

A State Perspective on the USEPA UV Disinfection Guidance Manual

Stephen Deem, PE,¹ David Dziejewski, PhD,² Michael Montysko, PE,³ and Richard H. Sakaji, PhD, PE^{4*}

Regional Engineer, Washington State Department of Health, Office of Drinking Water, Kent, WA
Research Scientist, New York State Department of Health, Bureau of Water Supply Protection, Troy, NY
Chief, Design Section, New York State Department of Health, Bureau of Water Supply Protection, Troy, NY
Senior Sanitary Engineer, California Department of Health Services, Division of Drinking Water and Environmental Management, 850 Marina Bay Pkwy, Bldg P, Richmond, CA 94804.

***Corresponding Author, Email: rsakaji@dhs.ca.gov**

ABSTRACT

IUVA posed three short, but broad questions to regulatory programs that have been implementing ultraviolet (UV) disinfection prior to promulgation of Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and in the absence of a final UV Disinfection Guidance Manual (UVDGM), in an effort to evaluate how the UVDGM has or will affect the implementation of UV. While the overall consensus is that the UVDGM is a good document, it does not provide the definitive word on UV disinfection that many states would like. There are still unresolved issues and areas of concern, even for states that have accepted and permitted UV disinfection systems. The author's hope is that this article opens a dialog among state regulators in an effort to move UV disinfection forward as a viable treatment technology in a manner that is protective of public health.

INTRODUCTION

For several years, utilities and regulators knew that *Cryptosporidium* would be regulated as a drinking water contaminant because of the accord that was struck between utility and regulatory stakeholders during the USEPA's regulatory negotiations in the late 90's. Initial development of the Long Term 2 (LT2) Enhanced Surface Water Treatment Rule (LT2ESWTR) did not consider UV because, although it has been well known that UV is an effective disinfectant for bacteria and most viruses, it was widely held that the UV doses for protozoan inactivation would be too high and too costly to attain.

The landmark work of Bolton et al. (1998) demonstrated that previously held beliefs regarding the UV doses (medium pressure) needed for *Cryptosporidium* inactivation were incorrect and that much lower UV doses could achieve the desired public health objectives. With the release of subsequent studies validating and extending the findings of Bolton et al. (1998) to low pressure UV (Clancy et al. 2000; Craik et al. 2001; Shin et al. 2001), the water industry knew UV was going to be a viable treatment technology providing an alternative to traditional chemical oxidants for protozoan pathogen inactivation. Utilities recognizing this, and those under compliance orders or who were proactive and were in the midst of planning capital improvements, began to approach state drinking water programs about designing and building UV installations. Consequently some states, rather than

putting the technology on hold to wait for a final guidance manual, began the journey toward implementing the technology in the absence of formal USEPA guidance.

Although the Surface Water Treatment Rule, promulgated in 1989, did include guidance (USEPA 1991, Table E-14) which recognized UV as being an effective disinfectant for viruses, the application of UV disinfection has been limited to low flow drinking water applications (e.g., point-of-use treatment or disinfection of small groundwater systems), and focused on virus and bacterial inactivation. Given the lack of overall experience with UV in the larger drinking water utilities, and the fact that it is generally recognized that the margin for error in larger scale plants can have a significant impact on the system performance and the costs, there was significant concern about how UV systems would be validated, designed, built, and operated to ensure pathogen inactivation objectives were met.

Bringing any new water treatment technology into the mainstream of the water industry is a daunting task. Regardless of how long a technology may have been used in another medium or in another environmental field, there is always a learning curve as regulators, consultants, and utilities familiarize themselves with the technology. UV disinfection is no exception, the three states participating in this short article have all taken different routes to gain their present state of knowledge and experience which,

along with many consultants, utilities, and manufacturers, has been used in providing feedback to the authors of the USEPA's UV Disinfection Guidance Manual (UVDGM) (USEPA 2006).

Now that the UVDGM has been finalized, IUVA posed three short, but broad questions to regulatory programs that have been implementing UV disinfection prior to promulgation of LT2ESWTR and in the absence of the UVDGM, in an effort to evaluate how the UVDGM has or will affect the implementation of UV.

The authors recognize the range of knowledge and zone of comfort with UV disinfection varies among regulatory agencies and utilities. Nevertheless, it is the intent of this article to stimulate an open dialog among regulators, consultants, and utilities as a means of finding solutions to those issues that remain hurdles to the use of UV as a disinfection technology.

