Santa Paula: A case study in energy efficiency

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Editor's note

Sometimes when a wastewater treatment works is found to be in non-compliance with regulations this can be the spur to producing a revamp which suddenly becomes a model for others to follow. Such is the case with the City of Santa Paula in California. As a result of the revised wastewater plant's equipment selection and robust design features, it is now one of the most energy-efficient and cost-effective membrane bioreactor installations in the world.

In the current environment of rising energy costs, municipalities are under pressure to reduce power consumption while continuing to maintain the quality and efficiency of public infrastructure. The City of Santa Paula faced this challenge when it became necessary to replace its noncompliant wastewater treatment facility.

As a result of an investment in energy-efficient technology, the new facility's power consumption costs for the first five months of operation are 35% lower than expected.

Project history

Santa Paula is located in Ventura County, California and has a population of approximately 30,000. Its original wastewater treatment facility was built in 1939 and had accrued more than US$ 8 million dollars in compliance related fines. The Los Angeles Regional Water Quality Control Board (LARWQCB) agreed that if the city could come into compliance by a certain date, they would waive the fines.

Although originally choosing the conventional design-bid-build approach, after years of work and funding engineering studies, the city council and staff realized this method would not meet their tight timeline or budget requirements. In July 2007, the council approved the design-build-operate-finance (DBOF) method of procurement and in May 2008, awarded the DBOF contract to Santa Paula Water LLC, a joint venture of PERC Water Corporation and Alinda Capital Partners.

PERC Water began the engineering of the project on 6 May 2008, the day after the DBOF contract was signed, and commenced construction two months later. Construction was completed in December 2009 and on 13 May 2010, seven months in advance of its 15 December 2010 compliance deadline, the facility took full flow from the city.

Facility Design

PERC Water designed a 4.2 million gallon per day membrane bioreactor (MBR) facility (see description page 18), where the majority of the treatment occurs in underground tanks. The operations buildings are constructed above the tank structure, reducing land requirements, and contain the process equipment, a laboratory, administrative offices, etc. The covered tanks and noise and odor controls makes the facility neighbor-friendly and a positive addition to the surrounding community.

The facility is in compliance with the LARWQCB's waste discharge permit for what the facility is intended to treat. The wastewater is treated to a tertiary level meeting Title 22 requirements and is currently disposed in 13 acres (5.26 ha) of percolation ponds located to the east of the new facility. The city is drafting an alternate use plan for the recycled water to reclaim and reuse it as an additional revenue stream for the City.

Energy Efficiencies

The contract stipulated that PERC Water would operate the facility for 30 years. Because the company is responsible for the long-term operations and maintenance costs of the facility, it designed and constructed the facility to control and minimize energy consumption costs and deliver the smallest environmental footprint possible. PERC Water invested its own funds beyond the contract cost in design enhancements during construction to reduce the energy consumption costs.

It paid off. In the first five months of the facility's operation, the power consumption costs have been approximately 35% lower than expected. The energy savings are split 50/50 with the city.

These energy-efficient features included:

UV Disinfection – The facility uses the Degremont Technologies' Aquaray® 3X UV Modules which are equipped with amalgam lamps for UV disinfection. Amalgam lamps are the most energy efficient lamps for generating ultra violet light at the high power density required. Additionally, the control system can vary the lamp output to precisely meet the UV dose requirements for disinfection, minimizing the electrical consumption.

Membrane system – The MBR technology combines biological wastewater treatment and membrane filtration into one unit process, producing a consistently high quality effluent in an extremely compact footprint. PERC Water incorporated Koch Membrane Systems' single header Puron™ membrane filtration modules into the MBR design because they are energy efficient and provide significantly lower lifecycle costs.

The Santa Paula MBR process could be one of the most energy efficient in the world

Aeration system – As membrane scouring and aeration account for nearly half of a facility's power consumption, PERC Water selected energy-efficient air production and usage systems. Most noticeable are the facility's K-Turbo High Speed Turbine blowers, which are used throughout the facility's various process areas. The blower's internal variable-frequency drives allows PERC Water to control, monitor and specifically adjust the air-flow for aeration over a wide range of operations.

Smart controlling system – A proprietary technology developed by PERC Water, the Supervisory Control & Data Acquisition (SCADA) system has the unique ability to gather, display, track and store live data generated by the facility. In an effort to optimize energy consumption, the SCADA system is designed to consistently update operators on the exact status and measurements of all of the facility's processes such as air flow, water flow and tank capacity and will notify operators of abnormal conditions directly to the operator's cell phone.

The SCADA system is accessed through Central PERC™, a web application where all the facility's current and historical operational data is integrated within one platform that can be accessed and controlled wirelessly from an iPad, iPhone, Droid or any other web-capable device.

