HAZEN AND SAWYER
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Validating Large-Scale UV Equipment

This edition focuses on critical issues currently faced by the U.S. drinking water industry.

As the size of disinfection facilities using ultraviolet (UV) light continues to expand to meet the drinking water demands of US cities, so do the challenges faced by utilities in validating the performance of UV units.

Validation for NYC's 2,020-mgd UV facility will be conducted at this testing facility in Johnstown, NY, which is being constructed/expanded to accommodate this effort.

Biodosimetry

In June 2003, USEPA issued its Draft Ultraviolet Disinfection Guidance Manual, proposing recommendations for a validation testing methodology called biodosimetry. Biodosimetry directly measures the effectiveness of a UV unit by flowing water through the unit, injecting live surrogate organisms at the inlet, and comparing inlet/outlet concentrations.

Validation is quite complex. Inactivation across the UV unit is measured at various combinations of flow rate, UV transmittance, and lamp power. A laboratory bioassay is performed separately, using the surrogate to determine the dose-response relationship on the water used in the field challenge. This measured dose delivered by the test unit is known as the reduction equivalent dose (RED).

The minimum RED required for inactivation credit is greater than the theoretical UV dose that could be achieved in a bench-scale test. It includes safety factors as large as three times the theoretical dose to account for uncertainties in validation testing, leading to significantly higher power requirements. However, these requirements may be greatly reduced without jeopardizing public health by optimizing validation procedures to reduce uncertainty.

Computerized Simulation

While not yet approved by USEPA, a potential alternative to full-scale validation is computer modeling using computational fluid dynamics (CFD) software, coupled with a UV light intensity distribution model. While engineers can use PC-based CFD software modeling to predict performance of units, the time and expertise required to develop and calibrate such a model is significant and is impractical for all but the largest installations.

Dual-Track Approach

In designing the world's largest UV installation—the 2,020-mgd Catskill/Delaware UV Facility—NYCDEP has taken a dual-track approach, based on full-scale validation, along with extensive modeling. The Catskill/Delaware

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Validating Large-Scale *continued*

facility will consist of 56 40-mgd UV units. No units of this size are installed anywhere in the world; thus, none have undergone validation testing.

The models accurately predicted the performance of several different UV units, and NYCDEP is working with USEPA towards gaining acceptance of modeling as a validation tool, while proceeding with full-scale validation.

Currently, only four UV validation testing facilities exist worldwide, only two of which were testing drinking water equipment when this investigation began. The larger of the two has a capacity of only 20 mgd; expansion would be needed to test this project's 40-mgd units. It would also be beneficial to test flow rates higher than the design capacity. Challenges associated with developing a facility of this size include locating a site with sufficient area to house the facility and a water source that can supply sufficient volume and quality for testing.

While the existing validation facility was originally limited to testing 8- and 24-mgd UV units, it will test 60-mgd units once expanded.

NYCDEP selected the UV Validation and Research Center of New York at the Gloversville-Johnstown Joint WWTF in Johnstown, NY, for validation testing. The WWTF normally operates at less than half its capacity, with several tanks active only during extreme wet weather, rendering them available for validation testing. Through NYCDEP funding, the validation facility is being expanded to allow testing of UV reactors of up to 60 mgd.

Risk-Based Decision-Making for Water Utilities

Putnam WTP Lime Hoppers.

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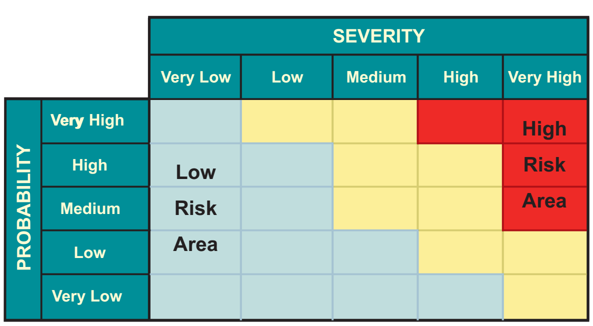
Prioritizing capital improvement projects at older water treatment facilities is a challenge for many utilities. To meet this challenge, some utilities have begun using a technique involving probabilistic risk assessment of the problems identified at their facilities, followed by prioritization of these problems based on their relative risk. This method uses a "risk matrix" that prioritizes actions based on the probability and severity of the risk associated with the problem to be solved, then analyzes the risk reduction that could result from implementing the various alternatives available. As such, the evaluation method serves as a valuable tool to facilitate the analysis of alternatives for capital improvements. This method offers several advantages:

- Provides a logical means for identifying the most beneficial alternatives.
- Quantifies the benefits associated with each recommended improvement.
- Enables the development of a credible and justifiable capital improvement plan that results in the most effective use of available funds and garners management support.