1. STATE PERSPECTIVE ON UVDGM ON CURRENTLY OPERATING UV FACILITIES (e.g., SEATTLE)

Many utilities throughout the United States have already installed and are operating UV disinfection facilities. Some utilities have sought to increase public health protection for their customers with an additional or secondary barrier against *Cryptosporidium* and *Giardia* while positioning the utility to meet upcoming LT2 requirements. Ongoing operational regulatory requirements for these utilities are generally minimal or do not exist since LT2 operational requirements are not in effect. The UVDGM will aid these currently operating UV facilities and their respective state regulatory agencies in finalizing operational requirements needed to meet LT2.

Several utilities, however, have installed UV technology as a primary disinfectant to meet existing *Giardia* inactivation requirements under the Surface Water Treatment Rule (SWTR) and/or *Giardia* and *Cryptosporidium* inactivation requirements under the Enhanced SWTR. These utilities operate under daily and monthly operational requirements similar to utilities employing chlorination for primary disinfection under the SWTR. One example is the City of Seattle's efforts that began in 2001 to obtain Limited Alternative to Filtration (LAF - Unfiltered Status) designation for the Cedar River supply and the use of UV technology as a primary disinfectant for *Giardia* and *Cryptosporidium* inactivation. Under Washington State requirements for LAF, Seattle must provide 3-log *Cryptosporidium*; 4-log *Giardia* and 5-log viral inactivation using at least three separate disinfectants. UV technology provides 3-log *Cryptosporidium* and 3 log *Giardia* inactivation in this setting. The Cedar UV treatment facility has relatively stringent daily and monthly operational and reporting requirements including time based compliance computed every minute while the facility is operating. The UVDGM will not greatly affect these approved operating facilities since regulatory requirements are based on existing regulations founded on the SWTR and Enhanced

SWTR regulations. However, we believe that the presence of national guidance for UV validation, design, operating and monitoring parameters will facilitate States and utilities allowing existing UV installations to gain credit for *Giardia* and *Crypto* inactivation credit under SWTR requirements.

Generally all water treatment facilities are required to monitor critical treatment parameters daily, to record parameter values and to submit monthly treatment reports to the State. Monitoring requirements for UV treatment facilities depend in part upon the rule application (i.e., SWTR vs. LT2ESWTR) and on the UV dose control method utilized. Set point control is simpler than UV dose control and requires less monitoring. Common monitoring parameters include monthly sensor checks, lamp hours, UV Transmittance, total volume of water treated, peak flows, hours operated, sensor readings, minimum UV doses and time operated outside of the validated range (off specification). Monthly treatment reports should also include information regarding any maintenance including cleaning, sensor calibration, lamp, sleeve, and ballast replacement. Utilities that have backup generator systems and / or uninterrupted power supply (UPS) need to document routine testing and maintenance activities for these critical systems.

2. STATE PERSPECTIVE ON HOW UVDGM WILL AFFECT PERMITTING FUTURE UV FACILITIES

Public health protection from waterborne pathogens that can cause acute diseases remains the primary purpose for UV disinfection. In order to ensure public health protection is not compromised by supply side economics, it is desirable to ensure economic advantages are not gained at the expense of public health protection. In order to meet the public health objectives with properly designed UV disinfection systems, the UVDGM establishes a standard test protocol under which performance of the UV system can be validated so UV systems can be compared equitably.

Because the UVDGM establishes a test protocol for the validation of UV systems, it should become easier to permit future UV facilities. By coupling the UVDGM content with lessons learned from the installation of earlier UV systems, future UV systems should be easier to permit as there will be increased confidence and comfort with the accuracy of the UV design, construction, and operation.

Acceptance of UV should only be provided for UV units that have demonstrated that they have been validated in accordance with the UVDGM either "on-site" or at a facility acceptable to the state. Ideally, UV units would be validated under a standard protocol by an independent testing organization. Certification or listing by the testing organization would be sufficient to ensure the unit was capable of meeting some minimum performance metric that would also reflect the public health objective, e.g., pathogen inactivation. This certification would also include testing under the conditions of installation so users would

know that the system was achieving the minimum levels of pathogen inactivation. NSF International has two programs that provide limited testing of UV devices. The ANSI/NSF standard 55 certification program covers the certification of small UV systems for point-of-use and point-of-entry applications, whereas, the USEPA/NSF ETV program certifies the quality of data in UV systems tested under the ETV protocols. To date neither of these programs has tested UV units for larger municipal systems as there are very few facilities capable of producing the large flows needed for the reactor tests.

In addition to the method outlined in the UVDGM, the UVDGM allows for the acceptance of units validated by the German Association for Gas and Water (UVGW), the Austrian Standards Institute (ÖNORM). At this time there are a limited number of remote testing facilities that have been accepted by the states authoring this article and they are the UVGW, ÖNORM, Johnstown, New York (Hydroqual Inc.) and the Portland, Oregon (Carollo Engineers) testing facilities.

