Zero-Discharge: An Application of Process Water Recovery Technology in the Food Processing Industry

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ABSTRACT

Water is a valuable natural resource and the food processing industry has been among the leading industrial water users in California. With support from a major northern California utility and the California Institute for Food and Agricultural Research, Tri Valley Growers (TVG) has successfully installed the first U.S. energy-efficient zero-discharge process water reclamation system at its Oberti Olive processing facility in Madera, California.

The advanced zero-discharge system is the largest application in the world of membrane filtration for recovering water from a food processing plant. Previously, the plant discharged an average of 1 million gallons of salty wastewater (brine) a day into 160 acres of evaporation ponds. However, new environmental regulations made the ponds obsolete. The cost of process water disposal using alternate biotreatment system was prohibitive and would make continued operation uneconomical with plant closure and job loss the likely outcome.

Through comprehensive pilot testing and subsequent system design and operational optimization, the advanced membrane filtration system with pre- and post-treatment now recovers about 80% of the process liquid in high purity form of water for subsequent reuse at the plant. The solids produced in olive processing, plus concentrated process liquids are used off-site as an animal feed component, thus achieving the plant zero-discharge scheme.

The successful implementation of the zero discharge system at the Oberti Olive processing plant has produced energy saving of 3,500,000 kilowatthours and 244,000 therms of gas a year of power as compared to the alternate biotreatment system. It also prevented plant closure and job loss. In addition, water conservation and the discontinuation of evaporation pond use is beneficial to the environment. The project was applauded by the California Environmental Protection Agency as a positive step forward for environmental technology in the agricultural sector in California.

Introduction

Tri Valley Growers (TVG) Inc. is the owner of the Oberti Olive processing operation in Madera, California. This one of the four olive processing facilities in the United States, all of which are located in California. TVG processes about one-fourth of the annual California crop.

Olives are stored in brine solution in more than 1,000 tanks, each capable of holding 12 to 25 tons of olives. During peak production, the plant processes 128 tons of olives per day, with a total annual production of 86.4 million cans. These olives are sold under the Oberti Olive brand as well as 130 other labels. Processing of black ripe olives requires a storage solution of one percent acid, a processing solution of one percent lye, large quantities of chemicals including salt and large volumes of water. The wastewater or brine outflow at the plant was in the order of one million gallons per day.

In 1935, when olives were first packed by the Oberti family, the accepted practice was to use clay-lined evaporation ponds for holding and disposal of the brine effluent. Over the years, the porous quality of the clay allowed seepage of the brine into the ground. In 1967, TVG purchased the olive processing plant and initiated a project to line all 160 acres of the evaporation ponds with plastic. This major project was completed after 11 years at a cost of $6.4 million dollars.

In 1984, new regulations were adopted by the State of California covering the specifications and construction of plastic lined ponds. These regulations required the Oberti ponds be upgraded to double lining. Compliance with the new standards would have cost about $40 million, which was not economically feasible. Plant closure and layoff of the 550 seasonal and full time employees was the imminent threat and the TVG management immediately started evaluation of all options.

Initially, the alternative that TVG was pursuing to replace the evaporation ponds was a biological treatment system which include a yeast fermentor, a bio-trickling filter, dryer, and an aerobic wastewater treatment unit. However, the high capital investment and operating costs, particularly high energy consumption of over six million kWhrs per year, were considered prohibitive and TVG continued to look at other options.

In 1991, TVG approached the Industrial Advisory Technical Committee (IATC), a team of technical experts assembled by the National Food Processors Association and the California League of Food Processors, to help the food industry address technical problems. As a member of the IATC, Pacific Gas and Electric Company participated in the study and recommendation of membrane technology to TVG. Through a tailored collaboration between Pacific Gas and Electric Company and the Electric Power Research Institute to promote energy efficient solutions to utility customers, Pacific Gas and Electric Company funded the design of a Mobile Test and Demonstration Unit (MTDU). By 1992, the MTDU was built under the direction of the Del Monte Research Center in Walnut Creek, California, consisting of a 48 foot semi-trailer complete with membrane pilot equipment and a laboratory. The California Institute of Food and Agricultural Research (CIFAR) at the University of California, Davis was chosen to operate the MTDU. Since 1991, Pacific Gas and Electric Company's Non-Residential Commercialization and Demonstration (NRCD) Program has funded the collaboration membrane demonstration at various California food processing companies. A two-month test program utilizing the MTDU started at the Oberti plant in Fall, 1992, to investigate and determine the feasibility and design specification of the appropriate type(s) of membrane and the necessary pre-treatment and post-treatment units.