The product of the probability times the severity determines where each project falls on the risk matrix above.

The Aquarion Example

Aquarion Water Company of Connecticut is an investor-owned utility serving about 400,000 people. Hazen and Sawyer assisted Aquarion in developing a capital improvement plan (CIP), which identified the most advantageous and cost-effective course of action at its Putnam and Mianus Water Treatment Plants. In developing the CIP, physical conditions and regulatory compliance were assessed at both plants, followed by development of alternatives and recommended improvements. Recommendations were based on both economic and technical/qualitative (non-economic) analyses. Following these analyses, a phased and prioritized implementation schedule for the recommended solutions was prepared for each facility.

Using the results of the regulatory compliance and facility status reviews, separate CIPs for the Putnam and Mianus Plants were developed. The evaluation methodology included the assessment of various plant improvements/rehabilitation alternatives, employing a probabilistic risk-based approach to the plants' problems. These problems were then prioritized based on relative risk.

Benefits to the Water Industry

The risk matrix is applicable to other water utilities, to facilitate master planning efforts. The matrix can be used to prioritize projects at a plant, at multiple plants, or for an entire system. Applying this method provides a means to assess master planning projects quantitatively, based on economic and non-economic factors.

Weighing the Value of Watershed Protection

Grantley Pyke served as Principal Investigator for the AwwaRF watershed protection studies cited in this article.

As Ben Franklin once said, "an ounce of prevention is worth a pound of cure." This philosophy seems evident in the 1996 Safe Drinking Water Act, which strongly emphasized preventing contamination through source water protection and enhanced system management versus treatment alone. The proposed Long Term 2 Enhanced Surface Water Treatment Rule further stresses the importance of source water protection by linking the required level of *Cryptosporidium* oocyst removal to raw water oocyst concentrations, and by granting 0.5 log credit for watershed control programs.

In response, many water utility managers are turning to watershed best management practices (BMPs) to preserve or improve raw water quality, either as an alternative or supplement to new or upgraded treatment facilities. But while watershed protection makes sense from an environmental perspective, quantitatively weighing its economic costs versus benefits is highly complex and extremely difficult. Instead, the benefits of BMPs tend to be highly site-specific, and are best viewed as long-term investments.

Since agricultural operations can be a major source of nonpoint water pollution, one recent AwwaRF study examined ways that utilities and farmers can collaborate to reduce such impacts.

These issues were recently explored in two AwwaRF research projects. The first (Report #2616) used watershed and water treatment plant models to investigate the impact of pollutants on WTPs and the potential for BMPs to cost-effectively reduce these impacts. The second (Report #2781) relied on 20 detailed case studies to investigate the effectiveness of collaborative alliances between water utilities and farming operations in reducing the impacts of agricultural nonpoint source pollution.

While the AwwaRF studies didn't result in a simple formula to measure source protection value, two general observations are:

1) In some cases, when the costs for inadequately protecting source waters are high, source protection is a better investment than treatment. Examples include New York City (to avoid building a 2-bgd filtration plant); Springfield, IL (to avoid frequent dredging); and Columbus, OH (due to excessive rates of PAC application).

2) While some utilities have attempted to apply a strict cost-benefit approach to source protection, many have not. Instead, the investment in source protection was often justified by the following beliefs:

- Without source protection, impaired raw water quality may lead to elevated treatment costs, regulatory violations, and poor aesthetic quality.
- Source protection is an inherently prudent approach that will ultimately improve water quality and potentially reduce long-term treatment costs.