In the past, some states have accepted the use of ANSI/NSF certified equipment validated by the ANSI/NSF Standard 55 (Class A) for small water systems. This standard is being reviewed and reevaluated by some state regulators including New York due to inconsistencies in the validation protocols between ANSI/NSF Standard 55 (Class A) and the USEPA UVDGM (USEPA 2006). As written, ANSI/NSF Standard 55 testing has been deemed unacceptable and not in conformance with the USEPA UVDGM in Washington State.

Although there are several validation protocols that are currently acceptable, States will have to decide if there are acceptable alternative surrogates to the MS2 or spores used in the validation work. Studies have shown that other bacteriophage viruses may approximate more closely the behavior of *Cryptosporidium* (Fallon et. al. 2007) with regard to UV dose response. The advantage is that with lethal UV doses closer to what will be needed for *Cryptosporidium*, surrogates more sensitive than MS2 would introduce smaller differences in the inactivation data obtained for the surrogate and *Cryptosporidium*. This, in turn, would require less of a correction factor between bioassay results and log-inactivation of the target organism during actual inactivation in the as-installed reactor (i.e. bias).

In addition, on-going work involving chemical actinometry may offer a standard for the future. Essentially, chemical dyes that are sensitive to UV would be used directly or coated onto a particle surface and introduced into reactors during validation work (Blatchley, et. al. 2006). Particles, for example, could be harvested after exposure and the extent of UV exposure determined via the extent of chemical change. This could also be a useful way of in situ testing of units that may have needed repair or upgrading.

With multiple testing facilities in operation and regardless of which microorganism or surrogate is used to validate a

UV reactor, there are data quality issues. States may ask themselves, what constitutes an acceptable validation test? Quality control (QC) over the results produced by these testing facilities is important to ensure equity among the UV manufacturers so that UV reactor performance can be compared. The UVDGM provides criteria, such as the use of National Institute of Standards and Technology (NIST) traceable calibrated radiometers for the collimated beam tests. However, there are no quality assurance criteria, other than the calibration certificates, to determine if the radiometers used during the collimated beam portion of the validation testing are actually in calibration. It is simply assumed that the radiometers are in calibration. Since these tests are the basis for determining the UV dose delivered by UV reactor during validation testing, ensuring the radiometers are calibrated is critical for establishing the UV dose delivered to the microorganisms passing through the reactor.

Another source of variability in the collimated beam test are the microorganisms themselves. The UVDGM provides confidence intervals (Appendix A) for MS2 and *B. subtilis* to show the reader where the UV dose response curve for each of the organisms should reside. However, if one examines the UVDGM confidence intervals for MS2 and *B. subtilis*, one is struck by two observations. First, MS2 and *B. subtilis* exhibit very different responses to UV inactivation. Second, for a given UV dose, say 40 mJ/cm², the confidence intervals for MS2 and *B. subtilis* are not equal in magnitude, that is, the log inactivation confidence interval for *B. subtilis* is much wider than the confidence interval for MS2. However, since different manufacturers could choose to validate their reactor with different microorganisms, one could end up with very disparate results between manufacturers. If the discrepancy was large this would lead to a large difference between the size and performance of each manufacturer's UV reactor that would translate directly into capital and O&M costs.

Quality assurance and quality control (QA/QC) is important because without these criteria, the chance of accepting incorrect data increases as the inherent uncertainty of the data set increases. In an attempt to impose some degree of quality assurance and quality control, the National Water Research Institute (NWRI) and the American Water Works Research Foundation (AWWARF) established a set of QA/QC boundaries for MS2 (NWRI/AWWARF 2003). These boundaries are narrower than the confidence intervals for MS2 published in the UVDGM. Through the application of the NWRI and AWWARF QA/QC boundaries contaminated seed cultures (all microorganisms exhibit different UV dose responses to UV) and improperly calibrated radiometers have been observed and caught before the data could be used in the design and operation of the UV units. As the NWRI/AWWARF boundaries are more restrictive than the USEPA confidence intervals, states may elect to continue using these boundaries as a quality control check whenever MS2 is used in the validation testing.

The UVDGM allows for the introduction of bioassay surrogates allowing states to use other surrogates for the bioassay testing. However, the UVDGM does not provide the states with any guidance on how or what adequate QA/QC requirements might be used to accept test results. Regardless of which surrogate microorganism is selected, bioassays are expensive and complex undertakings, a task not suited to small water systems.

