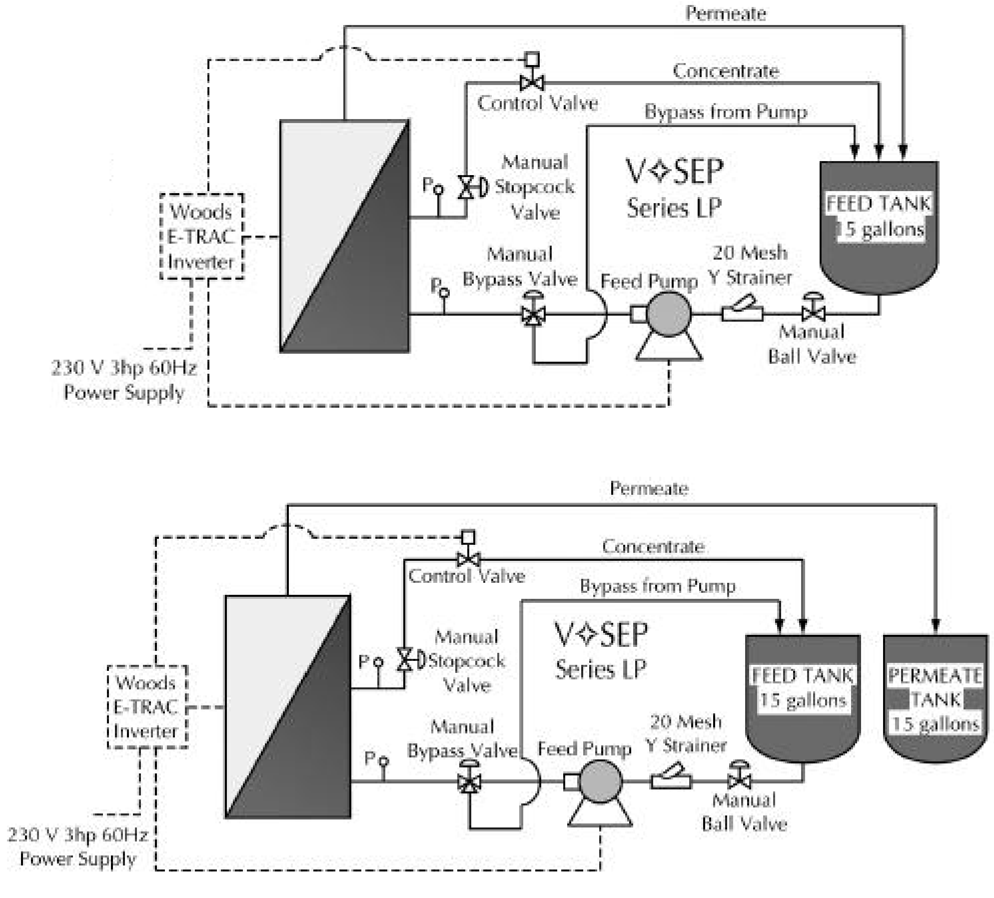


Figure 6 Pilot test schematic a) initial, b) batch circulation

Special Test Objective

The objective of this test is to observe that VSEP technology can help improving flux performance compared to conventional cross flow membrane. This is done by operating the VSEP pilot unit without vibration for 10 minute (while maintaining the feed pressure, and cross flow velocity) and check flow-rate during this period and after re-vibration. Test membrane was AF-5 which was the last membrane being tested.

3. RESULTS AND DISCUSSION

The following Table shows the relative performance of each membrane during 2 hour batch test.

Table 3: Initial test results

Membrane	Initial Flow*	Ending Flow*	Pressure	Conductivity	Color Appearance
NTR-7410	55.4	19.2	13.8 bar	1.75 ms/cm	Clear
C-100F	84.0	56.1	8.3 bar	2.83 ms/cm	Yellowish
AF-5	79.7	62.8	12.4 bar	2.84 ms/cm	Pale Yellowish

*Flow Rates are ml/min corrected to 42°C
Note: Product turbidity for all the three samples were < 0.1 NTU

Figure 7 Feed and Product of each membrane (NTR-7410, C-100F and AF-5)

Based on the initial test result, AF-5 is selected for a long term test to check the flux performance and cleaning efficiency (figure 8).

