

Reclaimed Water Optimize Groundwater Recharge Reliably

California's innovative use of re-purified water protects local groundwater resources from seawater intrusion while conserving the state's precious water resources. **BY GREG BRADSHAW**

SEVERAL CALIFORNIA agencies supplement their water supplies with purified recycled water used to protect local groundwater resources from seawater intrusion. Referred to as groundwater recharge reuse projects (GRRPs), such activities use sustainable, safe, and reliable water to protect local resources and reduce reliance on imported water. GRRPs have established a new standard for public acceptance and expectations of indirect potable reuse, using membranes and advanced oxidation processes (AOPs).

GROUNDWATER PROTECTION

The West Basin Municipal Water District was created in 1947 to protect the groundwater supplies in Los Angeles County where withdrawal exceeds natural recharge. A hydraulic pressure ridge along the coast was created by injecting imported water into the groundwater aquifer through a network of wells situated between seawater and the local groundwater source to prevent seawater migration into inland water supplies. This required more than 17 mgd of imported

water. In 1995, West Basin began using highly treated recycled or "purified" water blended with imported water to provide the barrier water. Recently the district was authorized to increase the percentage of recycled water injected into the West Coast Basin seawater barrier from 75 percent to 100 percent.

The district receives secondary effluent water from the city of Los Angeles Hyperion Treatment Plant and treats it through an advanced water treatment process of microfiltration (MF), reverse osmosis (RO), and ultraviolet (UV) disinfection and oxidation. The project is currently sized to treat an average flow of 12.5 mgd, with an ultimate treatment capacity of 17.5 mgd. Barrier water is monitored aggressively to protect the water supply and provide multiple barriers for removing potentially hazardous materials and pathogens.

As shown in Figure 1, the process train begins with automatic backwashing strainers to remove large particles in the secondary effluent feed supply. MF is then used to produce clean water for the RO system. Filtrate from the MF system is discharged into a break tank, which equalizes



UV oxidation is an important component of the West Basin Municipal Water District's recycled water program.

flow between the MF and RO systems. Sulfuric acid and an antiscalant are added to the MF filtrate ahead of the RO system to reduce scaling across the membranes. UV irradiation occurs on RO permeate, which has a low pH and provides a suitable environment to keep the UV system's quartz sleeves clean. Then decarbonation removes residual carbon dioxide and raises the pH. Calcium hydroxide is added immediately after decarbonation to provide further pH adjustment as required. Chlorine is added to provide a residual disinfectant for the distribution system.

West Basin partnered with the California Department of Public Health (CDPH) years ago to implement a project that subscribed to a groundbreaking draft GRRP regulation. Although the regulation has evolved with prescriptive requirements for membrane treatment, improvements in analytical testing have led to the identification of contaminants previously undetected. Therefore, the new regulation specifies reducing N-nitrosodimethylamine (NDMA) levels below the CDPH notification level and includes a general provision that serves as a safety net to



proved to be an effective treatment system. Although it remains unclear whether this approach improves or degrades water quality from an advanced water treatment system, public opinion supports natural treatment after a man-made treatment system. Travel time for recycled water injected into the groundwater can be determined by tracer or intrinsic tracer studies with a minimum 6-mo target. It's important to understand the fate and transport mechanisms.

Industrial Waste Pretreatment. The program identifies and reduces the impacts of industrial wastewater discharges to the wastewater treatment plant. It also provides a mechanism for operators to develop prohibitions against discharging nontreatable contaminants into the sewer system that ultimately serves the purification plant.

Basin Redox Conditions. It's important to evaluate site-specific redox conditions that could occur naturally in the presence of ammonia, sulfide, or reduced forms of iron and manganese.

Trace Organic Monitoring. Target organic compounds have been the subject of continued research to monitor significant process upsets or major changes in water quality. Such monitoring is intended to demonstrate the effectiveness of the advanced treatment processes. It's important to evaluate which chemicals are present in the water supply and then monitor those chemicals to cover the range of chemical properties represented, particularly polar, low molecular weight, neutral compounds.

Microbiological Monitoring. The program monitors *E. coli* in water sent to the seawater barrier.