Lighting design – Using a combination of natural lighting, LED lamps, mercury-vapor exterior lights, electronic ballast for fluorescent lamps, light sensors and automatic dimming devices, the facility exceeded the state's Title 24 (energy-efficiency standards for residential and non-residential buildings) requirements and Southern California Edison's stringent standard.

As a result of the energy-saving measures employed at the facility, PERC Water was awarded the 2009 Sustainability and Resource Protection Award by the *Environmental Business Journal* and a grant through Southern California Edison's "Savings by Design" program to help fund the energy saving technology.

Savings for city

John Quinn, the city's finance and public works director, said, "The City of Santa Paula is enthusiastic about our new water recycling facility's reduced power costs as it means savings for our citizens over the long term."

"It is imperative that infrastructure become more sustainable and fiscally responsible," said Brian Cullen, President of PERC Water. "The technology available in today's market raises the standard for efficiency and the Santa Paula facility demonstrates that investing in these energy-saving technologies results in savings to the ratepayers."

Dr Shane Trussell, a leading expert in membrane bioreactors and PERC Water's lead advisor for the facility's process design, described the facility as "world-class." He said, "As a result of the team's equipment selection and robust design features, it is one of the most energy-efficient and cost-effective membrane bioreactor installations in the world."

MBR Technology is energy efficient and reduces lifecycle costs Koch Membrane Systems

The City of Santa Paula selected the PERC Water / Alinda Capital team to design, build, operate and finance a 7.2 MGD (27,250 m^3/d) peak day flow (10.4 MGD (39,360 m^3/d) peak hour) membrane bioreactor (MBR) to meet compliance standards and enable the use of recycled wastewater for irrigation.

Santa Paula chose MBR technology because it combines biological wastewater treatment and membrane filtration into one unit process, producing a consistently high quality effluent in an extremely compact footprint.

PERC Water selected the single header Puron™ membrane filtration modules from Koch Membrane Systems (KMS) to incorporate into the MBR design because they were energy efficient and provided significantly lower lifecycle costs than other alternatives. The Santa Paula project is the first large MBR installation in North America to use Puron membrane filtration modules.

Compact design

The Santa Paula MBR facility has a compact design, with fully redundant headworks, conservative and efficient aeration design, biological foam spray system, hollow fiber membranes with incorporated aeration. Effluent from the system will discharge into evaporation/ percolation ponds, and a portion of the water will eventually be used for irrigation.

Figure 1 provides a general illustration of the overall system.

The new water recycling facility is designed to produce an effluent that meets or exceeds all current environmental wastewater quality standards mandated by the US Environmental Protection Agency and the RWQCB. The MBR is designed to produce a finished effluent with biochemical oxygen demand and total suspended solids concentrations of less than 5 mg/L, total nitrogen less than 8 mg/L and turbidity less than 0.2 Nephelometric Turbidity Units (NTU).

Table 1 shows the facility's water quality results for October 2010.

MBR advantages

An MBR is a biological process that combines secondary and tertiary treatment using a membrane filtration process. Because membranes are used to provide the necessary solids-liquid separation, MBR effluent is consistently high quality with low turbidity, low bacterial counts, and low TSS and NTU. The filtrate quality, in many instances, is suitable for feeding directly into a reverse osmosis (RO) process, if required in the future. An additional advantage of an MBR system is its compact footprint. This is achieved by replacing the secondary clarification process with membrane separation and by operating the biological process with higher mixed-liquor suspended solids than conventional activated-sludge systems.

Despite its advantages, using membranes for solids-liquid separation requires careful assessment of several critical design elements. Table 2 shows these design requirements along with a brief overview of how they were handled in the Santa Paula Water project.

According to Juergen Nick, PERC Water's vice president of design and

Table 1: Santa Paula Water Recycling Facility October 2010 Water Quality Results

	Influent	Effluent Permit Requirements	Effluent Results
BOD	340	10	1.1
TSS	283	10	<1
Total Nitrogen	n/a	10	6.0