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How Utilities Can Help

The research also showed that water utilities can make substantive—sometimes critical—contributions to watershed protection at minimal direct cost. Here are some examples:

- **Water quality expertise:** Utilities often use their in-house lab capabilities to support watershed protection efforts—for instance, to demonstrate the extent of water quality problems, mobilize support for protection efforts, identify contaminant source areas, or establish baseline data. Typically, these in-kind contributions count as matching funds to help leverage additional outside funding.
- **Monitoring program support:** Utilities can assist in the challenging process of measuring water quality impacts of BMPs, which, depending on the contaminant of concern and environmental setting, can take multiple years and requires a baseline of historical water quality data during the "pre-BMP" period.
- **Lobbying/advocacy:** With their roles as drinking water suppliers and public health protectors, water utilities can be effective source protection lobbyists, drawing attention (and funding) to such efforts.
- **Financial incentives:** Small contributions count. For instance, a relatively small contribution to cover some of a farmer's BMP cost-share responsibility or extra incentive payments can dramatically impact BMP implementation or program enrollment.

Step-by-Step Guide to MF Membrane Project Success

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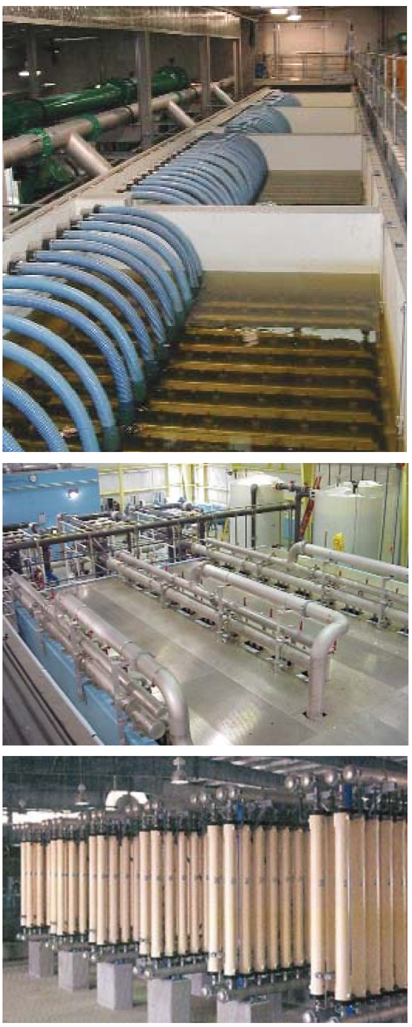
Widely recognized as a viable water treatment alternative, microfiltration (MF) membrane technology is becoming increasingly popular in the US. Successful implementation requires an understanding of the differences between available MF membrane systems and how they impact project execution, along with the know-how to navigate a MF project, from pilot testing through design and procurement.



One of the keys to success is understanding system differences. Shown above are three of the many available systems: 1) US Filter CMF-S system (at 33-mgd Coliban WTP, Australia); 2) Zenon ZW500 system (at iron removal plant, Seekonk, MA); and 3) Pall Aria MF system (at 5.2-mgd WTP, Ingleside, TX).

Market Research

There are different types of membrane systems commercially available, with varying flow configuration, construction, performance, and design criteria. Some vendors offer multiple types of systems that may be appropriate for a specific application. In addition, some systems require pretreatment, while others foul more easily or are more susceptible to chlorine. These factors must all be considered in selecting the most suitable MF system.

Pilot Testing

To identify pretreatment needs and determine a membrane system's effectiveness in treating a specific source water, pilot tests should be conducted. Performance should then be used as the basis for selecting systems for further evaluation. Pilot tests can also analyze the impacts of eliminating certain pretreatment processes, such as sedimentation. These analyses must be applied simultaneously to all MF systems being tested, using the same raw water, since the fouling characteristics of membranes are very sensitive to raw water quality.

Economic Analyses

Conceptual designs can then be prepared for each selected system. Costs can be estimated for the overall treatment process, including upstream and downstream equipment, such as pretreatment. Significant construction differences between systems ("footprint," excavation required, size of backwash and spent chemical disposal tanks, etc.) must be considered in estimating capital costs.

O&M costs must also be considered. The O&M cost analysis must encompass power consumption and costs for chemical cleaning/disposal and membrane replacement, along with warranty provisions for membrane life.

Alternatives should be further evaluated through life-cycle cost analysis. If recurring O&M costs are high, a MF system with a low estimated capital cost may be most expensive in the long run.

