Treatment of Acid Wash Wastewater from Electropolishing Parts with Ultrafiltration—A Case Study

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In the spring of 2000, an electropolishing company in Oakland, CA, that provides services for electropolishing stainless steel and aluminum parts was experiencing difficulty with its microfilter membrane system used for treatment of wastewater generated from the parts acid washwater operation. An ultrafiltration (UF) pilot was conducted to test the UF technology feasibility, performance and membrane cleanibility. The study showed the feasibility of UF to reduce the heavy metal constituents in the acid wash wastewater by 99 percent in the UF permeate. The study also showed that the UF membrane cleaning frequency could be extended to greater than six weeks, as compared to the microfilter technology that required cleaning every one to three days. In addition, the UF pilot study showed operational economic benefits superior to the microfilter when comparing the labor, chemicals and energy requirements. As a direct result of this study, the company purchased a commercial-scale UF system in November 2000 that is specified to treat 10,000 gpd of heavy-metal-contaminated wastewater. The UF system's analytical, productivity performance and operating economic details are presented.

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Introduction

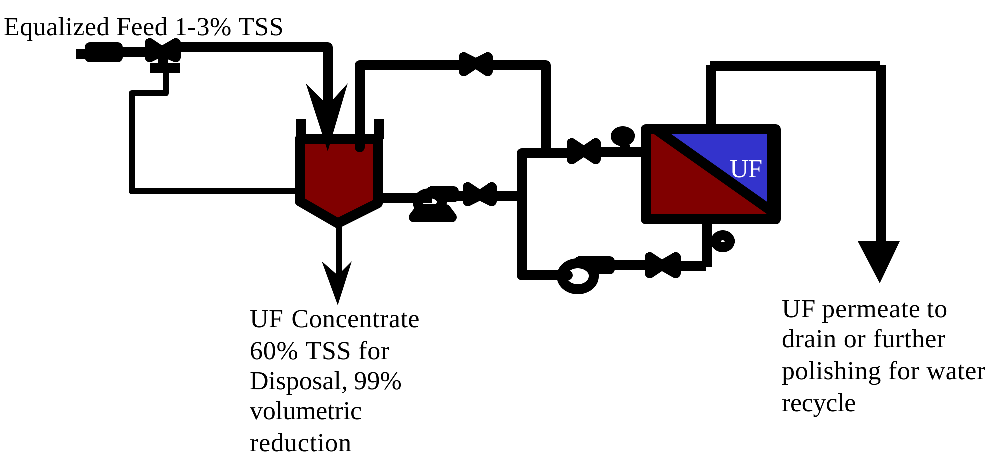
Ultrafiltration is a cross-flow membrane technology that removes insoluble contaminants such as emulsified oil, precipitated heavy metals and particulate. This precise separation capability plays a significant role in waste minimization strategies and opens the door to wastewater direct discharge or recycle options. UF offers a cost-effective option for compliance with the most stringent effluent discharge regulations.

Traditional technology is often used by the electropolishing industry to treat their wastewater as to prepare it for discharge. Typical technologies utilized consist of pH neutralization systems, precipitate and flocculation flash tanks, and clarifiers to flocculate suspended material and precipitate metals to prepare the effluent for direct discharge or further polishing. However, the cost associated with expensive chemicals and labor is significant to maintain and operate these treatment schemes. Also, consistent effluent quality is difficult to maintain and is contingent upon keen operator observation and excess chemical dosage to assure constituent collection.

Ultrafiltration systems are simple to operate and maintain. A simplified flow schematic for a typical UF system is shown in figure 1. UF systems convert oily wastewater and metal hydroxide precipitate wastewater into a clear liquid that can consistently comply with wastewater regulations, or provide superior feed water quality to ancillary polishing equipment such as NF or RO systems to recycle the water. UF more effectively removes oil and grease, suspended solids, and colloidal matter while utilizing no flocculents or coagulants.

Figure 1.

Typical UF Flow Schematic



Problem

An electropolishing company had a chemical / physical (microfilter) process designed to treat rinse water that was generated from the rinsing of electropolished steel and aluminum parts. The microfilter never met design capacity, required costly pretreatment chemicals and was labor intensive and needed frequent cleanings. Cleanings were conducted every 1-3 days to barely keep up with the wastewater generated.