This paper describes the engineering system utilizing membrane technology and including various pre-treatment and post-treatment technology for recovering the process wastewater to achieve the "zero-discharge" scheme. Representative system performance and energy-saving results are reviewed and the barriers or impacts of the use of membrane technology for the food processing industry is discussed.

Background

The MDTU was stationed at the Oberti Olive plant in the fall of 1992 for a two-month pilot test program. Similar types of MTDU utilization occurred over the following five years during which the MTDU visited 33 food processors throughout the United States, testing the viability of membrane technologies in raisin washing, fruit canning, potato and corn processing, candy and carbonated beverage manufacturing, poultry operations and dairies.

At the Oberti plant, the use of membrane technology to remove salinity, biological oxygen demand (BOD), total suspended solids, and other salt-laden materials was studied and demonstrated. The concept and the major categories of commercially available membrane processes are listed below in Figure 1.

MEMBRANE TECHNOLOGIES

A membrane is a thin barrier or film through which solvents and solutes are selectively transported. It may consist of organic polymers, ceramics, sintered metals or layers of chemicals. Application of a driving force (e.g., pressure, concentration, electrical potential, etc.) forces certain components of the liquid through the membrane. The spectrum of membrane permeabilities is summarized in the figure below.

As the size of the particles captured decreases, the pressure (and thereby the energy) needed to drive the permeate through the membrane increases. Microfiltration requires only from 1 to 25 psi; ultrafiltration requires 20 to 200 psi; reverse osmosis requires from 400 to 800psi.

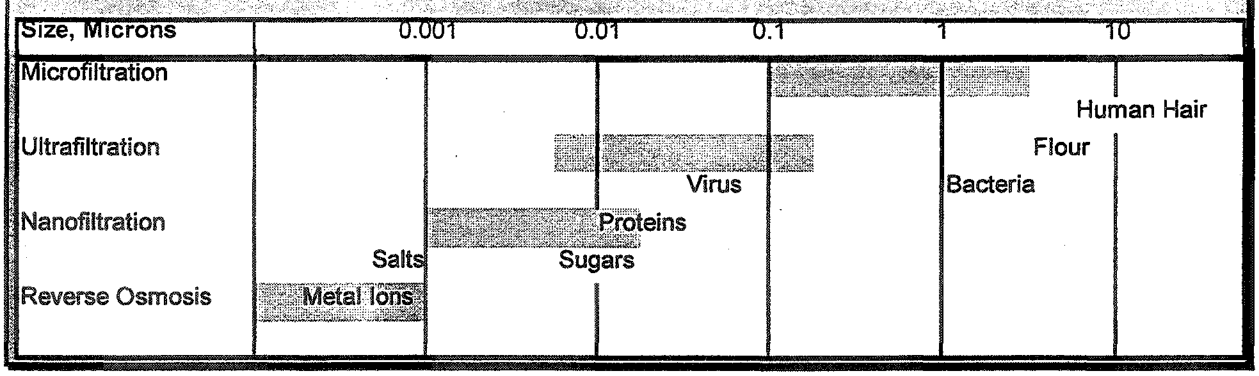

Figure 1. Spectrum of Membrane Performance

In any membrane process, the presence of suspended solids or oils could cause maintenance problems. Appropriate pre-treatment and/or post-treatment units may be necessary, e.g., sand filters, centrifuger, coagulators. Generally, the costs for membrane technologies range from $30 to more than $2,000 per million gallons treated. Based on results of various research collaborations, Pacific Gas and Electric Company has compiled a Technology Matrix (Matrix) as shown in Figure 2, which is a useful screening tool to assess various commercially available membrane-related technologies.

