DESIGN CRITERIA FOR A HIGH-QUALITY WASTEWATER RECLAIM SYSTEM

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JUL 2025

APEX

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Table of Contents

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1. Introduction

There are several reasons why reclaiming wasted water has become attractive in the past decade. They are as follows:

- Some regions of North America are “water stressed” such as the southwest US where a large segment of food and tech industries reside; in these areas water allotment is fixed, so any manufacturing growth is limited by water availability.
- Other regions of the country have stringent regulatory restrictions such as the Great Lakes Basin; POTW’s see a higher cost of treatment and strict discharge limitations, both of which are passed on to the industrial client.
- Corporations are concerned about their image and want to be seen as good stewards, so they are allocating resources to become leaders in the water conservation field.

Regardless of the reasons, purifying streams with biologically active organic BOD & TSS can be a treacherous undertaking, as the success rate is even at best and a complete loss at worst. The following report will illustrate how Apex engineers successfully designed a Reclaim System for an East Coast Dairy that has remained a successful operation to this day.

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2. Lessons Learned

The design of the successful Reclaim system started with an autopsy of past failures, both within and outside of the organization. The design team began by interviewing a coworker that was involved in a failed Gray Water treatment project. Without a full understanding of the biological activity in the source water, the design engineers recommended a "standard" system that would normally be acceptable for treating water with a *constant and reliable quality*. Of course, the first lesson in treating a wastewater source is that the quality is unpredictable.

The unpredictable nature of wastewater resides in the variable suspended solids content measured as parts per million Total Suspended Solids or TSS. In several cases the lowest capital cost ultra filtration membrane was selected based on the *average TSS* in the target stream. Be warned that employees that manage wastewater systems routinely characterize their water quality in terms of "best case scenario" thereby leaving the design team unaware of impending doom.
To further compound the matter, industrial water treatment design engineers are typically not familiar with treating streams that are biologically active and have virtually no hands-on experience in how typical "commodity" chemical treatment regimes affect Ultra Filtration flux rates nor Reverse Osmosis (RO) fouling.
In the case of the internal system failure there were two issues that proved insurmountable. First, the TSS would routinely spike above the UF Membrane tolerance which would in turn facilitate frequent backwashes and chemical cleanings thus needing extra attention and manpower. In addition, the active bacteria in the gray water would eventually proliferate throughout the UF and RO membranes (compounded by chemical selection) and require frequent RO cleaning which equates to manpower. The end results is a client that does not have the labor required to be chemically cleaning two membrane systems multiple times per week. Hence, the system is eventually abandoned.

A brief listing of Reclaim Failures:

a. A West Coast vegetable producer built a Reclaim Plant that used Pressure UF to process up to 1,000 ppm TSS post clarification. The clarification never worked correctly, however, and the UF's had to be cleaned multiple times per week. Since this plant was crucial to plant operation, however, the man-power was made available to keep the water flowing at reduced capacity.
b. An East Coast Dairy installed media filtration on a biologically active waste stream with 100 ppm TSS with the intention of using the filtrate as cooling tower makeup. The TSS was too high for media filtration, hence all the filtrate

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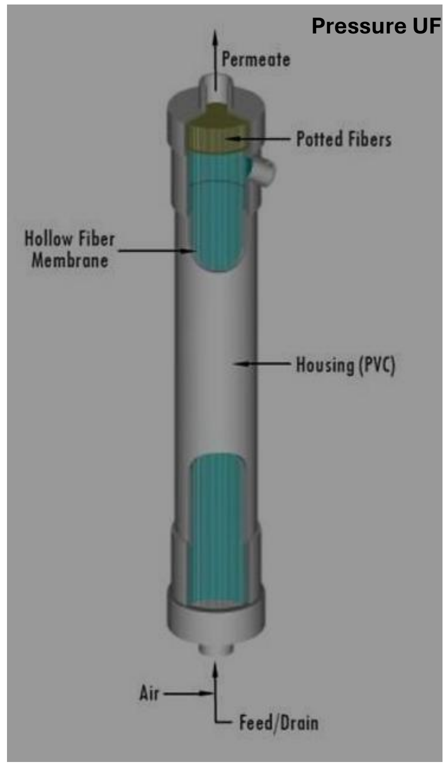
collected was needed to backwash the media, and no net reclaim filtrate was realized.