The original chemical / physical process diagram is shown in figure 2.

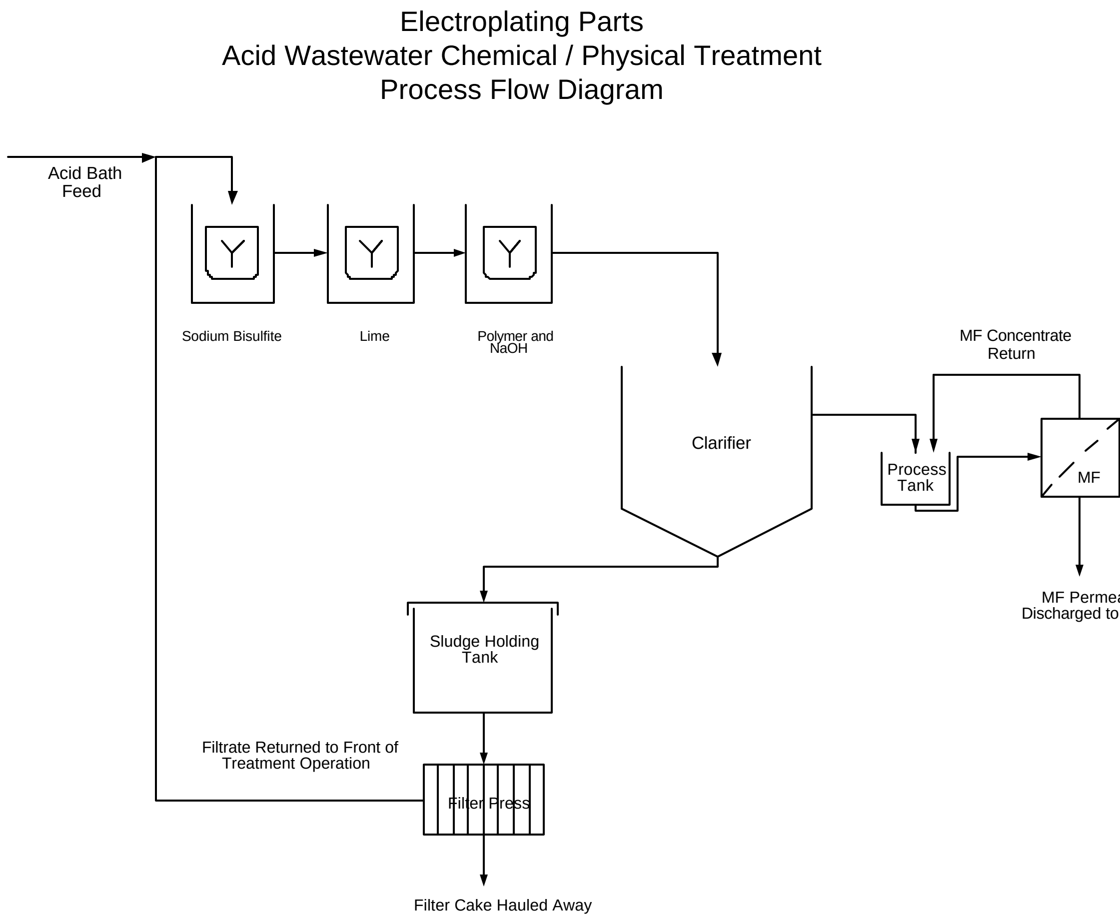


Figure 2. Wastewater Treatment Using Traditional / Microfiltration Technology

Solution

After a quick diagnosis of the problems at the electroplating operations facility, a redesign with proper application of membrane separations was proposed. A UF pilot was conductedthat showed the expected superior and consistent performance over the existing micro-filter operation.