Figure 2. Treatment Technology Matrix for Industrial Process Water

		DESCRIPTION	SOME TYPICAL APPLICATIONS	INDUSTRIES	ADVANTAGES	LIMITATIONS	PROCESS MATURITY (years in industrial applications)	CAPITAL COSTS (in $ 1,000)	ENERGY CONSUMPTION (in kWh/ 1,000 gal)	OPERATING LABOR (man-hrs/day)	MAINTENANCE PARTS AND CHEM. COSTS ($ 1,000/year)	REUSE OF BY-PRODUCTS	REUSE OF WATER
								Based on a system flow rate of 100 gpm					
COARSE FILTRATIN	SCREENS	wedge wire, woven, or perforated metal	removal of large solids	wide applications	some screens offer self cleaning features	shape and size of particles (>20 microns)	Established (>100)	low (10 - 25)	Very low (0.005 - 0.01)	very low (0.1 - 0.5)	low (0.2 - 0.5)	animal feed	may require further treatment
	CYCLONIC SEPARATOR	Centrifugal separation of dense particles	silt and sand removal	wide applications	1) low space requirements 2) no moving parts	1) solids density 2) inorganic particles only	established (>100)	very low (0.6 - 3)	negligible	negligible	negligible	possible value of recovered solids	may require further treatment
	SAND FILTER	liquid is filtered through a bed of sand and often another media like anthracite	1) prefiltration before membrane applications 2) final filtration before release of water into the environment	drinking water, sewage water industries	1) lowest cost removal of fine particles down to 10 microns, 2) self cleaning features	1) sand filters do not work well with FOG containing water 2) backflushing required	established technology (>100)	low (5 - 20)	very low (0.005 - 0.01) (e.g. for air lift blower)	very low (0.5 - 1)	low (0.2 - 0.5)	requires further treatment before reuse	may require further treatment before reuse
MEMBRANE PROCESSES	MICRO FILTRATION	cross-flow principle particle size range: 0.05 - 5 microns	1) removal of coarser suspended solids and bacteria 2) pretreatment before other technologies	wide applications	1) high flux rates 2) low operating pressure 3) prefiltration treatment before nanofiltration or RO	1) permeate still high in TDS & BOD 2) retentate may need further concentration	newer technology, (~25) expanding applications	medium (100 - 500) upper end for ceramic membranes	medium (15 - 25)	medium (1 - 2)	High (25 - 75) for parts and membrane re-placement + (2 - 8) for cleaning	1) animal feed 2) recovery of valuable solids	limited use (e.g. for floor cleaning)
	ULTRA FILTRATION	cross-flow principle molecular range: 10k - 550k Dalton (Dalton = Molecular Weight Cut Off)	1)removing oil 2)recycling emulsions in metal forming 3)recovery of caustics or acids for reuse in cleaning systems 4)concentration of whey solids 5)juice and wine clarification 6)recycling of stack scrubber water 7)E-coat paint recovery 8)Recycling of bacteria in membrane bio reactors 9)pretreatment before other technologies	food processing textiles metal working pharmaceutical pulp & paper bio-industries	1) will remove all TSS, FOG and some BOD 2) excellent pretreatment before nanofiltration or RO	1) will not remove TDS or eliminate BOD 2) retentate may need further concentration	newer technology, (~25) expanding applications ongoing new membrane and equipment development	high (125 - 350)	high (15 - 30)	medium (2 - 3)	High (30 - 100) for parts and membrane replacement + (2 - 8) for cleaning chemicals	1)animal feed 2)reuse of paint 3)recovery of valuable solids 4)recovery of metals 5)reuse of starches	for rinsing, washing