Depending on validated UV reactor results and corresponding safety factors, a UV dose of 40 mJ/cm² may be higher than needed for a specific log inactivation for the target organism. For some utilities the cost of power to operate at a higher UV dose than is needed may be significant. For smaller systems or systems that do not wish to deal with the expense and complexities associated with UV dose adjustment states may require that they operate their UV systems at a minimum UV dose of 40 mJ/cm². Since the power savings are far lower than conducting an on-site bioassay to optimize the UV dose, most small water systems will either choose to operate at the higher delivered UV dose or will be required to do so by the regulatory agency. Many small water systems will likely choose this option and the savings in energy associated with UV dose adjustment will not be significant enough to offset additional operation costs when compared to a constant UV dose operation. For some small water systems this could mean selecting an ÖNORM or DVGW validated reactor, which the USEPA UVDGM recommends as having demonstrated a UV dose delivery of 40 mJ/cm².

However, systems such as New York City's proposed 2.4 billion gallon per day plant may see significant energy cost savings in operation at a reduced UV dose. In larger water systems, a constant UV dose operating strategy can be expensive and wasteful so they may want to operate at narrower margins for power savings thereby reducing the O&M costs. The larger water systems may also have the managerial infrastructure to monitor their UV systems and process train more closely. The UVDGM allows larger utilities to optimize the operation of their UV systems by establishing the operating parameters for the UV reactor, using the validation test data.

For small water systems the easiest means of identifying a reactor might be to pick one off a list of validated reactors, something many design engineers would like to do also. However, at this time no such comprehensive list exists. The authors and numerous others have been considering and discussing this question for some time and there appears to be a great interest in the development of such a list from regulators, manufacturers, and consultants. Some of the major considerations for the development of a list are: maintenance of the list by a central organization, which states would accept it, and the process for including a unit on the list. Some ideas that have been discussed were to have an organization, such as the International Ultraviolet Association or NSF International, maintain a UV equipment list using a committee made up of academia, regulators, and consultants. The committee members would establish the detailed validation protocol, evaluate the validation reports, and determine if the UV units were validated appropriately. These

discussions will continue and hopefully over time the issue will be resolved and a list will be developed.

3. AREAS WHERE STATES MAY DEVIATE FROM UVDGM

As mentioned earlier, validation and/or reactor approval process may be different for small systems and large systems. For example, it may be simpler for the states to accept a uniform standard that uses a fixed 40 mJ/cm² as the validated UV dose (i.e., the UV dose delivered by the UV reactor through validation testing) for smaller systems that do not wish to adjust UV dose. This approach would have the advantage that many UV reactors have already been validated by ÖNORM or UVGW for 40 mJ/cm² using a set point method of control. In a sense, this is similar to what was referred to as a Tier 1 criterion in the earlier draft UVDGM; the reactors would be validated using a range of UVT (e.g., 70 – 95%), a specified maximum flow rate and a specified lamp output. These 'off-the-shelf' units would be installed and run at the maximum intensity/UV dose. States, therefore, may choose to limit UV dose control operations for small systems due to its increased complexity and difficulties verifying ongoing accuracy.

Larger plants that may wish to adjust UV dose, those with customized designs, or high capacity UV reactors would likely have to do extensive testing and modeling to demonstrate that these untested (unvalidated) reactors can demonstrate that they are capable of delivering a specified validated UV dose under unique conditions. These conditions may be due to unusual inlet or outlet pipe geometries (e.g. retrofitting large plants), lower than expected UVT values that may coincide with peak demand, etc. Ultimately one goal of being able to adjust UV dose would be, as noted earlier, energy savings when multiple units with throughputs in the multi-million gallon level are installed.

Although energy savings would be one of the objectives of the large installed units; the path to those energy savings may take several steps. During validation there may be concerns related to turbidity or color peaks that may coincide with maximum demand. These unusual conditions need to be tested so that, when installed, the reactor always meets the required UV dose for the pathogen of concern (in most instances this will be *Cryptosporidium*). These conditions may be incompatible with any temporary energy savings. Consequently, any validation must account for these unusual conditions and any unusual flow geometries, etc. However, testing for each and every condition would be prohibitively expensive. One way to overcome this is by coincident validation and reactor modeling. Critical testing (and or modeling) would need to be done in order to run at the lower UV doses. Modeling (flow and UV dose elements) needs to be backed up by physical validation. For example, New York State participated in blind testing to determine the efficacy of modeling to predict UV dose in advance of full-scale validation. Test parameters (e.g. bioassay parameters, physical conditions of flow, UVT, etc.) were

supplied to the modeling group from a remote facility that was currently validating a reactor. The results of the field test were only supplied to third-party regulators. The modeling group then calculated the RED using the model and, once calculated, their results were compared the field test. Both fit and correlation between the two sets of data were excellent with the model overestimating the actual bioassay RED by a small amount at very high UV doses (80 mJ/cm²). These results indicated that the model could be used to predict in-field testing and have the potential for use in anticipation of difficult events or operational control. More work needs to be done but it is possible that, modeling alone will never be considered a stand-alone gold standard.

