VALIDATION FACILITIES FOR DRINKING WATER UV SYSTEMS

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A key component in the design and application of UV light to drinking waters is the requirement to confirm the UV reactor's ability to deliver the targeted dose under prescribed operating conditions, and verify its ability to monitor, control and report this dose under varying conditions within the reactor's rated operating range. Regulatory frameworks have been built about this validation process, and a number of protocols have been developed to establish minimum testing requirements. Engineers use these validation data to verify that a UV system is properly sized to deliver a required UV dose under design conditions of flow, water UV transmittance (UVT), and UV output from the lamps to the water. Drinking water utilities use validation data to relate on-line measurements of flow rate, UV intensity, and water UV transmittance to dose delivery for the purpose of obtaining disinfection credit.

The validation process generally entails operating a full-scale reactor through its design operating range and confirming its dose-delivery claims via a microbial challenge with a microorganism of known UV dose-response. Concurrently, the system's monitors and control logic are validated to ensure that the reactor will always report accurately the delivery of the prescribed minimum dose. With the increasing demand for such testing, the need for test facilities also has emerged. UV validation testing can be conducted either at a dedicated test facility or on-site at the utility interested in implementing UV disinfection. On-site validations obviously are project-specific, and accomplished with temporary test stands or with the installed systems. Dedicated test facilities allow for greater flexibility and economies, and minimize the need for multiple on-site validations with equivalent reactors. Table 1 presents a summary of potential advantages and disadvantages associated with the on- and off-site options. These were excerpted, in large part, from the USEPA's Draft UV Guidance Manual (June 2003).

At present, four such facilities are operating, two in North America and two in Europe:

- DVGW Test Facility, Siegburg, Germany
- UV Validation and Research Center of New York, Johnstown, New York, USA.
- ÖNORM Test Facility, Austria
- Portland UV Validation Facility, Portland, Oregon, USA.

Each of these facilities provides the key components for conducting validation testing for UV reactors:

- Bioassay test stand to mount and operate the UV reactor
- Collimated beam apparatus to calibrate the challenge organism's response to UV.
- Microbiology lab to generate and harvest the challenge organism and to enumerate the challenge organism.
- UV sensor, lamp and quartz testing apparatus.

The bioassay test stand is designed to pass water carrying a challenge microbe through the UV reactor under controlled conditions of flow rate and water UV transmittance. The source water used for testing typically has high UV transmittance and a UV-absorbing chemical is added to obtain the UV transmittance used for testing. The test water should be free of disinfectants and coagulants that could interfere with the inactivation and assay of the challenge microbe. The added UV absorber and challenge microbe should be well-mixed spatially and temporally at the inlet sampling point prior to entering the UV reactor. The challenge microbe surviving UV disinfection should be well-mixed prior to the effluent sampling port. Static mixers and long pipe lengths can be used for mixing. Alternatively, the additives can be mixed with the source water contained in a feed tank before testing. Once water passes through the reactor, it should be properly wasted. During testing, water samples are collected from the reactor influent and effluent. The log-inactivation of the challenge microbe by the UV reactor is determined by measuring concentrations of the viable challenge microbe in those samples.

The collimated beam apparatus is a bench-scale device used to irradiate volumes of water with a known dose. During validation, the apparatus is used to determine the UV dose-response of the challenge microbe used for validation. The UV dose-response curve is used to relate the log-inactiva-

Table 1. *Advantages and Disadvantages of On-Site and Off-Site Testing Options*

Testing Option	Advantages	Disadvantages
Off-Site Testing at a Dedicated Facility	Greater flexibility, and cost efficiency	May require re-validation (on- or off-site) if site-specific conditions had not been previously tested
	Provides performance data to support the design of a facility	
	Ability to test over a wide range of operating conditions (UVT, flow, etc.), including inlet/outlet piping configurations	
On-Site Validation at the Subject Application	Match exact piping configuration	UV installation has to be completed before benefit of validation
	Providing testing support equipment on-site allows for future testing, if needed.	Limited to water quality (UVT) available
		Costs tend to be higher Logistics may be very difficult (Isolated test train and possible permitting)

tion of the challenge microbe by the full-scale UV reactor to a dose value termed the Reduction Equivalent Dose (RED).