	NANO FILTRATION	cross-flow principle molecular range: 300 - 1k Dalton (Dalton = Molecular Weight Cut Off)	1)BOD reduction in sugary streams 2) separation of sugars with different molecular weights 3) desalting of whey products 4) acid recovery in metal finishing 5) dye removal from textile water 6) ethylene glycol reclamation	food processing textiles metal working pharmaceutical pulp & paper bio-industries	1)separation based on particle size 2)will remove all suspended solids and most dissolved large 3)molecules like sugar 4)lower capital costs than RO systems	1)will leak small amounts of dissolved solids 2)lower retentate concentration than with RO 3)will not remove salts 4)retentate may need further concentration	new technology (~10) ongoing new membrane and equipment development	high (150 - 400)	high (15 - 30)	medium (2 - 3)	High (30 - 100) for parts and membrane replacement + (2 - 8) for cleaning chemicals	1)animal feed 2)recovery of valuable solids 3)reuse of sugars	reusable (may contain salts and traces of dissolved solids)
	REVERSE OSMOSIS	cross-flow principle range: 99.5% pure water up to 300 Dalton (Dalton = Molecular Weight Cut Off)	1) polishing evaporator condensate before reuse 2) preconcentration of juices before evaporator 3) sugar recovery in candy mfg. 4) landfill leachate treatment 5) hardness, sulfates and nitrates removal 6) replace ion exchange in H2O softeners 7) boiler feed water treatment	food processing pharmaceutical bio-industry electronics industry	1) will remove all dissolved solids 2) gentle handling of product due to low temperatures 3) cost effective over other systems at low solids concentrations.	1) max. achievable concentration limited by osmotic pressure (< 20% TDS) 2) current RO membranes cannot tolerate any chlorine 3) retentate may need further concentration	newer (25) technology, expanding applications ongoing new membrane and equipment development	high (150 - 450)	high (20 - 40)	medium (2 - 3)	High (35 -125) for parts and membrane replacement + (2 - 8) for cleaning chemicals	1)animal feed 2)recovery of valuable solids 3)reuse of sugars	fully recyclable and reusable water
CENTRIFUGE	DECANTER	Removal of dense particles, oil. Particle size: > 2 microns g-force: < 3,500g uses vertical bowl	1) wine and juice clarification 2) pressed vegetable oils 3) coffee, tea extract 4) chemicals, dyestuffs, pigments 5) rendering processes 6) edible fats	food processing, chemical pharmaceutical, oil, metal, and textile industries	1) can handle high initial solid content (up to 60% by volume) 2) low space requirements	Separation by density limits areas of application	established technology (>75)	high (225 - 275)	medium (3.0 - 5.0)	low (0.5 - 1.5)	medium (2 - 4) for parts (bearing, scroll screw replacement)	1) animal feed 2) fat recovery	not reusable without further treatment
	DE-SLUDGER (bowl type)	Removal of dense particles, oil. Particle size: >0.5 microns g-force: < 60,000g uses horizontal cylinder	1)cheese manufacturing 2) rendering processes 3) juice and wine operations separation, 4)marine application 5)oil separation,fish industry 6)bio tech applications 7) starch industry 8) chemical and mining industry 9) pharmaceutical industry	food processing, chemical, pharmaceutical, oil, metal, textile industries	1) low space requirements 2) sanitary operation	Separation by density limits Areas of application. Will remove more suspended solids than a decanter due to higher g-forces	established technology (>75)	high (275 - 300)	medium (3.5 - 4.5)	low (0.5 - 1.5)	medium (2 - 5) for parts (bearing, gasket replacement)	1) Fat, dye, crystal recovery 2) animal feed	potentially reusable water (but may contain dissolved solids)
	BASKET CENTRI-FUGE	removes dense particles particle size: >1-5 microns g-force: < 800g uses wire mesh or perforated cylinder	1) copper fines recovery from slurries 2) high purity pharmaceuticals 3) chemical recovery which require a washing process	chemical, pharmaceutical, mining (mineral and coal) industries	1) achieve high solids in the range of 85 - 92% 2) washing operation possible 3) sanitary operation	1) not very effective below 20% solids (by vol.) in incoming stream 2) batchwise operation	Established technology (>50)	High (250-300)	High (6 - 12)	very low (0.25 - 0.75)	Low (0.5 - 1.5) for parts	the solids are the desired end product	not reusable without further treatment

