UV Regulatory Framework in CA for Tertiary Reuse

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Frequent inquiries on new technologies are received at the California State Water Board, Division of Drinking Water (DDW, formerly located in California Department of Public Health or CDPH). The most popular topic is in regard to using UV light as a disinfection process instead of chlorine. The details of acceptable UV disinfection operation are not spelled out in the regulations. UV disinfection falls under the alternative treatment technology section of Title 22 Code of Regulations, Chapter 3 Water Recycling Criteria. Since it is so popular and being used more commonly, it is important to understand about UV operations, what DDW requires, and what to look for in a properly run UV process.

UV disinfection design and operation requirements are not specified in California regulations. That is because UV disinfection falls under the alternative treatment technology section of Title 22. Equivalency to using chlorine disinfection (5 mg/L total chlorine residual for 90 minutes, or a 450 mg-min/L CT) must be demonstrated. Off-site validations have become the industry standard using the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse*, Third Edition, published in August 2012 by the National Water Research Institute (NWRI) and Water Research Foundation[2]. Commonly known as the NWRI UV Guidelines, it states, “The overall predictive model used for design and operation shall be derived using the lower 75-percent confidence prediction interval, making use of all of the inactivation results.”

As can be seen in Table 1, the dose requirements are intended to inactivate enteric viruses. Therefore, the NWRI UV Guidelines utilize MS-2 type Male Specific bacteriophage as a surrogate, rather than Adenovirus. The NWRI Guidelines call for a UV dose for tertiary recycled water depending on the type of filtration and UVT.

Table 1
NWRI UV Guidelines

UV dose	Application	Minimum UV transmittance
100 mJ/cm^2	Following non-membrane filtration	55%
80 mJ/cm^2	following membrane filtration	65%
50 mJ/cm^2	following Reverse Osmosis (RO)	90%

The 2012 edition was updated to specify what has become the common industry practice of on-site “spot-check” bioassays, which are required to check and ensure the

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[2] http://nwri-usa.org/documents/UVGuidelines3rdEdition2012.pdf

installed reactor behaves like the validation. Hydraulic and short-circuiting issues have been found during on-site testing. The reasons vary from poor design of inlets to inadequate control of the high water level at maximum flows. Thus, some onsite bioassays have indicated underperformance. This can be corrected in the permit by adding a conservative factor that ensures adequate disinfection.

The NWRI UV Guidelines have been developed over approximately 25 years. There have been changes as the applied engineering science has developed. Initially, the demonstrations were done plant by plant. Then off-site validations became the industry standard. The 2003 edition speaks of on-site velocity profiles, but they were very hard to interpret and soon a different method was proposed by UV experts. Often in the past they were called “check-point” bioassays, now in the 2012 edition “spot-check” bioassay is defined. This performance evaluation is important, because it checks to ensure the installed reactor behaves like the validation.

Secondary Recycled Water

An important distinction must be made between “Secondary” and “Tertiary” recycled water. Without going into the specific regulatory definitions, the main difference is that in California, tertiary requires stringent filtration and disinfection standards to protect public health from spray irrigation, cooling towers, impoundments, etc., which are some of the many uses allowed in Title 22 Water Recycling Criteria. A chlorine CT of not less than 450 milligram-minutes per liter is required (5 mg/L total chlorine residual for 90 minutes) at all times.

For secondary recycled water, there is no chlorine CT requirement, but rather a total coliform limit is specified. Since this is the case, there is no UV equivalency demonstration needed. DDW receives many inquires about this; however, DDW does not provide any UV disinfection requirement or guidance for secondary recycled water. The inherent issues with secondary effluent include various technologies used for secondary treatment, plant upsets, inadequate nitrification, and a wide range of microbiological water quality levels. Therefore, DDW does not review UV disinfection for secondary recycled water.

Tertiary Recycled Water

Tertiary recycled water also has a total coliform limit specified. UV disinfection systems designed and tested following the 2012 NWRI UV Disinfection Guidelines, when combined with accepted filtration technologies, should be adequate to achieve the microbiological water quality objective of Title 22 Chapter 3 Article 1 Section 60301.230 (b)[3]. However, this total coliform water quality standard is not adequate, in and of itself, to ensure the overall microbiological water quality objective is being met. Therefore, as specified in the NWRI UV guidance. a UV system must be operated to ensure a

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[3] §60301.230. Disinfected tertiary recycled water.
Daily monitoring of total coliform standard of a seven-day median of 2.2 MPN/100mL, not to exceed 23 MPN/100mL in any sample

continuous UV dose delivery of a 100 mJ/cm^2 for media filters or 80 mJ/cm^2 for membrane filtration.