Non-Economic Analyses

Some owners may place greater weight on system reliability, vendor experience, and ease of operation than on cost, and may select a more expensive system if there are tangible technical benefits. For example, an inexperienced vendor can underestimate the difficulty of applying its product to a particular market, resulting in both installation and operational problems. Therefore, non-economic factors should also be scrutinized.

Procurement Method

Due to the differences between MF systems, one set of contract documents for all system types cannot be bid simultaneously. Therefore, the procurement method for the membrane system should be identified as early as possible during design.

Pre-purchasing membrane equipment before awarding the General Contract offers several advantages: no contractor markup, and full adherence of the MF system vendor with the design of the remainder of the facility. The owner is thus in full control of the contract and able to negotiate a favorable, comprehensive "package," incorporating payment terms, warranties, bonds, schedule milestones, and contract price. However, the owner will likely have to provide additional insurance coverage during installation, and must coordinate or delegate design, construction, and start-up activities.

If membrane equipment is purchased as part of the General Contract, scope, price, and warranty conditions must be negotiated before bidding, so that contractors can include the same fixed prices within their proposals. This poses the risk that vendors may not fully cooperate in providing information, possibly resulting in significant cost increases during construction, as omissions or inadequacies come to light. Paying the MF system vendor for shop drawings and documents ahead of a purchase order virtually eliminates this risk.

Alternatively, two sets of design documents for comparable, relatively similar MF systems may be prepared and bid. Savings resulting from competitive bidding could outweigh the extra cost of designing two systems.

Finally, while design/build has been touted as an effective project execution alternative, it has experienced mixed results in the US water industry. Owners are also concerned about design and equipment quality under design/build, and bidding laws for municipal utilities in some states may preclude this delivery system. ◣

Viewpoint: Selecting New Drinking Water Technologies: The Basics Still Apply

By Mark M. Bishop, P.E., DEE, *Vice President*

A century after Allen Hazen's quote, our responsibility to provide good drinking water is more important than ever. The drinking water industry is in a period of significant change, with new federal regulations, high customer expectations regarding water quality, and many available treatment technologies. Many utilities are also in the midst of upgrading old infrastructure or planning significant expansions to meet increasing water demands.

> *"Investigation should be made at this point; and if the water is not at fault, the responsibility should be located. If the water is guilty, it either should be purified or a new supply obtained."*
> ***Allen Hazen***
> *regarding disease outbreaks from* ***Filtration of Public Water Supplies, 1900.***

Drinking water technology has also advanced significantly, with processes such as high-rate settling, membranes, ozone, UV disinfection, and organics removal with synthetic resins. It now seems archaic to talk about long basin detention times or conventional filter rates, or to use the term "tried and true" with regard to process selection. Considering today's available treatment options, planning new facilities or upgrading old ones can be a daunting task.

Back to Basics

In spite of a wider range of treatment options, we must still remember the basics of good design practice, namely:

- Providing multiple barriers.
- Minimizing operational complexity.
- Incorporating reliability and redundancy.
- Optimizing residuals management.

Multiple Barriers. Provision of multiple barriers should not be lost with the addition of new treatment processes.

We are not at the point of completely understanding or preventing treatment failures, operator errors, or process problems. In fact, we cannot even continuously analyze for organisms of concern, such as *Cryptosporidium* or *Giardia*, or predict possible movement of these organisms through our plants. Therefore, provision of more than one treatment barrier continues to be good "public health" engineering practice. For example, pretreatment of surface water upstream of a membrane system should always be objectively evaluated, since membranes can be affected by high organics, turbidity, manganese, or algae conditions. Allowing for ample chlorine disinfection time after ozone or UV disinfection, or utilizing membranes that are considered a microbe removal process, is still a good idea.

Operational Complexity. Good operations and preventive maintenance training programs are critical with any new treatment scheme, to minimize risks of extended shutdowns or loss of capacity.

While many new technologies have performance advantages, they can also be much more complex. With complexity, often comes automation, along with the question: What happens when the automation fails? New technologies, such as sand-ballasted settling, UV disinfection, and high-rate filtration, operate at rates much higher than current conventional processes. Operators need to know how to assess and respond immediately to problem situations.

Reliability/Redundancy. Reliability and redundancy are still important factors when considering new technologies.