Figure 2 (cont.). Treatment Technology Matrix for Industrial Process Water. ()

		DESCRIPTION	SOME TYPICAL APPLICATIONS	INDUSTRIES	ADVANTAGES	LIMITATIONS	PROCESS MATURITY (years in industrial applications)	CAPITAL COSTS (in $ 1,000)	ENERGY CONSUMPTION (in kWh/ 1,000 gal)	OPERATING LABOR (man-hrs/day)	MAINTENANCE PARTS AND CHEM. COSTS ($ 1,000/year)	REUSE OF BY-PRODUCTS	REUSE OF WATER
									Based on a system flow rate of 100 gpm				
COAGULATION PROCESSES	DISSOLVED AIR FLOTATION (DAF)	Air is dissolved under pressure into water Bubbles carry the solids to the surface forming a sludge that is skimmed off.	1) FOG and suspended solids removal in vegetable, meat and poultry processing, bakeries, salad dressing, and prepared food operations 2) water treatment before land applications	food industries like meat, poultry, fish, dairy and bakeries; tanneries,pulp & paper, laundries, automotive	1) simple operation 2) sludge with up to 20% solids is obtainable 3) works very well on waste streams with high FOG levels	1) needs pH adjustment addition of coagulating and flocculating chemicals 2) will not remove dissolved solids 3) flow equalization required	established technology (>50) still expanding into new applications	medium (50 - 70) + (12 - 25) for tanks, pumps etc.	low (0.5 - 0.9)	medium (1 - 2)	High (0.6 - 0.8) for parts + (15 - 60) for coagulating & flocculating chemicals	animal feed	irrigation as is, needs further treatment for food applications
COAGULATION PROCESSES	ACCELERATED GAS FLOTATION (AGF)	Pressurized air is injected into a water vortex through a porous tube causing the controlled creation of micro bubbles	1) FOG & suspended solids removal in vegetable, meat and poultry processing, bakeries, salad dressing, prepared foods 2) water treatment before land applications	food industries like meat, poultry, fish, dairy and bakeries; tanneries, pulp & paper laundries, automotive	1) smaller size than DAF for some throughput with lower equipment and chemical costs 2) may run without chemicals 3) multistage design	1) may need pH adjustment addition of coagulating and flocculating chemicals 2) slightly higher energy costs than DAF	new emerging technology (~5) with many new applications	medium (30 - 50) plus (12 - 25) for tanks, pumps etc	medium (1.5 - 2.5)	medium (1 - 2)	medium (0.6 - 0.8) for parts + (7 - 30) for chemicals	animal feed	irrigation as is, needs further treatment for food applications
COAGULATION PROCESSES	INDUCED AIR FLOTATION (IAF)	Creates bubbles through mixing with air and cavitation, using a high speed impeller	Potentially same applications as Dissolved air flotation shown above	Same industries as with dissolved air flotation shown above	1) simple design 2) easy operation	1) slightly lower efficiency versus AGF 2) needs chemicals 3) space requirements as DAF	(~20)	Medium (40 - 60) + (12 - 25) for tanks, pumps etc	low (0.3 - 0.5)	medium (0.5 - 1.0)	High (0.5 - 0.7) for parts (15 - 60) for chemicals	animal feed	irrigation as is, needs further treatment for food applications
COAGULATION PROCESSES	ELECTRO-COAGULATION (EC)	An electric current between 2 sacrificial electrodes induces a chemical reaction in water	1) reduction of heavy metals, oils, silica clay, hardness 2) recycling wash waters from automotive steam cleaners 3) water recycling in metal finishing	chemical, pharmaceutical, oil, metal, printing textile industries	1) produces non water soluble, non-hazardous sludge 2) no or reduced addition of coagulants or flocculants	1) will not remove non-ionic or mono-valent compounds 2) requires periodic replacement of the sacrificial electrodes	New technology (~15)	high (220-260) plus (50 - 75) for clarifier, tanks, pumps	medium (4 - 10)	medium (2 - 3)	high (12 - 20) for parts (replacement of electrodes),	1) recovery of metals 2) reuse of cleaned ethylene glycol	potentially reusable water
EVAPORATION	SINGLE EFFECT THERMAL EVAPORATION	direct flame injection, steam coils or electric heater	1) plating wastewater 2) machine coolants 3) ink or photographic waste 4) zero discharge applications	metal, paint, photographic, printing industries	1) Simple design 2) Acceptable capital costs for very low flow rates	only justifiable for very low flow rates (0.1 - 2.0 gpm)	Newer Technology (~25)	very high (60 for 1 gpm); $1,000/gallon evap./hour	very high (3 - 8 Cents/gal) based on natural gas as fuel	very low (0.25 - 1)	High (5 – 10) for parts and cleaning chemicals	1) recovery of metals or other solids	clean condensate for reuse
EVAPORATION	MULTIPLE EFFECT THERMAL EVAPORATION (with thermal vapor recompression)	• falling, rising film, or forced circulation • the more effects, the more energy efficient • energy supplied by heating with steam	1) further concentration of membrane retentate to 40-70 % solids 2) egg processing, rendering waste water concentration 3) RO or electro dialysis reject 4) cooling tower blowdown 5) zero discharge applications	food processing, dairy, chemical, pharmaceutical industries, electric utilities	1) lower energy costs than single effect evaporators 2) wide range of flows are available (6 to 3,000 gpm) 3) concentration to high level (60 -80% solids), even to full crystallization	1) not as cost effective as RO for low concentrations 2) Corrosive liquids will require titanium heat exchanger surfaces 3) Regular CIP cleaning with caustic required	Established Technology (>50)	very high (1,800 - 2,200)	very high steam use: 8-12,000 lbs/hr requiring 250BHP boiler	medium (2 - 4)	High (5 – 8) for parts + (6 – 10) for CIP cleaning	1) recovery of animal feed 2) recovery of valuable solids	clean condensate for reuse