c. A Midwest Food plant attempted a similar media filtration system with 25 ppm TSS, but the salinity of the filtrate was not addressed. Hence, water with 650 ppm NaCl was sent to galvanized cooling towers where the structures were promptly corroded out, needing replacement.
d. A Southern Biofuels plant used pressure UF to filter Municipal Gray Water (the example from above). TSS spikes and high bacteria, compounded by uninformed chemical program choices resulted in frequent CIP demands
e. A Midwest Biofuels operation attempted Reclaim with a good UF system that could handle high TSS. However, the system had no pretreatment, and it was never piloted so the design flow (flux) was never achieved. The UF vendor added extra capacity to correct the problem, but it still wasn't enough. Thus the system was abandoned.
f. A Western anaerobic digester installed an equally robust UF system for reclaim, but the necessary pretreatment was not installed, and the system did not function properly, and was eventually abandoned.

Submerged Hollow-Fiber UF

Pressure UF Module



In addition to this list, the author of this paper had spent considerable time piloting the effluent at a Midwest Anaerobic Digestor with pressure UF. It became clear that pressure UF modules are not designed to handle TSS above 150 ppm due to the enclosed nature of the technology. The solids simply have no place to go, and they become entangled in the hollow fiber tube bundle. Once the bundle is saturated with solids, a copious amount of backwash is needed to remove them; the results is a low, net filtrate volume.

The author returned to this site several years later with a submerged pilot membrane from Sumitomo. Submerged membranes are commonly used in Membrane Bio Reactors (MBR) which routinely operate with 5,000 ppm TSS in the membrane tank.

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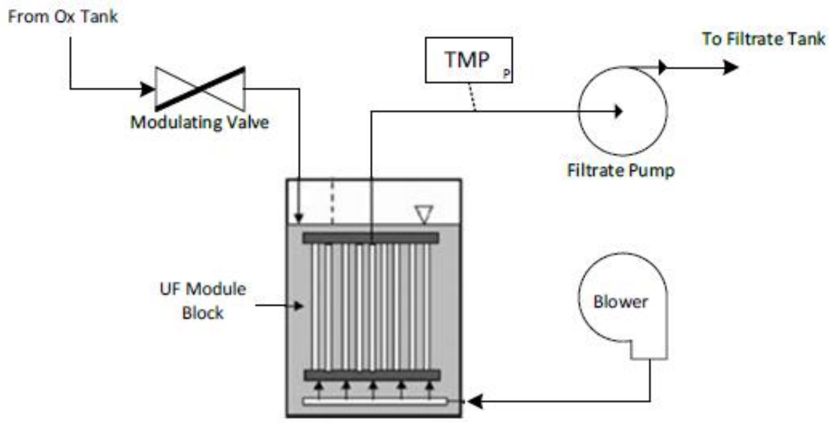
These membranes rely on continuous air scour to vibrate the hollow fibers and maintain the flux rate.



Although this type of membrane is a good fit for reclaim from a waste water clarifier; the challenge is to optimize the flux rate to make the capital expense affordable, as these systems are not skid mounted, but require a pit or large tank. The path to flux optimization revolves around a suitable pretreatment program.
The first foray into UF pretreatment was using sodium hypochlorite to both kill the bacteria and keep the membranes free of biofouling for an optimal flux rate. The use of chlorine in this pilot accomplished neither. Free chlorine levels were approaching 5.0 ppm in the UF Filtrate, which would have required a significant chemical dechlorination upstream of the RO. Qualitative observations during the pilot revealed that this would be a bad idea, as bisulfite is a nutrient for slime forming bacteria in RO membranes.

Subsequent pilot work in non-UF applications exposed the design team to other forms of Advanced Oxidation, especially regarding metals precipitation. So, with an organizational understanding of Reclaim pitfalls, the team set out to design a UF/RO Reclaim system for customer (b) above.

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3. Effective Design

An East Coast Dairy was looking to utilize the infrastructure built to support their multi-media reclaim system that was abandoned. It was decided early in the process to run small batch pilot tests on the target water, at the site before a proposal was offered to the client.