The microbiology lab prepares stock solutions of the challenge microbe used to bioassay the UV reactor and measures the concentration of the challenge microbe in water samples obtained from the bioassay test train or irradiated by the collimated beam apparatus.

The UV sensor test stand is used to verify the properties of the UV sensors. Verified properties can include spectral and angular response, linearity and calibration, and temperature response. Other component testing may include verification of lamp spectral output and quartz transmittance.

DVGW TEST FACILITY SIEGBURG, GERMANY

The DVGW Test Facility was established at the Wahnbach Reservoir Association (WTV) near Bonn (Hoyer, 2002). Since 1998, the test facility has conducted more than 500 test runs with UV systems from all major UV-firms worldwide at flows up to 3,000 m³/h (19 mgd) capacity in accordance with the DVGW Standard W 294. The challenge microbe is B. subtilis spores and the UV absorber is lignin sulfonic acid. B. subtilis spores are grown and assayed on-site. Figure 1 presents a schematic of the test facility and a photograph of the large-test train. The water source is groundwater with a UVT greater than 98% (1 cm). The challenge microbe and UV absorbers are pumped into a side stream to ensure good temporal mixing. Static mixers are used to obtained good spatial mixing. Water passed through the reactor is discharged to the Rhine River.

UV VALIDATION AND RESEARCH CENTER OF NEW YORK, JOHNSTOWN, NY, USA

The New York test facility was brought on-line in June 2003 and has since been conducting validation tests on both large and small reactors. Test flows have ranged between 158 and 3,500 m³/h (1 and 22 mgd), and transmittances between 70 and 97% (1 cm). The facility is assembled to be expandable. With negotiations underway to conduct validation, the reactor design that will be selected by the New York City Department of Environmental Protection for its planned 320,000 m³/h (2.0 billion gallons per day, bgd) Catskill-Delaware UV Disinfection Facility, the capacity of the validation facility will be increased to approximately 9,500 m³/h (60 mgd). The current facility was assembled with support from the New York State Energy and Research Authority (NYSERDA) and several major UV manufacturers and is operated by HydroQual, Inc. All field and laboratory support is provided by HydroQual, Inc., and the Lighting Research Center at Rensselaer Polytechnic Institute assists with sensor and lamp measurement issues.

A schematic diagram and photographs of the facility are provided on Figure 2. A filtered, dechlorinated surface water supply is used for testing, with UV transmittances levels up to 98.5% (1 cm). Feed water is held in a 2,725 m³ (0.72-MG) tank, with an additional 4,920 m³ (1.3-MG) tank available for feed water storage. Multiple centrifugal pumps are installed (with the ability to expand the number of pumps) to draw water from the tank and discharge to a manifold pipe. Injection of the challenge organism (MS2 coliphage) and a UV absorber (lignin sulfonate) is done downstream of the primary feed pump. Flow can be to either of two piping trains, one for larger system validations and the second for reactors up to approximately 1,100 m³/h (7 mgd). In-line mixing is provided both upstream and downstream of the test reactors. Flow is measured via magnetic flow meters. The facility can accommodate different inlet and outlet piping configurations, depending on the test requirements. Discharge of seeded/adjusted waters is to a 4,920 m³ (1.3-MG) tank, with a second 3,030 m³ (0.8-MG) tank available. To conserve water when operating with unadjusted waters, both trains are equipped with a recycle line back to the clean water tank.