EVAPORATION	SINGLE- OR MULTI- EFFECT MECHANICAL VAPOR RE-COMPRESSION EVAPORATOR	• falling film principle • main driving force is a powerful electrically driven turbo fan	1) leachate from landfills 2) pulp bleaching effluent 3) metal & photo waste water 4) paper machine effluent 5) dairy waste water 6) zero discharge applications	pulp & paper, chemical, food processing, pharmaceutical industries	1) lowest energy consuming 2/ runs efficiently with elect-ricity as main energy source 3/ can handle corrosive liquids	1) TSS in feed stream to be <1,000 ppm 2) max. concentration 40% - 50% solids	New Technology (~15) expanding into new applications	very high (1,000 - 1,800)	very high (25 - 50)	medium (3 - 4)	High (5 – 8) for parts + (6 – 10) for CIP cleaning	animal feed	clean condensate for reuse
DISINFECTION	OZONE TREATMENT	Ozone is produced in gaseous form in an electric generator using UV or corona discharge. It can be used in gaseous form or mixed in water. In June 1997, FDA established GRAS status for ozone contact with food.	1) disinfection of potable water 2) taste, color and odor removal 3) bottled water sterilization 4) phenol, cyanide, iron etc. removal 5) bleaching of pulp and paper 6) cooling tower water treatment 7) surface pasteurization of foods like fruits, nuts, seeds, etc 8) irrigation water treatment 9) swimming pools, aquariums	municipal water works, pulp & paper, food processing, residential swimming pools	1) stronger oxidizing agent than chlorine 2) production on site 3) leaves no toxic residues 4) kills parasites and cysts like giardia and cryptosporidium 5) does not form toxic trihalo - methanes 6) reduced chemical costs	1) needs clean, dry, pressurized feed air; achieves higher efficiency with oxygen-enriched air or pure oxygen feed. 2) leaves no "residual", therefore 1 ppm of chlorine must be added to ozonated municipal drinking water for residual	Newer Technology (~30) continuing efficiency and design improvements	medium (30 - 130) air fed (20 - 70) oxygen fed	low (0.25 - 1.25) dosage: 1.5-3 ppm for potable water 5 - 15 ppm for for waste water	very low (0.05 - 0.2)	Low (0.5 - 1) for parts	no byproducts	recommended for treatment of recycled water before reuse. For drinking water addition of 1ppm of chlorine is still required as "residual".
DISINFECTION	MIXED OXIDATION	An on-site electrolytic generator produces a liquid solution containing ozone, hypochlorite and chlorine dioxide	1) drinking /emergency water 2) laundries 3) food process water 4) waste water treatment 5) cooling tower water 6) swimming pools	water treatment, food processing, laundry, swimming pools	1) stronger oxidizing agent than chlorine alone 2) safe on-site production 3) kills cysts and oocysts 4) maintains chlorine residual	systems are designed for smaller chlorination requirements up to max. 200 lbs/day chlorine equivalent	new technology (~10)	low (2 - 5)	low (0.02 - 0.1)	very low (0.02 - 0.2)	Medium (1 - 1.5) for parts & Replacement of Electrolytic cell +(0.2 - 2) for sodium chloride	no byproducts	reuse for washing, cleaning operations, drinking water
DISINFECTION	ON SITE ELECTROLYTIC CHLORINATION	An on-site electrolytic generator produces a liquid solution of sodium hypochlorite	1) drinking water 2) waste water 3) cooling tower water 4) industrial bleach 5) cyanide destruction in metal plating 6) Olympic size pools	municipal water works for fresh and waste water; textile and food processing industries	1) safe on-site production 2) no large storage tanks vis a vis liquid hypochlorite 3) less cost than bulk hypochlorite 4) maintains chlorine residual	1) systems are designed for larger chlorination requirements of outputs of up to 2,000 lbs/day equivalent 2) does not kill giardia or cryptosporidium	Established Technology (>50)	low (7 - 12) (smallest available size can treat >>100gpm)	low (0.02 - 0.1)	very low (0.01 - 0.1)	Medium (1 - 1.5) for parts & replacement of anodes + (0.2 - 2) for NaCl salt	no byproducts	reuse for washing, cleaning operations, drinking water
DISINFECTION	ULTRA VIOLET LIGHT	UV-C (<280 nm) light is produced in a quartz arc tube at low or medium operating pressure, continuously or pulsed	1) fish and shellfish farming 2) to meet microbial discharge limits 3) municipal drinking water 4) bottled water 5) brewing and soft drinks 6) sugar refining 7) decorative fountains	food, pharmaceutical, electronic industries	1) simple design and operation 2) high efficiency of energy utilization 3) no toxic residuals 4) alternative to chlorine	1) fouling of quartz tube requires regular cleaning 2) does not work well in water due to "shade cloudy effect" 3) does not effectively kill oocysts like giardia 4) limited lamp life	low pressure syst. are well established, (~30) med. pressure applications are emerging	low (5 - 15)	low (0.08 - 0.12)	very low (0.1 - 0.5) lamp cleaning once a month	medium (3 - 5) for parts and lamp replacement every 8k - 14k hours	no byproducts	reuse for washing, cleaning operations possible use as drinking water