This water source is a dissolved air floatation (DAF) clarifier upstream of an aerobic digestion plant supporting a large dairy. The clear water was being sent to the POTW at a rate approaching 500 gpm. It was desired to produce approximately 100 gpm of RO Permeate to the plant cooling towers, which accounted for roughly one third of plant water consumption.

During pilot planning it was decided to test electrochemical advanced oxidation to the raw water as pretreatment to the UF Membrane. The team had seen coagulative properties in other pilots, and employing non-chemical treatments would eliminate a chemical cost to the client, thus streamlining the process with fewer variable control points. The design team was also looking for “solutions that fit”. Adding chemistry in one area and neutralizing it in another was considered lazy and sloppy.

Electrochemical Advanced Oxidation was successful during two pilot periods. The first pilot was a “proof of concept” 3 L/hr system, followed by a 30 L/hr system that ran overnight. The team was fortunate to have a clarifier upset happen during the second pilot run, where the TSS increased from 100 to 500 ppm over the course of an hour, and stayed there for two hours. The submerged UF membrane-maintained flux during this event with a minimal increase in Trans Membrane Pressure (TMP). See chart below.

The goal of any UF system is to pilot until *Critical Flux* is established. Critical Flux is defined as the flux rate where stable TMP is maintained for ≈24 hours. The subsequent design should then be based on the critical flux rate. In the dairy design, however, an optimum flux rate was used which is not recommended; even when a 2 x 75% array was used, the final system could reliably maintain about 75% of name plate capacity.
Early in the piloting process it was assumed that Silt Density Index should be the Key Performance Indicator for RO Operations. Over many years of successful RO design

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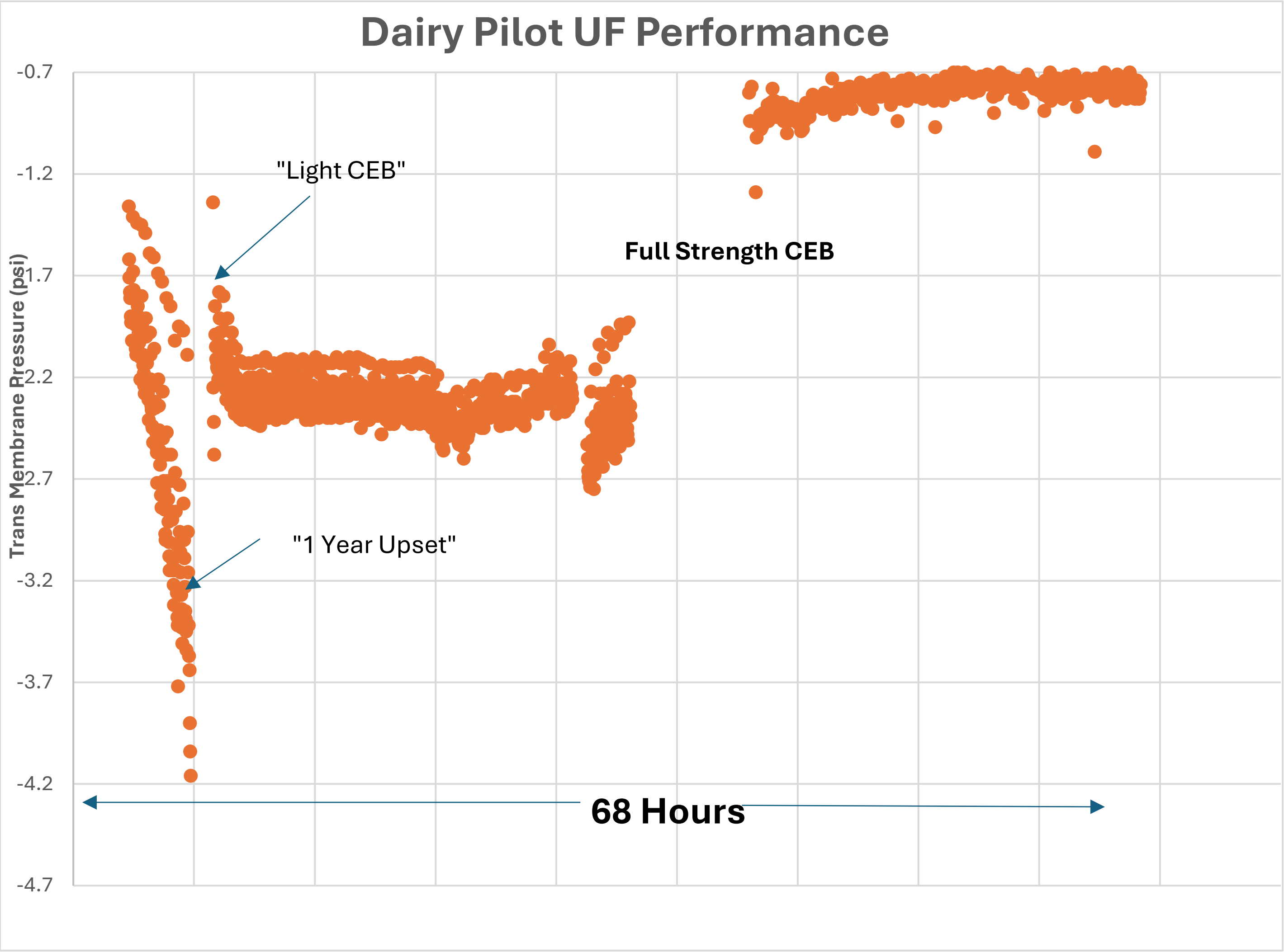
on well water, SDI had proven to be extremely reliable. However, these assumptions