The UF system showed significant labor savings and eliminated chemical usage during processing. In addition, the UF permeate quality and productivity was superior. The UF system required cleaning only once every six weeks. The UF system's spongeball capability for cleaning the tubes was used once per day to remove the boundary layer from the membrane surface and restore any productivity reduction that occurred during that day of operation. The UF permeate required no polishing to send directly to the sewer while complying with the local authority discharge regulations and the filter press concentrate was drastically reduced due to the elimination of pretreatment chemistry i.e., lime and polymer.

Figure 3 shows the overall ultrafiltration treatment scheme at the electropolishing operations facility.

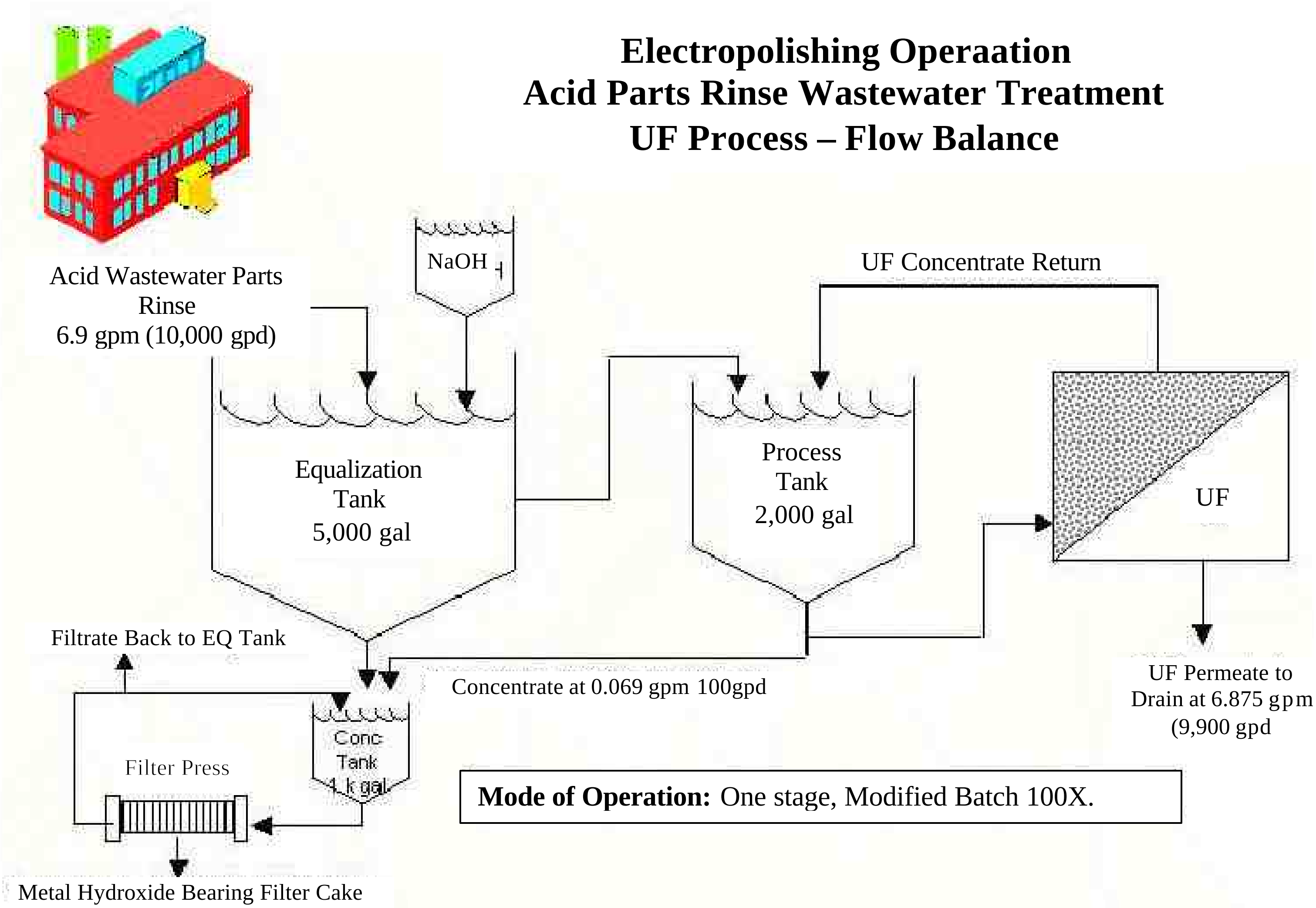


Figure 3. Electropolishing Parts Rinse Wastewater Treatment Operation

Membrane Technology

