Atlantium
Illuminating Water Technologies

CASE STUDY

UV Water Treatment
Hydro-Optic™ Technology

Evaluation of Long-Term Membrane Performance with Continuous Use of Hydro-Optic™ UV Dechlorination at Plant Bowen

Plant Bowen, a 3,160 megawatt coal-fired power station, in Cartersville, Georgia evaluated and installed a non-chemical dechlorination process, the Hydro-Optic™ (HOD) UV water treatment technology, to improve the overall quality of reverse osmosis (RO) feed water. After three years of operation, the RO membranes are operating at the same level as new elements. Since the installation of the HOD UV technology the facility has reduced the use of SMBS and also minimized the frequency of micron filter replacement. In 2019 this application was recognized for its technical excellence and received an Electric Power Research Institute (EPRI) Generation Technology Transfer Award.

Background

In 2014 Plant Bowen was facing frequent membrane and micron-filter maintenance and replacement as a result of biological fouling and oxidation despite their use of a sodium metabisulfite (SMBS) dechlorination process. Free chlorine compounds are removed from feed water with the dechlorination process; protecting the membrane elements and other chlorine sensitive equipment. The facility undertook a three-month evaluation of the HOD UV technology, a non-chemical dechlorination process, to improve the overall quality of RO feed water.

Three RZ300-13 HOD UV systems were provided to Plant Bowen in March 2014 to accommodate a flow rate of 680 gpm (154 m^3/hr) with 95% UV transmittance. The units were installed in series on existing stainless steel piping after the media filters and before the micron and RO trains. At the conclusion of the evaluation period in May 2014, the technology had effectively removed free and total chlorine from boiler feed water to undetectable levels from inlet free and total chlorine levels above 1 ppm. Free available chlorine (FAC) levels at or below 0.1 ppm are required in order to protect the RO membrane elements and ensure optimal performance. Following the successful demonstration of the technology, Plant Bowen incorporated the system into full-scale operations at the plant — a decision that has proved favorable for dechlorination efforts.

Plant Process and Operations

Plant Bowen receives its source water from the Etowah River. Following clarification and multimedia filtration, water passes through a two-stage micron filter process before entering the RO system. The two-stage micron filter process is composed of two trains, each containing a 3-micron filter followed by a 1-micron filter. The RO system consists of two 250 gpm (114 m^3/h) trains (Train A, Train B) containing 72 membranes per train. The RO system is arranged in a double pass configuration with 48 membranes in the first pass, followed by 24 membranes in the second pass.

The facility samples twice a week for feed water quality (pH and turbidity) and permeate and concentrate values of the RO system. Given the Plant's problem with microbial growth and the creation of a biological matrix in the RO filters that restrict flow; differential feed pressure, effluent pressure, normalized flow, and chlorine residual are measured daily. A 10% increase in differential pressure alerts operational staff to undertake a cleaning of the membrane system with a caustic and acid solution. The membrane cleaning process requires the facility to run at half capacity for 48 hours since each train is taken offline for a 24-hour period to have the membranes rinsed before being returned to service.

Prior to the installation of new membrane elements in March 2014 an autopsy was performed on the existing elements and it was determined the facility had a sulfur reducing bacteria contributing to their microbial growth problems. Operational staff felt that reducing the use of SMBS would lessen the biofouling potential since the bacteria's food source would be eliminated; enabling nature to take its course and cause the bacteria die off. However, under the existing system design this reduction could not be achieved given that free available chlorine was above 1 ppm. Alternative dechlorination methods were then evaluated.

As a non-chemical approach to decompose the free chlorine oxidant and protect the RO membranes, the HOD UV technology provided the facility with the opportunity to reduce or eliminate the use of SMBS and reduce maintenance and associated costs.

HOD UV Technology: Principles of Operation

The HOD UV technology is a physical process for disinfection that exposes bacteria, viruses and protozoa to germicidal wavelengths of UV light, measured in nanometers (nm), to render them incapable of reproducing or further infecting a water system. UV light can destroy chemical contaminants through a process called UV oxidation.

The HOD UV technology is equipped with medium-pressure (MP) UV lamps that provide polychromatic UV light (200-415 nm) to enable the production of a high-density broad-spectrum UV light that can inactivate a range of bacteria, viruses and organisms. The light emitted by MP lamps is within the absorption spectrum of FAC (200-360 nm), making it the ideal for dechlorination applications.

The HOD UV technology has consistently achieved FAC levels below 0.01 ppm, or non-detect levels, in full-scale commercial application with some systems operating for more than six years with extraordinary results. The HOD UV technology is unique in its ability to disinfect and dechlorinate in a single, non-chemical process.

The HOD UV technology measures four critical parameters including % UVT, flow rate, UV lamp intensity (kW) and UV apparatus (consisting of Total Internal Reflection and Dose Pacing) in real time to maintain the minimum required UV dose. The system uses a proprietary Total Internal Reflection (TIR)-based design that, when coupled with the comprehensive monitoring of critical parameters, allows the system to achieve and maintain the specified UV dose.