UV/AOP Considerations. There's scant information on the efficacy of the AOP and no convenient target organic compounds yet available on which to base a dose of H_2O_2 . It's possible the currently applied dose is more than is required, but the additional treatment provides an added safeguard against trace organics

that may not be removed by the upstream physical/chemical/biological treatment processes.

Partnering With Regulators. Developing partnerships with regulators is critical to developing criteria for system design, installation, testing, and operation to meet goals. Early in the project, the district partnered with CDPH to identify project needs to increase by more than 50 percent the amount of recycled water to the barrier. The partnership also commissioned an independent expert panel, conducting a series of workshops from 2000 to 2008 and issuing two reports that summarized the recommendations, many of which became the basis of the CDPH draft GRRP regulation, including the need for an advanced oxidation process.

SYSTEM VALIDATION

A validation protocol was developed with CDPH to demonstrate that the system complied with established objectives. The West Basin Ultraviolet Disinfection and Oxidation System consists of three parallel trains, each comprising two chambers connected in series, with two reactors per chamber. Each reactor houses 72 low-pressure high-output (LPHO) amalgam lamps. The lamps have a turn-down capability of up to 60 percent of their rated nominal input power of 257 watts. The UV control system was set to operate and monitor the performances of all four reactors in a train.

The UV intensity sensor readings were recorded during the NDMA validation testing and ranged from 11.6 mW/cm^2 to 19.3 mW/cm^2 when operated at 100 percent power and 9.5 mW/cm^2 when operated at 60 percent power, still achieving a minimum 1.26-log NDMA reduction.

The UV system is required to provide disinfection in accordance with California Code of Regulations Title 22 requirements and the specific requirements for use of UV for disinfection as delineated in

address oxidation of complex compounds grouped as trace organics.

The draft regulation mandated among other things the following requirements for projects with average recycled water contributions exceeding 50 percent:

- UV light treatment with a fluence of at least 1.2 mJ/cm^2
- Hydrogen peroxide addition with a dose of at least 3 mg/L

PROJECT GOALS

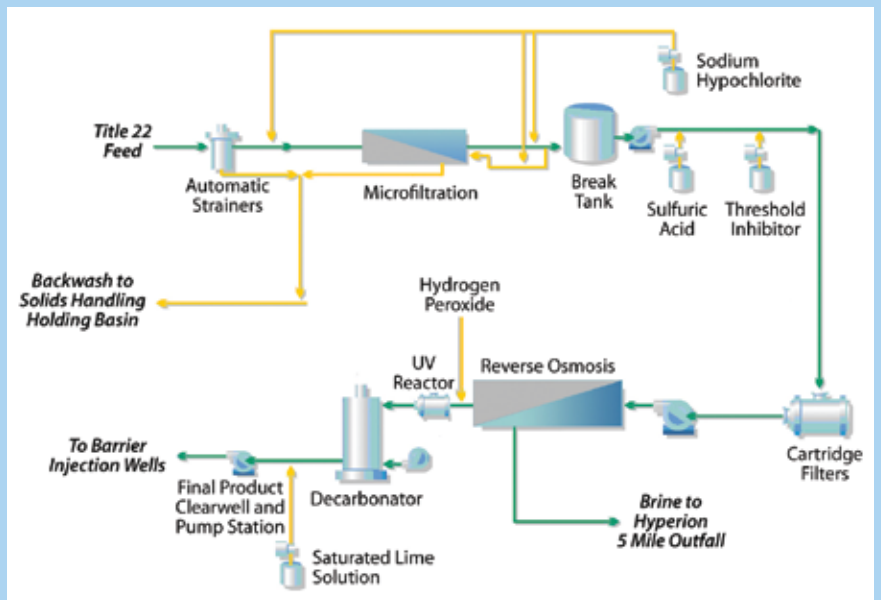
At the project's inception, several goals were established for the program, including multiple barriers, soil aquifer treatment, industrial waste pretreatment, basin oxidation-reduction (redox) conditions, trace organic monitoring, microbiological monitoring, UV/AOP considerations, and partnering with regulators.