Cross flow ultrafiltration is a pressure-driven filtration process in which the process liquid flows parallel to the membrane surface. Figure 4 shows the separation capability of ultrafiltration and reverse osmosis compared to other filtration methods. UF membranes retain particulates, macromolecules, colloids and emulsified oils. Under 20-100 psi pressure, the filtrate passes through the membrane and exits as a clear permeate. The retained species are concentrated to the desired end point.

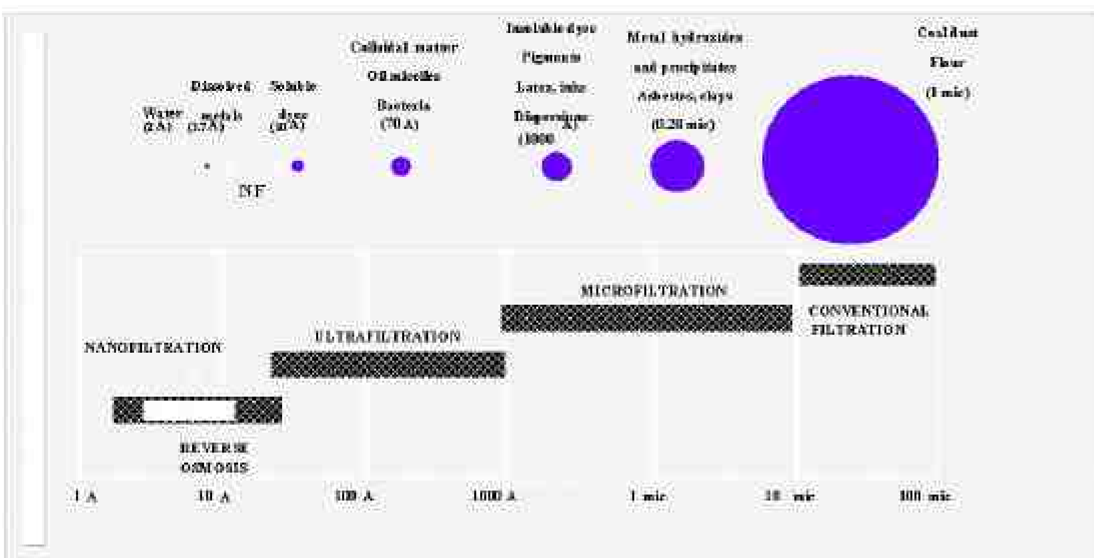


Figure 4. Separation Ranges of Various Pressure Driven Wastewater Processes

Membrane performance is measured in terms of flux rate and rejection. The flux rate is the volume of permeate generated per unit of membrane area in a given amount of time. Rejection is the percentage of the total amount of a particular component, which is retained by the membrane.

Figure 5 compares the pore construction of ultrafiltration membranes to that of Conventional filtration media, such as bag or cartridge filters. The UF membrane pores are asymmetric in shape. Since the pores are shaped like inverted cones (photo 1) the