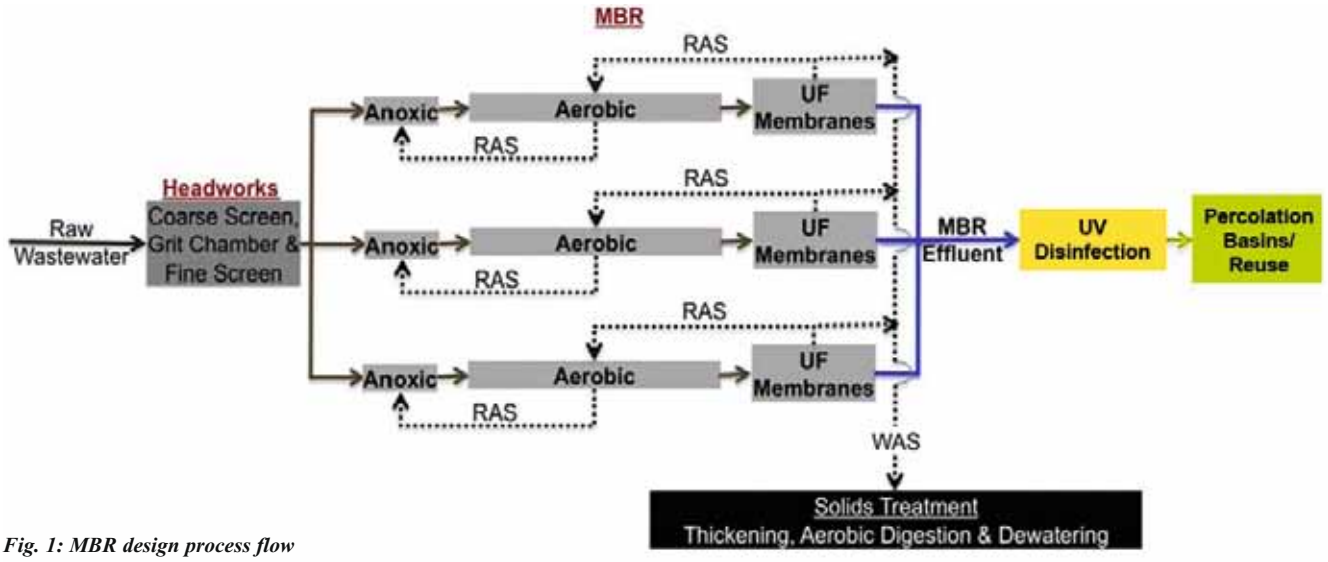

Fig. 1: MBR design process flow

engineering, "The water recycling technology we are employing in the Santa Paula Facility sets the industry bar to help control and minimize operational energy costs within the smallest environmental footprint possible. As membrane scouring and biological aeration account for nearly half of the facility's power consumption, PERC Water chose to employ the most energy-efficient air production and usage systems on the market . . . KMS' Puron membranes. In total, 24 PSH-1500 modules were installed, making it one of the largest MBR installations in North America."

Puron modules are energy-efficient, with the lowest energy demand of all commercially available MBR modules. The system is easy to operate, with features that are designed to provide significantly lower lifecycle costs, including a single header design that provides better solids management in the module, braided fibers to reduce the risk of fiber breakage, and highly effective air scouring that virtually eliminates sludging.

Single header design

An important advantage of the patented Puron module is the use of a single header with reinforced hollow fibers that are fixed only at the bottom. The sealed upper end of the fiber is allowed to float freely. The free floating tip design eliminates the build-up of hair and fibrous materials that typically clog the upper ends of membrane fibers in MBR module designs that employ both top and bottom headers.

Solids and particulates, including bacteria, are retained by the membrane and remain on the outside, while permeate is drawn through the membrane to the inside of the fibers. The outside-to-inside flow pattern provides optimal solids management and a high flow-rate.

Figure 2 illustrates the single header design of the Puron module's fiber bundles.

Larger Puron module

The Santa Paula facility includes the larger 1,500 m^2 Puron module, which simplifies design, operation and retrofit

Table 2: Unique MBR design requirements

	Influent	Effluent Permit Requirements
Wastewater characterization	Confirms the design assumptions and ensures compliance with product warrantees	Independent laboratory performed the water quality assessments to ensure proper design and warranty compliance
Accurate estimates of peak flows	MBR facilities are even more susceptible to wet-weather flows than conventional gravity solids-liquid separated plants	Flow hydrographs used to understand the peak-hour flow-rate and determine the time elapsed to produce the inflow volume. To reduce the peak wet-weather flow that would need to be sustained, this design incorporated a 1.0 MG (3,785 m3) equalization basin to attenuate flow
Careful design of headworks	Headworks protect the membranes and minimize the accumulation of inert debris in the membrane tanks, and ensure reliable performance without requiring extensive maintenance	Facility designed with two gross solids removal processes ahead of the fine screens. Headwork process units were oversized to reduce the frequency of required maintenance and ensure consistent performance
Membrane equipment selection	Ensures reliability, compatibility with competing products, energy efficiency and customer support	Hollow fiber membranes were selected for the solid-liquid separation to provide an energy efficient solution with separate membrane tankage for ease of maintenance and process control.
Biological foam control	MBRs provide a perfect trapping environment for filamentous bacteria that float and cause biological foaming, which can result in undesired loss of biomass and increased membrane fouling rates. The PERC facility's unique covered aeration basin design made this issue a particular challenge	Automated spray system designed to fit the roof design for each basin using the smallest practical nozzles, achieving full coverage spray of the water surface at the normal average operating level
Aeration design and operation	Special concern with the MBR process due to the increased mixed liquor suspended solids concentrations at which MBRs operate compared to conventional processes	Required airflow rates to maintain the aerobic zones at dissolved oxygen concentrations of 2 mg/L were determined using an αfactor of 0.45 and a standard oxygen transfer efficiency of 30% for the membrane aeration panels
Biological treatment concerns	MBRs may trap filamentous bacteria that floats and causes biological foaming events	Biological modeling simulations were performed using a modular, multipurpose modeling environment used for the simulation of municipal and industrial wastewater treatment plants
Softened water requirement	Inorganic foulants can be a significant factor in MBR facilities when the wastewater contains high mineral or metal concentrations, causing increased operation and maintenance costs due to additional chemical cleans required to maintain design capacity	The design includes a reverse-osmosis skid to provide sufficient softened water for the sprayer system, maintenance cleans and intensive cleans
Biological startup	Crucial to plant success and should be designed to minimize the startup period to quickly reach stable activated sludge process operating conditions and maintain overall membrane integrity and mitigate untimely membrane fouling	The biological startup process was modeled using GPS-X process simulator, while taking into consideration the system's physical constraints