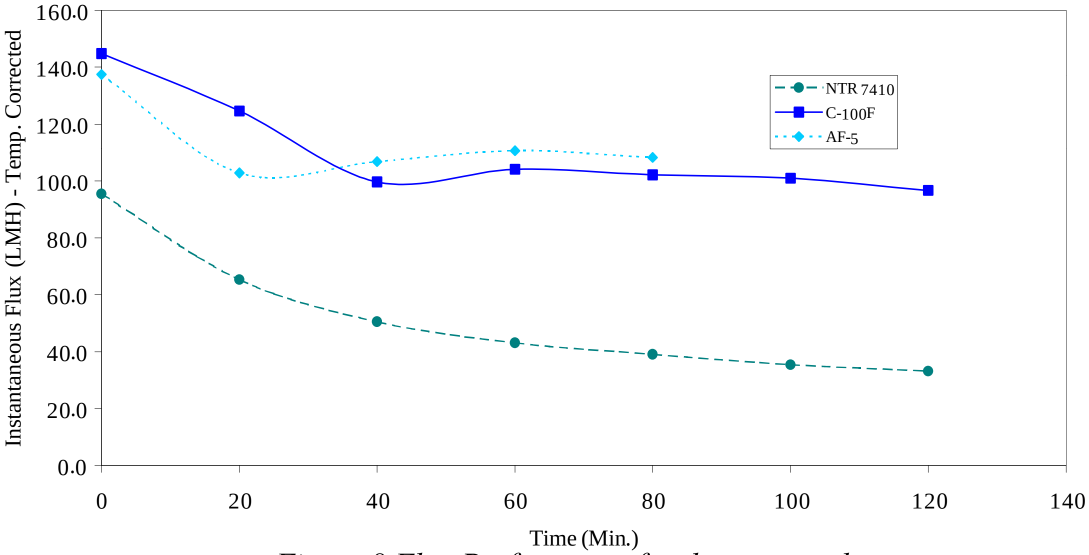


Figure 8 Flux Performance for the test membranes

Test with a NTR 7450 is conducted for 3 hours. The membrane is then cleaned with 1% Na-EDTA by adjusting pH to 10.5. Na-EDTA is a basic cleaning chemical used to remove fouling from membrane surface. The cleaning period was around 20 minutes. The test is then continued for another 3 hours. Test results shows a tighter membrane like NTR7450 tends to foul quickly (figure 9) though short term cleaning can improve the flux. The reason is probably due to an affinity of the polyethersulfone to the starch in the wastewater. Feed conductivity on the second day sample was 1.6 ms while rest of the properties was similar.

Table 4: Test result for NTR 7450

Membrane	Initial Flow*	Ending Flow*	Pressure	Conductivity	Color Appearance
NTR-7450	37	21	15 bar	0.545 ms/cm	Clear

*Flow Rates are ml/min corrected to 42°C
Note: Product turbidity was < 0.1 NTU

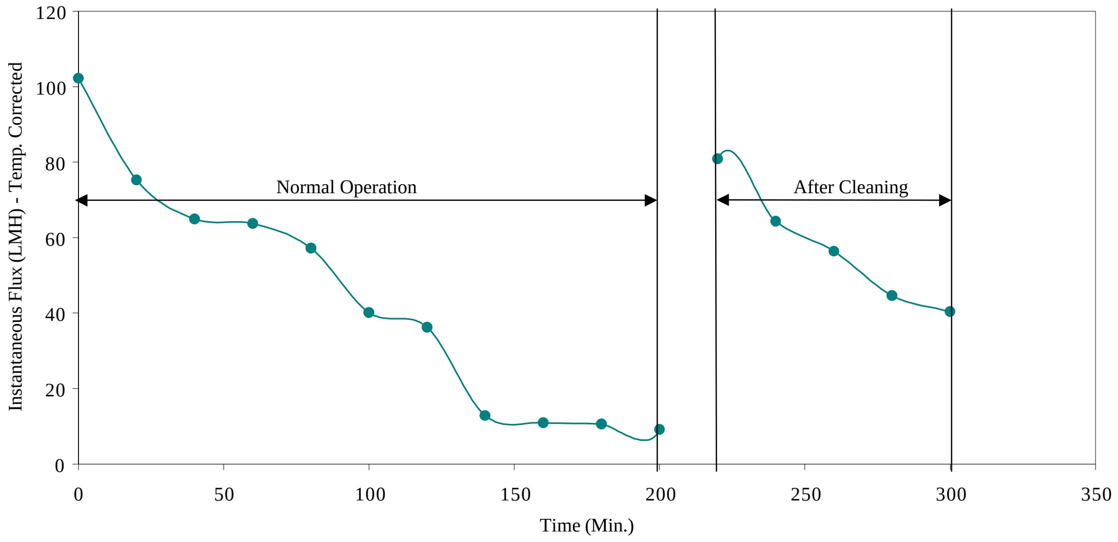


Figure 8 Flux and cleaning Performance for NTR-7450 membrane

The following Table shows the relative flux performance during the "Special Study":
Table 5: Test results on Special study

Time	*Flux**	Pressure
Operate without Vibration		
0 min.	53.8 lmh	12.4 bar
10 min.	38 lmh	12.4 bar
After Re-Vibration		
0 min.	38 lmh	12.4 bar
5 min.	109 lmh	12.4 bar

* Flux rates are temperature corrected to 42°C and are given in terms of lmh (liter/m^2/hr).

4. CONCLUSIONS

The test results shows AF5 and C100F have higher and stable flux of over 100 lmh. Though NTR 7410 produced much better quality water but the flux rate is too low. Based on the objective we suggested continuing further test with AF5 and C100F. Again between this two, AF5 is mostly preferred due to the membrane properties that can withstand harsh operating condition. Test with tight Nanofilter like NTR 7450 produced a much lower and less stable flux for this particular feed material.

Special VSEP test also proved a very effective way to reduce membrane-fouling tendency that could be applied in high solid wastewater application. Economic feasibility is also under consideration and very much dependent of specific application need.

5. REFERENCES

Culkin, B., Plotkin A. and Monroe, M., 1998. Solve Membrane Fouling Problems With High Shear Filtration, A Reprint from Chemical Engineering Progress.

Culkin, B., Monroe M., 2000 www.vsep.com

For more details on VSEP related case study, please visit www.vsep.com/downloads