The Matrix groups various technologies into families, such as membrane processes, evaporation technologies, and disinfection, etc. Within each family, the Matrix lists three or more specific treatment methods. Across the top of the Matrix are columns that characterize industries in which the method is used, advantages and limitations, and ranges of typical capital and operating costs.

Prior to the review of membrane process, TVG had tested several biological treatment systems including yeast fermentation and a bio-trickling filter. High capital and operating cost, particularly high energy consumption made these biological systems unattractive, e.g., one proposal which was considered to be the next best alternative estimated a total power usage of over 6 million kWHr/Year.

Methodology

The goals for the new membrane system are that it is cost-effective, easy to maintain and operate, and has no environmental impact. As the operator of the MTDU, CIFAR oversaw and conducted the tests involving various membranes on several process waste streams at the Oberti olive plant.

Based on test or demonstration results and technical information provided by membrane manufacturers and the collaboration research staff, a preliminary system design was developed. To achieve a zero-discharge scheme, the identification of a reliable source for viable use of the by-product concentrate was performed. Risk assessment and economic analysis were also conducted.

Results

Technical and Engineering Design –

After the completion of thirteen in-plant demonstrations together with CIFAR's and EPRI's experience in membrane technology, it was recommended that ultrafiltration followed by reverse osmosis would offer the most promising design to treat and recover Oberti olive plant process water.

The first prototype design was the implementation of a brineless grader, a pre-screen, holding tank, ultrafiltration (UF), reverse osmosis (RO), followed by evaporation. In particular, the following steps were undertaken:

- The reduction of salt in the process by incorporating a brineless grader.
- The use of a 50-75micron screen to remove larger suspended solids.
- The incorporation of a holding tank to isolate the membrane system from process flow fluctuations.
- The sequential use of UF and RO to stepwise remove particulates and dissolved solids. An UF spiral wound membrane will be utilized.
- The shipment of concentrate from the evaporator to one of several leading animal feed formulators.

Specifications based on the prototype design were compiled and a pilot installation was completed as shown in Fig. 3, except that the charcoal filter was added later during start-up in order to remove the build up of a non-hazardous material, methyl phenol, which affects the taste quality of the canned olives. The design incorporated the following parameters:

- Feed rate to the UF system = 900 gpm with a concentration factor of 20X.
- Acceptable Feed Composition to the UF system comprises of :

❑	Free Oil & Grease	<30 ppm
❑	BOD	<1,700 ppm
❑	TDS	<3,700 ppm
❑	TSS	<210 ppm
❑	Chloride	<300 ppm
❑	Carbonate/Bicarbonate	<1,500 ppm
❑	Sodium	1,000-2,000 ppm

- System Operating Temperature Range is 55-85 deg F.

Follow-up operating experience and trouble-shooting effort was used to evaluate and develop the ultimate optimal system configurations that addressed the various risk assessment concerns:

- Proper sizing of the prescreen to prevent excessive fouling of the UF membranes.
- Optimal frequency of cleaning-in-place of the UF membrane to maximize the performance and life expectancy of the UF membranes.
- Sufficient removal of oils to prevent the irreversible fouling of the RO membranes by installation of a clarifier or other oil removal units
- Monitoring system to allow immediate detection and warning of a membrane failure.