Multiple Barriers. The existing treatment trains using MF, RO, and UV photolysis and oxidation of secondary wastewater provide multiple barriers for removing known and potentially unknown chemicals and pathogens.

Soil Aquifer Treatment. Natural treatment through geologic filtration has

Figure 1. Process Flow Diagram

The process train starts with automatic backwashing strainers to remove any large particles in the secondary effluent feed supply.



Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute. CDPH's approval of the UV disinfection and oxidation system was contingent on site-specific demonstration of NDMA photolysis and the application of disinfection validation studies previously completed at Orange County Water District on reactors of the same size and design as the West Basin reactors.

Disinfection. The UV reactors demonstrated a minimum 4-log_{10} virus removal and a minimum reduction equivalent dose delivery of 115 mJ/cm^2 per reactor and that four reactors in series can achieve (4 logs/reactor) at least a 16-log_{10} reduction of MS-2 bacteriophage.

NDMA. NDMA formation and reduction varies with the treatment process, as shown in Figure 2. In this case, NDMA is increased after chlorination of MF influent but reduced through membrane treatment and subsequent UV photolysis to nondetectable levels. Sizing a UV photolysis system is significantly influenced

by the NDMA target concentration, so understanding the treatment process and minimizing NDMA formation is important.

NDMA destruction validation testing conducted in August 2006 illustrated that the West Basin system can provide a 1.3-log NDMA reduction through four reactors in series at train flow rates from 1.1 mgd to 4.2 mgd, equating to a system flow rate of 12.5 mgd. This equates to a 0.325-log NDMA reduction through each reactor, which relates well to the validated performance of the OCWD system and further reinforces the conclusion that the two systems will perform similarly.

NDMA validation studies were performed in each reactor and as a complete train. The testing at West Basin and OCWD was conducted with a minimum UVT of 95 percent. The UVT is monitored continuously and factored into the control system to establish the target fluence.

MONITORING PARAMETERS

A unique challenge was to develop parameters for demonstrating real-time

feedback on UV output and compliance with disinfection and NDMA photolysis. UV disinfection and photolysis systems use control logic based on a theoretical yield to deliver the target dose, as opposed to a residual-based compound loop similar to chlorine or ozone systems. The system is being monitored for coliform and NDMA, but the feedback loops aren't time sensitive. Commercially available equipment that's 100 percent accurate in confirming UV fluence doesn't exist. Because the West Basin UV system operates in a steady-state condition, the control system can only vary in two parameters, output power and flow. Therefore, a feedback loop considering these parameters was used to monitor the system in real time. As lamps age, UVT decreases and train flow rate changes. The control system adjusts power accordingly to achieve the target fluence.

For UV photolysis-based systems, the electrical energy required per log order reduction (EE/O) metric provides instant system performance feedback. The EE/O value is used within the control system to determine the calculated output based on flow, number of reactors, number and age of lamps, and UVT values. The UV control system continuously displays the delivered EE/O value for each train, and the value is provided to the plant's distributed control system.

Measuring UV intensity provides useful monitoring parameters, such as water quality UVT changes and lamp aging and failure. Intensity monitors aren't useful in determining the fluence because

- they only measure intensity at a given point, not the reactor's average intensity.
- they don't consider the influence of reactor hydraulics.
- intensity readings can be influenced by the monitor's degradation from UV exposure.

In theory, the intensity reading multiplied by the retention time yields the

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fluence. But this doesn't account for reactor hydraulics, possible short circuiting, and actual fluence delivered. Therefore, the UV advanced oxidation industry typically uses intensity monitors to detect changes in water quality and lamp emission, but not to measure fluence.

INDUSTRY CHALLENGES

Because laboratory results for NDMA may require up to three weeks, the West Basin UV system targets worst-case historical NDMA concentrations. As a result, the UV system frequently uses more power than needed. UV system operations could be optimized with continued research. Two of the challenges involve on-line monitoring of actual performance and determining the appropriate amount of hydrogen peroxide for an advanced oxidation process.

Actual Performance. UV systems can determine applied power but not actual fluence delivered. Ongoing research, such as on-line chemical actinometry, would allow operators to receive immediate feedback on performance. Another approach is to identify a surrogate constituent that meets potable water criteria and a correlation between a given quantum yield of chemical reaction for given amount of UV light.