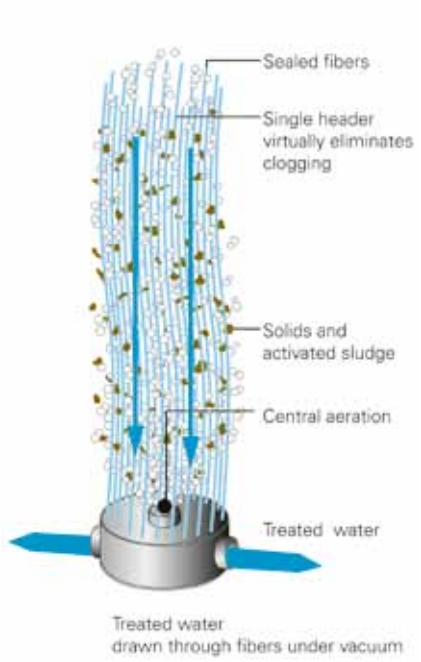

Fig. 2: Puron MBR module design

of large-scale MBR plants. The improved submerged membrane module features greater packing density, lower energy costs for aeration, and simplified installation while providing even greater compatibility with other commercially available systems.

The 1,500 m² module is particularly significant because it was specifically designed for large-scale MBR projects. Features such as an optimized permeate extraction manifold and air supply lines reduce the number of piping connections during installation.

For additional flexibility, the new product line enables users to easily retrofit the advanced Puron technology into systems with comparably sized modules. Figure 3 shows how the module works.

In addition, to simplify membrane cleaning and maintenance, the central aeration system and the bottom header have been redesigned. The new aeration system reduces the flow rate during air scouring, resulting in a decrease in air usage by up to 20% over the original design.

PERC Water's innovative design uses 5 acres (2 ha) less land than would be required by a conventional wastewater treatment facility. The plan includes a recycling education center, where local students can learn how water recycling facilities function.

The Santa Paula Water Recycling Facility in California

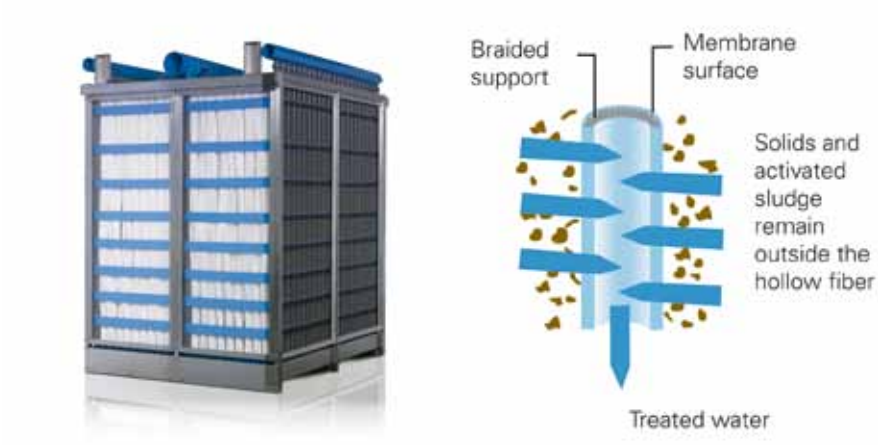

Fig. 3: Overall design of the 1500 m² module

Low power consumption

In its first few months of operation, the power consumption of the plant was only 4.4 kWh/1000 gallons treated. The consumption is based on power used by all processes throughout the facility including digestion, building power, MBR process, UV system, RO system etc. As flows increase, it is expected that the power consumption per thousand gallons will further decrease.

With the equipment selected for this facility, Santa Paula's MBR promises to be one of the most energy-efficient MBR installations in the world.