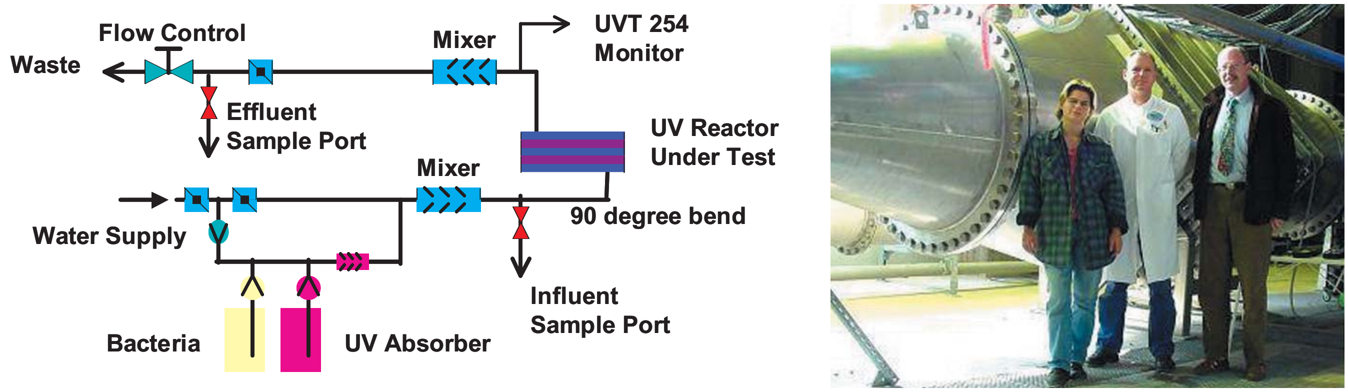

Figure 1. *Schematic and photograph of the DVGW test facility (Hoyer, 2002).*

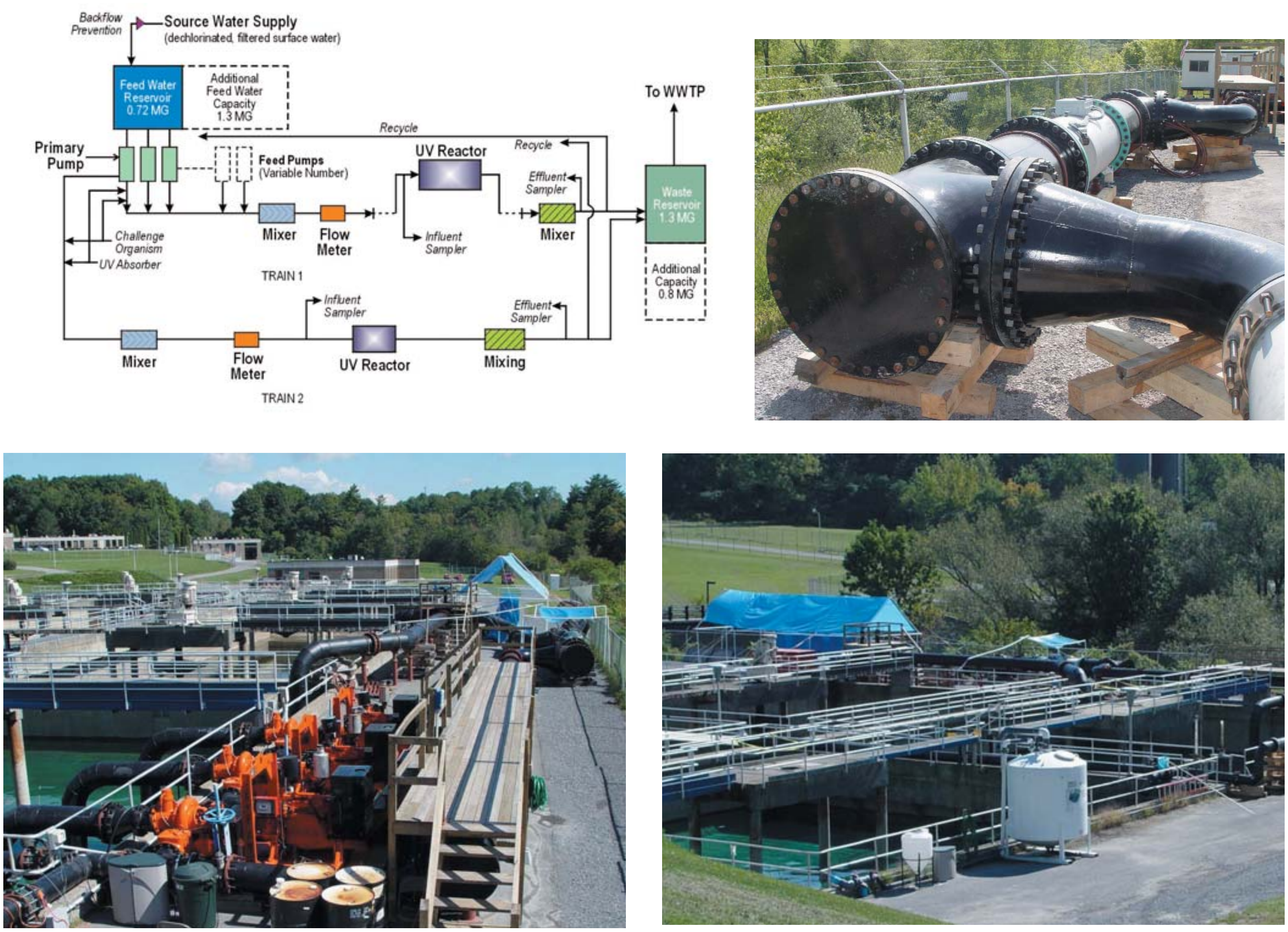

Figure 2. *Schematic and Photographs of the UV Validation and Research Center of New York*

PORTLAND UV VALIDATION FACILITY, PORTLAND, OR, USA.

The Portland Test Facility (Figure 3) is located on the site of the Groundwater Pump Station of Portland's 14,200 m^3/h (90 mgd) South Shore well field (Wright et al, 2003). The facility, funded by Calgon Carbon Corporation and WEDECO-Ideal Horizons, has been operational since March 2003, validating large-scale UV reactors at flows from 158 to 6,300 m^3/h (1 to 40 mgd) and UV transmittance from 70 to 98% (1 cm). The water source is chlorine-free groundwater with UVT greater than 98% (1 cm). A 7,570 m^3 (2 million gallon) reservoir provides constant head to the test train.