DDW reviews the design and checks that the UV system is sized appropriately using all of the factors in the validated UV dose equation. The most important variable, besides flow, is UV transmittance (UVT). Actual UVT data is critical, and is often lacking during the planning stage. This is because prior to conversion to UV, most plants do not have the data, unless a special monitoring effort is initiated. Without this effort, the minimum UVT in Table 1 could be assumed; however, in some cases actual UVT has been less than 55%.

UV treatment should be capable of producing disinfected recycled water during any component failure prior to distribution to a use site. Providing at least two reactors (or independently controlled banks) per train ensures that some disinfection occurs until the standby equipment is brought on-line in the event that one of the on-line banks or reactors fail. Redundant modules, banks, reactors or trains should be designed and constructed. The UV disinfection system must be capable of applying the required design UV dose with any failed or out-of-service reactor. If the minimum dose can't be met, then the contingency plan must address a response. As with chlorine disinfection systems, off-spec conditions (inadequate treatment) should divert effluent to waste or recycle to the head of the plant for proper treatment.

Conditions outside of the validated ranges must have alarms that initiate a quick response. These conditions should all be carefully highlighted in the validation report. Alarms that immediately initiate a response (additional banks or reactors) include power failure at a bank of lamps or multiple side-by-side lamp failure. Other critical UV operational alarms include the following in Table 2:

Table 2
Critical UV Operational Alarms

Alarm	**Common Setpoint**	**Units**
Low UV dose	100 or 80	mJ/cm^2
Low UV intensity	depends on the validation report	mW/cm^2
High flow rate	depends on the validation report	gpm/lamp or MGD/reactor
Low UVT	55 or 65	%

<u>UV Field Commissioning</u>

To verify performance of the UV system, a "Reactor Spot-check Commissioning Test", including a spot-check bioassay using seeded Male-specific bacteriophage (MS-2), must be conducted. Appendix A of the NWRI UV Guidelines provides "*Example 3: Conduct a spot-check bioassay to validate the performance of a full-scale UV disinfection system"*. Test runs should be conducted at worst case conditions, including high flow and low UVT. The test protocol must describe all of the specific details and must be reviewed and approved by DDW prior to conducting the tests Frequently, sleeve fouling studies are conducted at the same time. This can assess the actual fouling potential of the treated water and determine a cleaning frequency.

Bioassay testing as outlined in the NWRI UV guidelines, must be performed by an independent third-party, experienced in UV disinfection of recycled water and qualified to perform the study. Tests should be conducted or witnessed by a PE qualified and experienced in this testing. The results, good or bad, must be documented in short report and stamped by the PE.

UV Operations

UV is more complicated for operators than chlorination. Proper start-up and on-going training should be provided initially and via continuing education. Generally, other than typical manufacturer startup, training is not available for operators. Design manuals do not substitute for good operator training. IUVA could provide valuable service to this growing industry by helping develop UV curriculum specifically for operators.

System component failure can be expected with any treatment process. Failure of UV systems can be due to any number of conditions including, but not limited to, failure of the power supply, cleaning mechanism, and cooling system for electrical components.

UV disinfection requires timely and proper maintenance to clean, maintain and properly operate. The UV units should have an on-line mechanism for cleaning sleeves. Manual cleaning is labor intensive, hazardous, and may lead to operators putting-off this critical maintenance. A Fouling Factor (FF) is also typically used, because the sleeves get fouled, decreasing the amount of UV photons applied. A default FF is 0.8.

UV intensity decreases over time and it will depend on the specific lamp (default is 0.5, but testing can usually demonstrate much higher). It is often referred to as an End-of-Lamp-Life (EOLL) factor, which is tested and has a specific maximum hours of use.

There are a few exceptions where a reactor has been validated and accepted without a FF or a EOLL; however, in this case the sensor must monitor the decrease in intensity due to age or fouling accurately. Superior UV intensity sensors, like the ones used in potable drinking water UV can be used. In this case the sensors become a critical part of the commissioning process. In one case a sensor was not properly located. As with potable drinking water UV applications, these type of UV intensity sensors must be verified monthly by checking them against a reference UV intensity sensor.