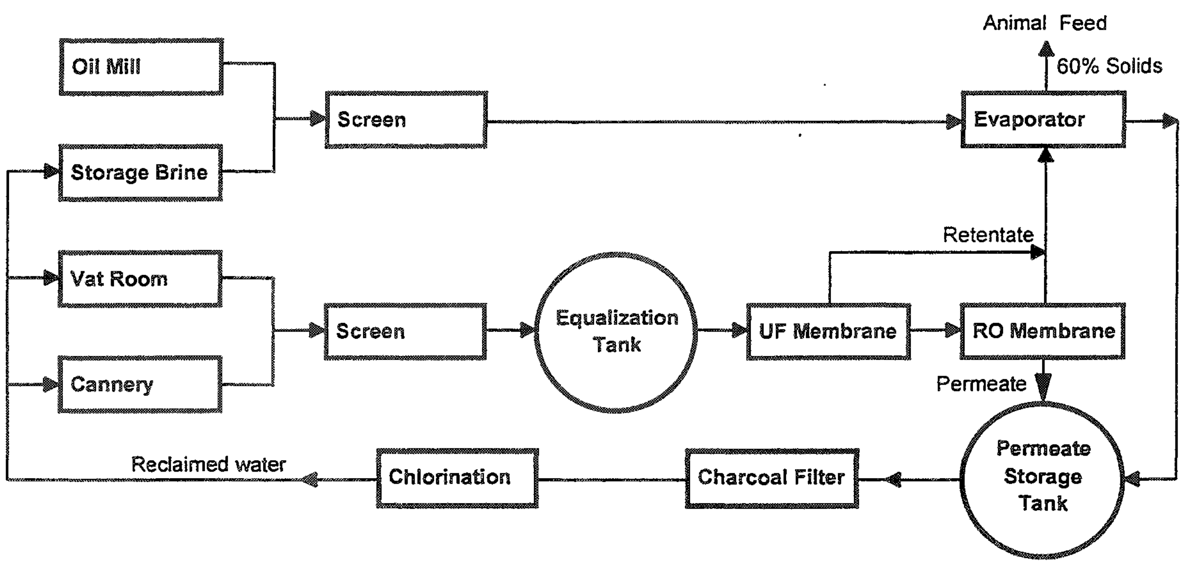

Figure 3: Schematics of Zero-Discharge Process Water Recovery System

The membrane system treats and recovers on the average 500,000 gallons per day of process water and produces 50,000 lbs. of animal feed. It is estimated that, at full capacity, the system can treat 900,000 gallons of process water in which 720,000 gallons are reclaimed for reuse and 10,000 gallons are released as moisture content in the 90,000 lbs. of animal feed produced.

Economic Analysis and Environmental Considerations-

The original design based on the best alternative was a biological treatment system including a yeast fermenter, a bio-trickling filter, box dryer, and an aerobic wastewater treatment unit. The membrane system installed has lower capital cost and more cost-effective operating and maintenance expenses. A summary of the economic analysis is presented in Fig. 4.

	Biotreatment System	Membrane System
Capital Cost	$13-$15 million	$8 million
Gas Usage	3,453,000 therms/yr	1,560,000 therms/yr
Electricity Usage	7,900,000 kWh/yr	5,541,600 kWh/yr
Gas Savings	n/a	244,000 therms/year
Gas Savings @ $0.25/therm	n/a	$61,000/year
Electricity Savings	n/a	3,500,000 kWh/year
Elec. Savings @ $0.08/kWh	n/a	$189,000/year

Figure 4: Summary of Economic Analysis

The new membrane system offered several environmental benefits which include:

- Recovering and reuse of up to 800,000 gallons of water per day which helps preserve the valuable natural resource of water.
- Continuing plant operation without the use of evaporation ponds which eliminates the potential release of undesirable brine to the groundwater.
- Replacing the otherwise best alternative of a biological treatment system. The resulting energy savings eliminate the need to burn the equivalent amount fossil fuels for power generation, thereby conserving the natural fuel resource and reducing the corresponding emissions of NOx and COx gases.

Discussion

It is noteworthy that the development and installation of the membrane system was supported by a $400,000 grant from the U.S. Department of Energy with the support of the California Energy Commission (CEC), a $250,000 grant from the California Trade and Commerce Agency; and a collaboration funding from the Pacific Gas and Electric Company. In addition, the Madera County Economic Development Commission helped TVG procure an $8.1 million bond.

From the conceptualization to the installation, start-up and optimization phase of the zero-discharge membrane system, the commitment from the project team members to work with suppliers, regulators, researchers and community authorities is critical for the ultimate success. Technical barriers were overcome by the addition of the charcoal filter, dissolved air flotation unit and the fine-tuning of the membrane cleaning process.

Conclusion

With the successful application of advanced membrane technology and installation of the complete zero-discharge process water reclamation system, the partnerships between TVG and CIFAR, the Regional Water Quality Control Board, CEC, Pacific Gas and Electric Company and the residents of Madera County demonstrated the dedication of TVG's management in pursuing progressive, visionary and proactive steps to revitalize and ensure the Oberti plant's future. The plant is now continuing to process 100,000 tons or 360 million cans of olives each year while recovering and reusing 80 percent of the maximum 900,000 gallons per day of process water and recycling some of the remaining 20 percent as an additive for animal feed. The California Energy Commission has expressed a positive outlook to replicate this type of system through California's food industry. The California Environmental Protection Agency has also applauded TVG growers for this state of the art waste water recycling system as a positive step forward for environmental technology in the agricultural sector in California.

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