The system's patented TIR technology, which is similar to fiber optic science, recycles UV light energy within the HOD UV chamber. The core of the technology is its water disinfection chamber made of high-quality quartz surrounded by an air block instead of traditional stainless steel (Figure 1). This is especially important given that in traditional UV systems metal adsorbs or "detracts" the UV dose the closer it gets to metal, whereas the TIR enhances the UV dose.

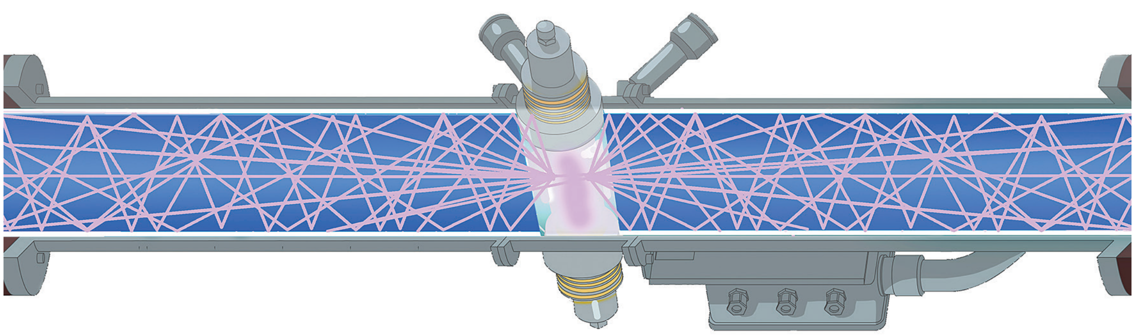

Figure 1: HOD™ UV lamp and chamber depicting the photons bouncing off the quartz surface

This configuration uses fiber optic principles to trap the UV light photons and recycle their light energy. The photons repeatedly bounce through the quartz surface back into the chamber, effectively increasing their paths and their opportunities to inactivate microbes and oxidize organic compounds.

Long-term Membrane Performance with HOD UV Dechlorination

Plant Bowen uses a five-year replacement cycle for the RO elements, the last installation occurred in March 2014. The HOD UV system was also installed and placed into continuous operation in March 2014. After three years of operation, the RO membranes are operating at the same level as new elements.

Data for the membrane system's differential pressure, normalized salt passage and rejection, permeate flow, and normalized permeate flow under the use of the HOD UV system was analyzed for a 940 day period from August 2014 to February 2017 (Figures 2–5). Normalized permeate flow is higher compared with a new membrane, while the quality of the permeate (salt passage and rejection) is similar to a new membrane.

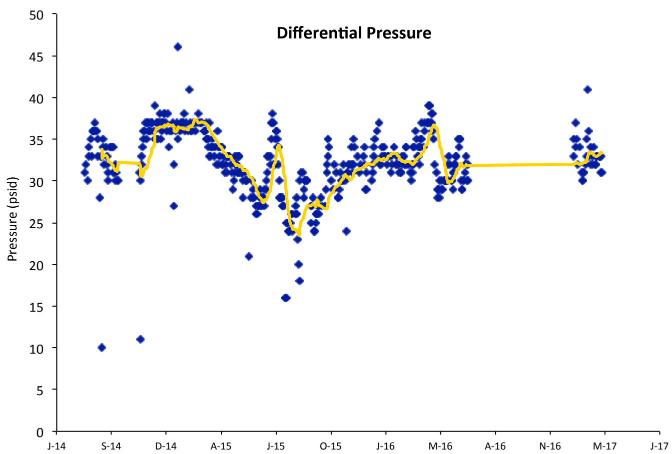

Figure 2: Train A Differential Pressure during 940 days of operation

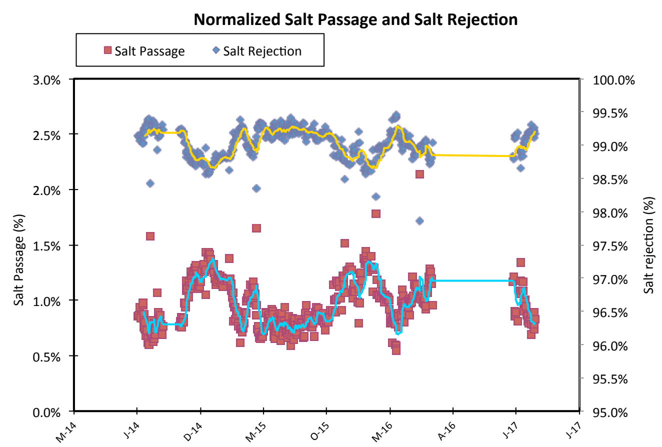

Figure 3: Train A Normalized Salt Passage and Rejection during 940 days of operation