One area where States may expand more than deviate from the UVDGM is in the application of UV technology as a primary disinfectant for compliance with the requirements of the SWTR and Enhanced SWTR. Use of UV for primary disinfection will require more stringent monitoring and reporting than is outlined in the UVDGM. Likewise this expansion may require 'time based' compliance determinations versus 'volume based' compliance determinations as specified in the UVDGM for LT2 compliance. In addition some states may also set more stringent performance goals to help minimize untreated or off specification events.

SUMMARY

The UVDGM is a good document. The testing protocol remains in guidance because many specifics regarding UV disinfection technology have not been resolved. As with any technology, the lack of specificity in the LT2ESWTR regulation can be viewed as providing an opportunity for the utilities using the technology to development other aspects of the technology, for example, the development of new bioassay surrogates. The lack of specificity also provides some design and operating flexibility under the rule, but everyone should exercise due diligence in their selection of approaches. The underlying theme of all self monitored regulatory programs is that all parties are expected to employ their best engineering skills and judgment to the final project design and construction and permitting to meet the water quality objectives.

Other states should not feel as though they are entirely on their own when issues arise, as there are states who have faced many of the issues you will be facing, we encourage our colleagues in other states to contact us with questions. We cannot guarantee we will have all the answers, but may be able to provide you with our thoughts or direct you other colleagues with additional resources (you may also bring to light issues that haven't been addressed. We look forward to working with you to bring this disinfection technology into the drinking water field.

REFERENCES

- Blatchley III, E.R., Shen, C., Naunoivc, Z., Lin, L.-S., Lyn, D.A., Robinson, J.P., Ragheb, K., Gregori, G., Bergstrom, D.E., Fang, S., Guan, Y., Jennings, K. and Gunaratna, N. 2006. Dyed Microspheres for Quantification of UV Dose Distributions: Photochemical Reactor Characterization by Lagrangian Actinometry, *J. Environ. Eng.*, 132:1390-1403.
- Bolton, J.R., Dussert, B., Bukhari, Z., Hargy, T. and Clancy, J.L. 1998. Inactivation of *Cryptosporidium parvum* by Medium-Pressure Ultraviolet Light in Finished Drinking Water, *Proc. AWWA 1998 Annual Conference*, Dallas, TX, Vol. A, pp 389-403.
- Clancy, J.L., Bukhari, Z., Hargy, T., Bolton, J.R., Dussert, B. and Marhsall, M. 2000. Using UV to inactivate *Cryptosporidium*. *J AWWA*, 92(9): 97.
- Craik, S.A., Weldon, D., Finch, G., Bolton, J.R. and Belosevic, M. 2001. Inactivation of *Cryptosporidium parvum* oocysts using medium- and low-pressure ultraviolet radiation, *Wat. Res.* 35(6),1387.
- Fallon, K.S.; Hargy, T.M.; Mackey, E.D.; Wright, H.B. and Clancy, J.L. 2007. Development and characterization of nonpathogenic surrogates for UV reactor validation. *J AWWA*, in press (scheduled to be published March 2007)
- National Water Research Institute; American Water Works Association Research Foundation. May 2003. Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse, Second Edition, National Water Research Institute, Fountain Valley, CA.
- Shin, G.-A., Linden, K.G., Arrowood, M.J. and Sobsey, M.D. 2001. Low pressure UV inactivation and subsequent DNA repair potential of *Cryptosporidium parvum* oocysts, *Appl. Environ. Microbiol.*, 67: 3029-3032.
- USEPA. 2006. "Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule," United States Environmental Protection Agency, Office of Water (4601) EPA 815-R-06-007, Washington DC. November, 2006. http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf
- USEPA. 1991. Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Sources, American Water Works Association, Denver, CO.

**MALCOLM
PIRNIE**

INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Leaders in UV Disinfection

- UV facility planning, design and start-up services
- Project Manager & co-author of EPA's UV Disinfection Guidance Manual
- AwwaRF, EPA & NYSERDA funded collaborative research projects
- Co-authors of UV disinfection chapter in AWWA WTP Design Manual

800.759.5050 • www.pirnie.com • offices nationwide