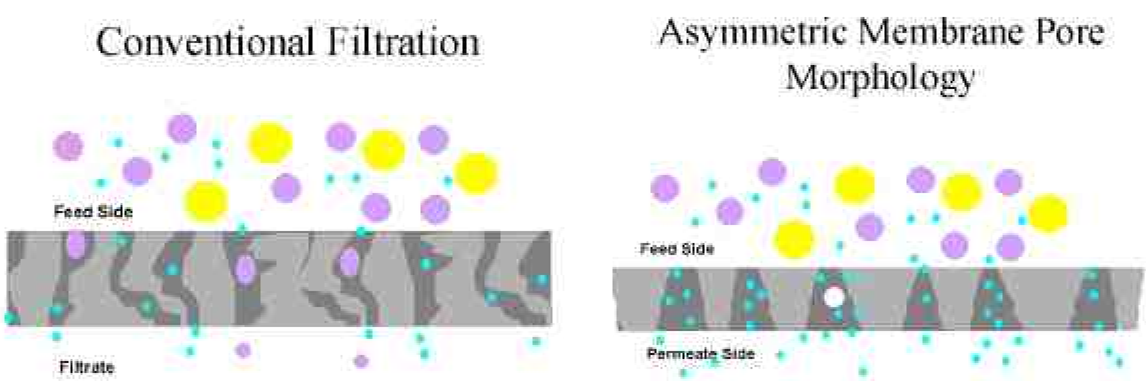


Figure 5. Conventional Filtration and UF Filtration.

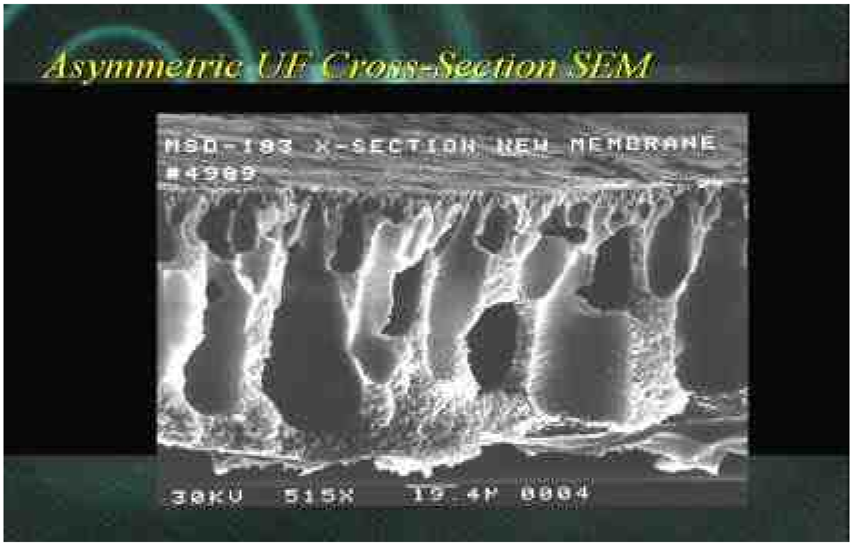


Photo 1. SEM of Membrane Asymmetric Structure.

membrane pores do not plug. Any material, which passes through the membrane, continues unimpeded without accumulating within the filtration device. This unique feature allows membrane filters to be easily and inexpensively cleaned in place. The operation and maintenance of UF systems are relatively simple. Routine cleanings allow for repeated use over long periods of time. With proper operation and maintenance UF membranes will operate for several years without replacement.

UF Membrane Materials and Construction

Advancements in polymer science enable membrane scientists to utilize engineering plastics to improve the structure-property relationships of membrane products. The most common membranes are based on durable polymers such as PVDF (polyvinylidene di-fluride), PS (polysulphone), and PAN (polyacrylonitrile). These materials are capable of continuous reproducible processing cycles and are cleaned with acid, caustic, and/or surfactants. Membrane life expectancy is dependent on the process conditions and the cleaning frequency. Three to five years' life is normally expected.

Membranes are packaged into tubular, spiral, and hollow fiber formats. The most significant difference among the three is the characteristics of the flow channel through which the process liquid flows. Tubular membranes are open channel designs, ¼-1" diameter, which accommodate wastewater's having large particles, higher viscosity's, and/or high concentrations of suspended solids. Tubular membranes process such liquids without channel plugging and extensive prefiltration.

Compared to tubular membranes, spiral modules have a thin channel, ranging from 0.020"-0.10" in height. The flow channel is constructed of porous netting placed between adjacent layers of flat membrane sheets. The materials are combined with permeate carrier and adhesive, then wound into a cylindrical shape. The feed liquid then passes over the netting and membrane. Permeate collects on the low-pressure side of adjacent membrane sheets and travels to the central collection tube. The flow channel is not completely open. The flow channel of a spiral module is easily plugged by fibers, lint, or other suspended solids, making their use limited to water which is largely free of such matter, or in cases where the ability to reach high concentrations is not important.