gradually changed through many hours and weeks of piloting. Through piloting and subsequent startup, it was observed that minimum oxidation levels must be maintained through the UF system to have adequate RO operations. These excursions in low oxidation potential manifested in spiked SDI readings; increasing from <5 to >10.

Another KPI in RO performance is Filtrate Turbidity. Turbidity was tracked early in the pilot process, but its significance was not fully understood, nor was the analytical instrumentation up to quality standards. The new standard for filtrate quality (RO Makeup) became <0.20 NTU which is difficult to maintain if the aerobic process upstream of the UF is not sufficient.

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Reclaim waters tend to be high in bacteria and organics, so even the UF Filtrate has a much higher bacteria load than municipal water. In these cases, it is feasible to design the RO for *chemical flushes* rather than full-blown CIP. Whereas chemical flushes can be performed and return the unit to service in less than 30 minutes. This works when the foulant is predictable and uniform.

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4. Results

By employing these design strategies, the system operates reliably at 80% of design. Fortunately, for the client, 80% of design was able to provide 100% of the cooling tower demand, as the actual cooling tower makeup had not been accurately metered. The RO Permeate quality started out in the 50 µmho range and deteriorated to ≈200 µmho over the next two years. For reference, the city water conductivity is 400 µmhos and 134 ppm Calcium Hardness as $CaCO_3$.

As predicted, the RO needs more CIP than a typical system on city or well water. The average number of CIP's per week is 1.5 with the great majority being only high pH. Unlike a typical utilities RO, usually just the high pH is necessary to sufficiently lower the RO pressures. It is very important to CIP the RO back to the lowest possible Primary pressures or else remaining biological fouling will quickly compound and require another cleaning within 24-48 hours. There was quite a learning curve in regard to RO CIP during this project.

The unforeseen issues upon startup revolved around the DAF polymer application, as these issues were not present during piloting. It is important to feed the DAF polymer at the required dosage, with no extra, which can be tempting to the operators. There also needs to be a sufficient polymer make-down volume to prevent "snot balls" from reaching the UF membrane tank and causing high TMP. Another unforeseen issue was blower air supply to the UF tanks for membrane scour. The air supply instrumentation needs to be accurate, so the proper volumes are delivered to both tanks, and if one blower is used for UF two tanks, the level control in each tank must be accurate to prevent the majority of the air flow favoring the tank with the lowest level.

Budgetary Strategies This is a valuable lesson for reclaim project cost justifications. In most cases, industrial engineering projects employ robust capacity redundancy. However, when providing cooling tower reclaim water, how much redundancy is necessary? Since the fall-back position is using city water, as has been done for 20 years, why spend hundreds of thousands of dollars on non-profit-center redundancy? In this case, the supplier offered a system with little redundancy because of budget restraints, and on 80% of days, the Reclaim System provides +100% of the cooling water. That is seen as a "win" by the client, and a valuable lesson for future sustainability project budgeting.