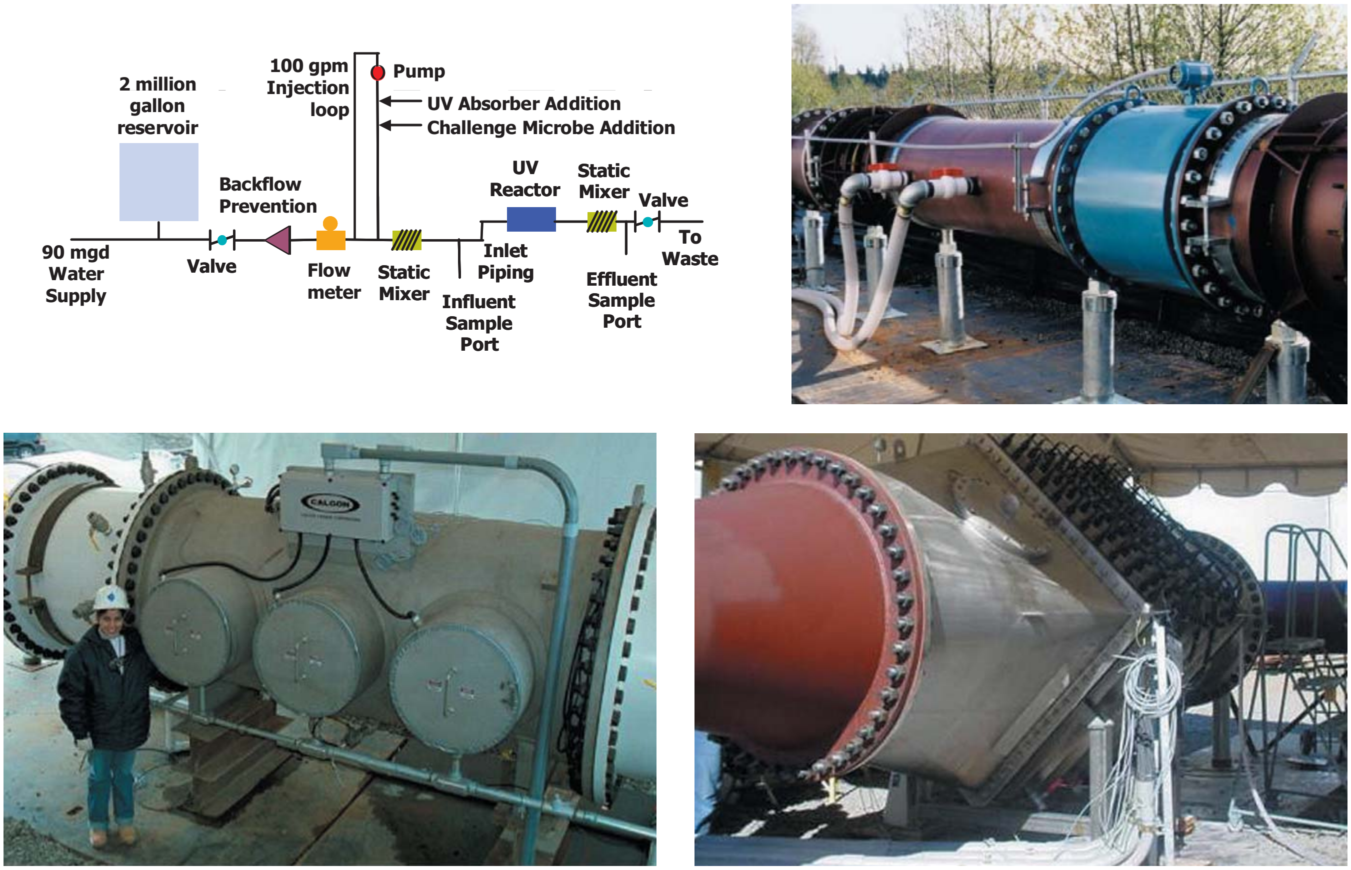

Figure 3. *Schematic and photographs of the Portland Test Facility.*

MS2 phage and lignin sulfonate currently are used as challenge microbes and UV absorbers. MS2 phage is grown and assayed off-site by Clancy Environmental Consultants. Similar to DVGW, the additives are injected into a sidestream to promote temporal mixing, and static mixers are used for spatial mixing. Inlet piping to the reactor is flexible and velocity profiles can be measured using pitot tubes. Water passed through the UV reactor discharges to the Columbia River under existing permits. Validation testing is conducted as per the draft USEPA UV Guidance Manual with oversight by Carollo Engineers.

VIENNA UV VALIDATION FACILITY, AUSTRIA.

In Austria, the installation of new UV reactors in public water works only is allowed if the plant has been type-tested and if it has received the quality sign of the ÖVGW. Biodosimetric tests are conducted following the Austrian national standards ÖNORM M 5873-1 (2001) for plants with low-pressure mercury lamps and the recently finished ÖNORM M5873-2 (2003) for plants with medium-pressure mercury lamps.

The test facility is at Arsenal Research in Vienna and has a capacity up to approximately 520 m^3/h (3.3 mgd). About 40 UV plants (low-pressure and medium-pressure) have been tested since 1990. A new test facility is planned near Vienna with a capacity up to approximately 3,150 m^3/h (20 mgd). The microbiological work is done by the Klinisches Institut für Medizinische Mikrobiologie, Universität Wien (Univ.-Prof. Dr. Regina Sommer), the UV-measurements are conducted by the optical laboratory of the Institut für Medizinische Physik und Biostatistik (IMP), Veterinärmedizinische Universität Wien (Dipl.-Ing. Alexander Cabaj), and the test stand in the Arsenal is operated by Ing. Georg Hirschmann. A schematic diagram of the test stand and photographs are found in Figure 4.

Type testing of sensors and other optical measurements, which are especially demanding under Part 2 of ÖNORM M5873, are conducted in the optical laboratory of the IMP before biodosimetric testing. Microbiological testing is performed with spores of Bacillus subtilis. UV absorbers added to the test waters are sodium thiosulfate (low-pressure lamps) or coffee (medium-pressure lamps). The UV-sensitivity of the challenge organism is calibrated in an apparatus with quasi-parallel radiation from low-pressure mercury lamps.