The appeal of some new technologies is the chance to do more with less, while others just provide a higher treatment level. Providing for units "out of service" due to cleaning processes, mechanical failures, or loss of power should be part of an objective comparative analysis of any treatment scheme. Loss of a single process unit and the ability of a parallel or standby process to treat water are examples of reliability issues. Chemically cleaning a membrane skid might mean two days "out of service" for that unit, with a corresponding loss of treatment capacity. The addition of UV disinfection has similar issues with individual reactor capacity and off-line reactor redundancy. Uninterrupted power supply and standby power are also critical to the reliability of a UV disinfection process.

Residuals Management. The handling of waste process water and solids is sometimes overlooked in comparing technologies. However, the tail can, and sometimes does, "wag the dog." For example, discharge of membrane reject water can determine process viability in some parts of the country. Also, some high-rate coagulation processes generate large amounts of wastewater during high-turbidity periods, and must be properly handled in the waste management scheme.

Handling "Guilty" Water

Our water sources seem to be even more "guilty" and our drinking water quality much more regulated than they were in Mr. Hazen's time, 100 years ago. Engineering our water treatment systems to meet future needs requires careful evaluation and consideration of multiple factors, particularly those described above. Now, more than ever, it is incumbent on us to make good treatment decisions, using "the basics" as a foundation.

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Hazen and Sawyer Happenings

Gary Haubner has joined H&S as manager of our new Cincinnati office.

Cincinnati Office Opens

Hazen and Sawyer recently opened a new branch office in Cincinnati to serve the needs of water and wastewater clients throughout Ohio, Northern Kentucky, and other parts of the Midwest. While currently operating at a temporary location (tel: 513-618-6426, fax: 513-618-6526), the office will relocate to a permanent address in April (11311 Cornell Park Drive, Suite 135, Cincinnati, OH 45242, tel: 513-469-2750, fax: 513-469-2751). Along with this news, we're also happy to announce that Gary J. Haubner has joined us as a Senior Associate and Cincinnati office manager. Mr. Haubner has 14 years of experience in water and wastewater engineering. He has conducted work for the Greater Cincinnati Water Works, Cincinnati Metropolitan Sewer District, Sanitation District No.1 in Northern Kentucky, and many other communities, particularly throughout Ohio. Mr. Haubner holds a BS in Civil Engineering and MS in Environmental Engineering from the University of Cincinnati. He is also a registered P.E. in Ohio and an active member of the Ohio WEA, as well as WEF and AWWA. ◣

Our firm's newest VP, Jim Avirett, manages our Baltimore office.

James Avirett Joins H&S-Baltimore

James (Jim) A. Avirett, Jr., recently joined H&S as a Vice President and Baltimore office manager. Mr. Avirett has 33 years of experience in planning, design, and construction management of water and wastewater treatment and conveyance facilities, including large pumping stations and large-diameter pipelines. He also has expertise in enhanced nutrient removal and biological nutrient removal. His credentials include a BS in Civil Engineering from Lafayette College and MS in Environmental Engineering from Johns Hopkins University, as well as P.E. licenses in Maryland, Virginia, the District of Columbia, and six other states. Mr. Avirett is also an active member of the AWWA, WEF, NSPE, ASCE, and APWA. ◣

Paerdegat Slurry Wall Wins Highest Honor

Award recipients: (standing) Paul Zoltanetzky (DEP) and Reza Marandi (DEP), and (seated) Nayan Shah (DEP) and Anna Walsh (H&S).

In the 2004 American Council of Engineering Companies-New York Engineering Excellence competition, a Diamond Award (first prize) went to the Paerdegat Basin CSO Facility Slurry Wall project, which was completed by Hazen and Sawyer, along with geotechnical subconsultant Mueser Rutledge, for the NYC Department of Environmental Protection (DEP). H&S serves as DEP's engineering consultant for the Paerdegat Basin Water Quality Facility in Brooklyn, NY, which will store stormwater runoff and thereby improve water quality in the Basin. Construction of this facility presented a major challenge: how to build 40-foot-deep tanks with foundations of up to 60 feet deep in a densely populated area with a groundwater table only 10 to 15 feet below grade. The solution was the deepest slurry wall cutoff system in the tri-state area, which avoided an estimated $23 million in impacts to the surrounding community versus use of conventional dewatering. ◣

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