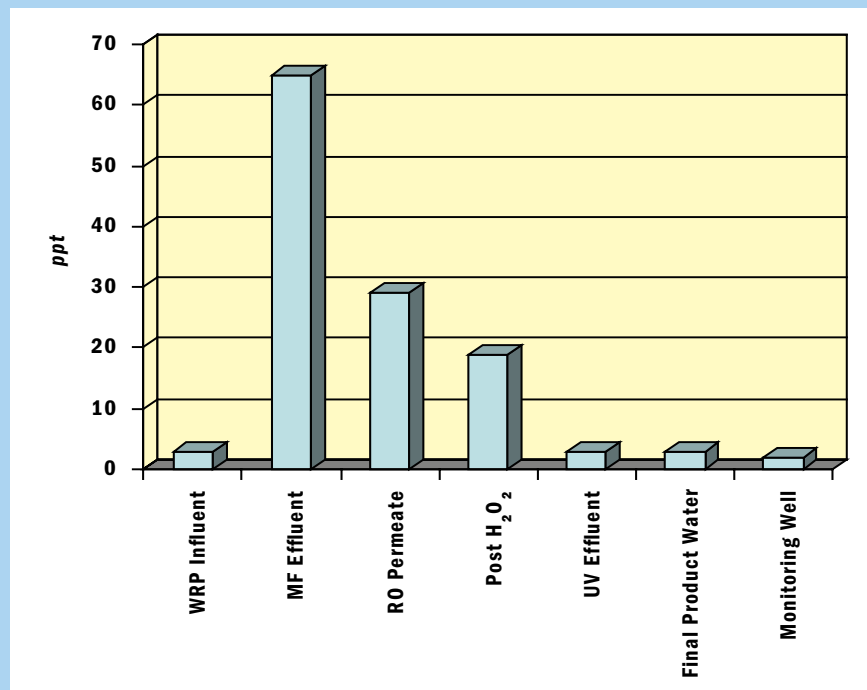
Hydrogen Peroxide. The question remains how much peroxide is needed to form hydroxyl radicals and how much yield is needed to oxidize trace organic concentrations. In the West Basin system, the barrier water has a typical total organic carbon (TOC) level around 0.2 mg/L.

Conversely, answering how much peroxide is too much and what the potential for by-product formation might be is just as challenging. Additionally, data from the site-specific reductions of pharmaceutically active compounds indicate that the RO system effectively removes monitored constituents.

The overall objective of the peroxide-feed system is really a safety net to oxidize

Figure 2. Mean NDMA Profile Through the Water Reclamation Plant

NDMA is increased after chlorination of MF influent but is reduced to nondetectable levels through membrane treatment and subsequent UV photolysis.



trace organics and address unknown constituents. Although the benefit of peroxide feed isn't fully documented, there are minor issues to consider. Peroxide's UV absorbance spectra lowers the UVT and overall efficacy by about 1 percent for each 7 mg/L. Also, formation of by-products such as aldehydes and ketones are possible at doses in excess of 10 mg/L. However, the use of peroxide is perceived as an overall benefit to the system.

The decay rate for hydrogen peroxide is fairly slow and can last up to several days. This decay can create additional chlorine demand, as peroxide will oxidize the chlorine into chlorate. Residual peroxide carried to the groundwater injection well contributes to biofouling because the residual will release oxygen within the well where the water has TOC levels of about 3 mg/L.

POSITIVE RESULTS

The environmental benefit of purifying recycled water for groundwater recharge and protection is exceptional. Committed to water conservation and recycling programs, California's West Basin Municipal Water District expanded its water recycling plant to annually conserve more than 10 bil gal of imported water. The project also reduced the impact of increased wastewater disposal and provides high-quality water that can be safely returned to the environment.

Author's Note: Thanks to the West Basin Municipal Water District, Orange County Water District, and Los Angeles Water Replenishment District for their dedicated research efforts, commitment to preserving public health, and patience in resolving key challenges in the implementation of these projects.