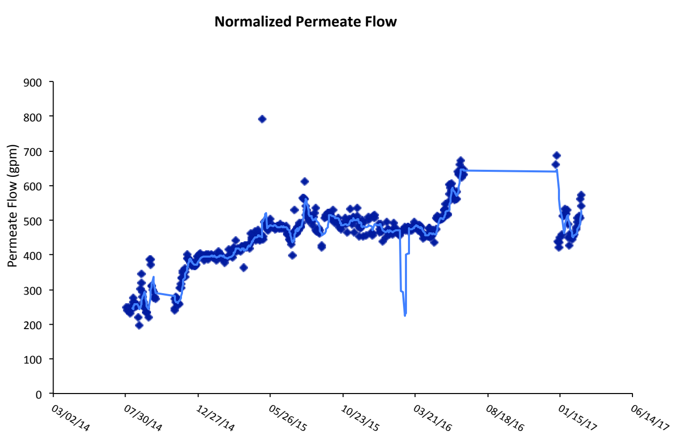

Figure 4: Train A Normalized Permeate Flow during 940 days of operation

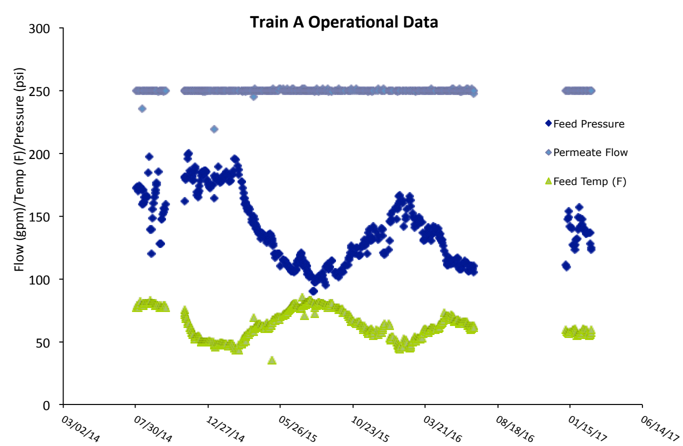

Figure 5: Train A Permeate Flow, Feed Pressure, and Feed Temperature during 940 days of operation

Prior to the installation of the HOD UV technology the membranes were cleaned one to two times per month. Following the installation of HOD UV in 2014, the clean-in-place (CIP) frequency reduced to once every two months. After five years of operation, the membranes average 30-35 psi differential pressure from the original 27 psi when they were put into service; indicating a longevity of the membrane elements that didn't exist without the use of the technology. Comparatively, the pre-2014 membrane elements showed they were running at a 50 psi differential pressure after just three years of operation.

Performance of the micron filtration system has also been enhanced with the use of the HOD UV technology and there has been a reduction in replacement events that has resulted in an annual cost savings of $60-$80K, prior to the installation of the HOD UV technology replacement costs averaged $100-$120K per year (Table 1).

Table 1: Micron Filtration Replacement Events and Annual Cost

Year	3 Micron (Total Replacements)	1 Micron (Total Replacements)	Total Replacement Cost*
2015	10	0	$100K
2016	2	2	$40K
2017	2	2	$40K
2018	4**	0	$40K

*Each micron filter element is $10K to replace. There are a total of two 3-micron and two 1-micron filters. The 3-micron and 1-micron filters are always changed in pairs (Train A, Train B).

**2 replacements were the result of a mechanical failure on the media filters.

Since the installation of the HOD UV technology the chemical feed rate has decreased by 75%; whereas the facility was originally feeding SMBS at 4 ppm rate in 2014, the current feed rate is 1 ppm. The monthly chemical usage had been reduced from 44.2 gallons per month in 2013 to 7.6 gallons per month. The facility has realized an annual cost savings of $5K with the reduction in chemical usage.

Although the HOD UV has been proven to effectively remove free and total chlorine to undetectable levels from inlet free and total chlorine levels above 1 ppm; the facility prefers to maintain the oxygen scavenger (1 ppm SMBS feed rate) as an asset protection method in the event of a power failure that would prevent the operation and delivery of dechlorination control from the HOD UV system.

Conclusion

Process improvements upstream of the HOD UV technology, coupled with the full-scale operation of the UV system, have lead to a significant reduction in biofouling at Plant Bowen. In addition to reducing the use of SMBS, the facility has also minimized the frequency of micron filter replacement and CIPs for membrane cleaning. These process improvements have resulted in a cost savings of more than $200K, providing Plant Bowen with a less than two year return on investment after purchasing the technology. Moreover, there has been no reduction in performance to the RO membranes with the use of the technology. As a result, Plant Bowen has been able to maintain the integrity of their feed water for the boiler and steam cycle, ensuring production and quality levels necessary for the facility to operate efficiently.

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