Hollow fiber membranes are made by extruding polymers into the shape of a tube. The flow channel diameter for hollow fiber ranges from 0.020-0.10”. Compared to spirals, hollow fibers are more resistant to channel plugging. Hollow fiber may be back pulsed or subjected to reverse flow conditions to achieve optimum removal of foulants.

Electroplating Facility Commercial UF System Performance

The UF commercial system was designed to treat 10,000 gallons per day of metal bearing acid wastewater. The system was equipped with 78 one-inch tubular membranes. The membrane system was designed to operate with 6 passes of 13 one-inch tubes in series. The membrane utilized was an anionic charged, HFP-276 PVDF membrane, which has a 120,000 molecular weight cut-off.

The following is a picture of the commercial UF unit:

Photo 2. UF K-78 Tubular System at Electroplating Parts Operation

The UF system actual permeate discharge performance is 12,000 gallons per day exceeding the design by 20%. Table 1. Shows the UF system easily met the local authority discharge requirements.

Table 1.
UF Feed and UF Permeate Analytical Results

Feed/Concentrate and UF Permeate Characteristics			
Metal	**UF Feed mg/l**	**UF Permeate mg/l**	**Discharge 4 day Avg. Requirement (mg/l)**
Chromium	19.0	0.04	1.71
Copper	11.0	0.24	2.07
Lead	3.0	0.03	0.43
Nickel	3.9	0.70	2.38
Zinc	0.40	N.D.	1.48

Note: N.D. = Non Detect

The following is a photo of samples of the UF permeate and UF feed:

Photo 3. UF Permeate (left) and UF Feed (right)

Economic Results

The following are the economic benefits expected from the use of ultrafiltration to reduce metals (refer to Table 2 for detailed summary of economics):

- **Lower Chemical Costs**

When ultrafiltration is used in place of traditional technology such as DAF, clarification, flocculation or coagulation coupled with microfiltration the use of expensive chemicals is no longer needed. Chemical savings for this study were estimated to be $14,000 annually.

- **Reduced Labor Requirements**

Jar testing, in order to determine proper chemical dosages, is not needed when ultrafiltration is used in place of traditional technology coupled with membranes for this case. For this exercise there was a 66% reduction in labor which resulted in a $90,000 in annual savings.

- **Reduced Disposal Fees**

Using ultrafiltration in place of a traditional technology significantly reduces the sludge that would normally be generated by the use of chemical flocculation with lime. The sludge volume reduction was estimated to have an annual savings $15,000.

Table 2.
Ultrafiltration versus Clarification / MicrofiltrationTechnology
Initial Capital Cost and Annual Operating Expenses Summary

Expense	UF	Clarifier/MF Expansion
Capital	$50,000	$30,000
Installation	$10,000	$10,000
Construction	$5,000	$5,000
Initial Capital Cost	**$65,000**	**$45,000**
Labor	$45,000	$135,000
Electrical	$5,000	$5,000
Disposal	$5,000	$20,000
Chemicals	$1,000	$15,000
Annual Operating Cost	**$56,000**	**$175,000**

Conclusion

The electropolishing parts operation selected ultrafiltration to treat their metal bearing wastewater for metals reduction over traditional/microfiltration technology approach. Ultrafiltration offers a positive barrier solution to reduce metal hydroxides in the wastewater as to have a consistent wastewater discharge quality. Traditional technology i.e. clarification, DAF or flocculation coupled with microfiltration can not produce the consistent wastewater stringent discharge quality needed for this type of application.

The use of ultrafiltration results in lower chemical costs, reduction in labor and diminishes overall sludge volume generated by traditional/microfiltration technology. The annual savings realized for this application would be greater than $119,000.

Membrane filtration is a versatile and cost effective tool for wastewater management. Membranes are used alone or in combinations (UF&RO) to purify wastewater's containing heavy metals, surfactants, oil and grease, colloidal matter, and soluble dyes, for example. For a given case, the most efficient process design is a function of the wastewater composition and end user requirements. UF and RO will be needed in the future for most wastewater applications as local and federal discharge requirements become more stringent.