SUMMARY

The application of UV radiation to drinking water systems is accelerating in the United States, and the regulatory and design frameworks are being established to enssure that critical public health objectives are met with this technology. Performance and monitor validation is key to this

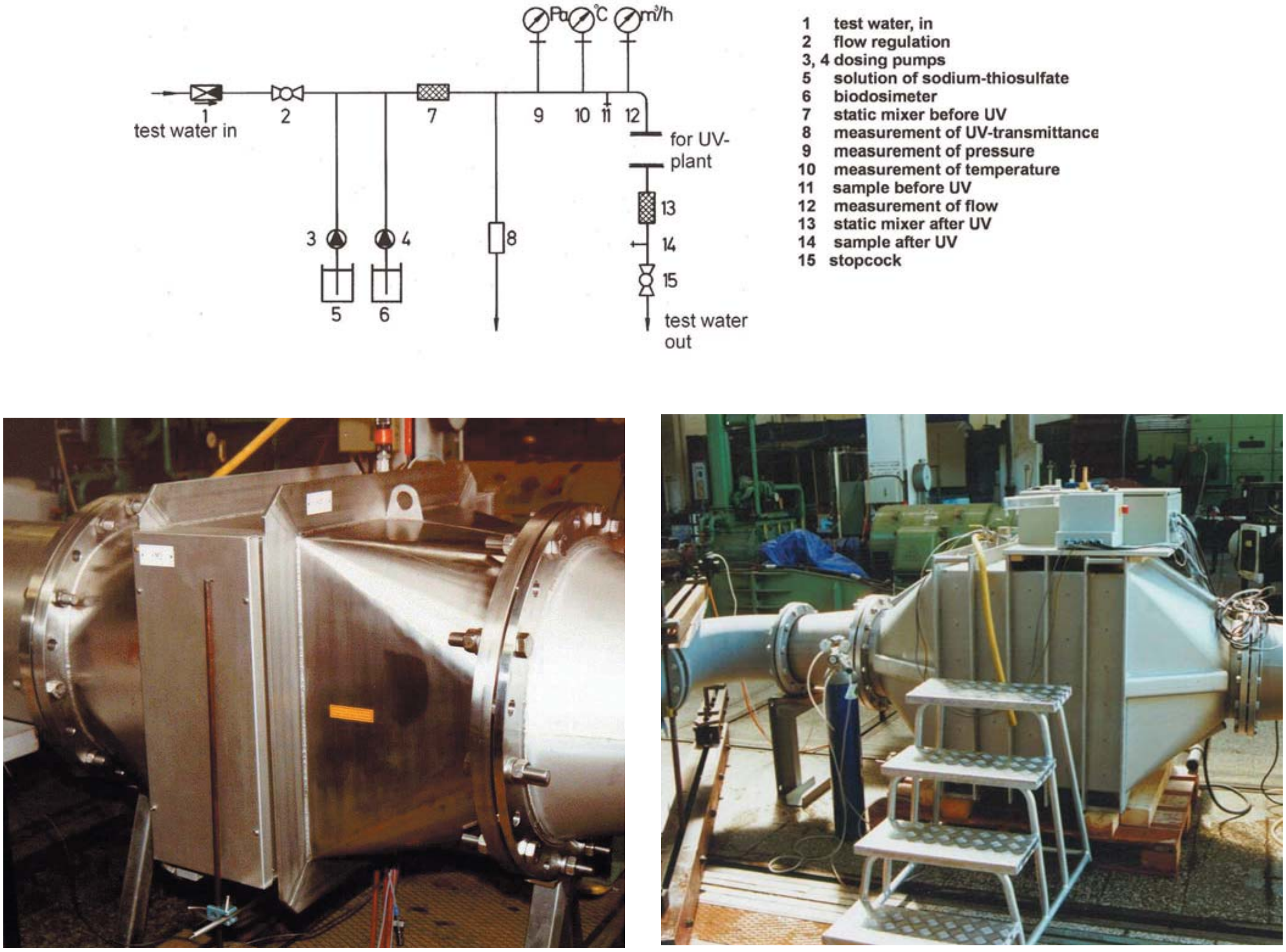

Figure 4. *Schematic and photographs of the Vienna Test Facility.*

ensurance, with owners and their design consultants having the option to conduct such validation testing either at their site, or at a dedicated off-site facility. Experience with both options likely will be gained over the next few years; the availability of off-site facilities allows such a choice, and responds to a critical need within the water industry.

REFERENCES

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