THE LINKS BETWEEN WATER AND WASTEWATER UV DISINFECTION: The Past, Present, and Future

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BACKGROUND

The development of drinking water and wastewater UV disinfection has paralleled each other with strong links between the two. The first use of UV disinfection was directed towards drinking water application in the early 1900s. However, the interest in its continued use for this purpose waned. This may be attributed to high cost relative to chlorination and the failure of the enumeration methods (e.g. staining and excystation) to detect inactivation by UV light. Meanwhile, the wastewater industry became interested in the potential application of UV disinfection and borrowed and improved upon the drinking water UV disinfection expertise. Again, the ready availability of chlorine at low cost delayed the further development of the technology in wastewater treatment until the 1970s when harmful effects of chlorine were recognized. Fueled by the desire to eliminate aquatic toxicity of chlorine residual, prevent formation of chlorinated byproducts, and enhance plant safety, wastewater treatment plants were turning to UV disinfection. This resulted in a rapid technological development of wastewater UV systems over the last 20 years. During this period, the drinking water UV disinfection market was virtually at a standstill.

In late 1990s, Bolton et al. (1998) first presented evidence of the efficacy of Cryptosporidium inactivation with relatively low UV doses. This work, based on mouse infectivity assay, was published later by Bukhari, et al. (1999). Craik et al. (2000) published similar findings with respect to Giardia inactivation. As a result of these studies, a resurgence of interest occurred in UV technology, and the drinking water industry turned to the wastewater field to capture and use the state of knowledge in UV disinfection to develop application-specific UV systems for potable water disinfection. The table below provides examples of how the wastewater industry has influenced the development of the UVDGM and vice versa.

RELEVANT DEVELOPMENT IN WASTEWATER UV EQUIPMENT

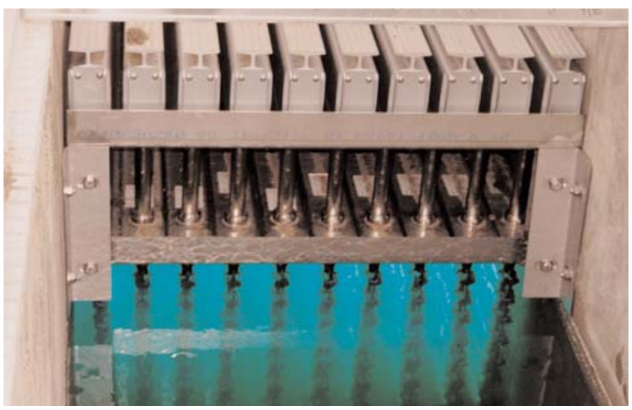
A review of the history of wastewater UV disinfection reveals the following crucial developments, which have influenced the design of the present day drinking water UV reactor (Whitby, 2002):

- The use in 1972 of a system consisting of UV lamps surrounding Teflon tubes carrying the effluent. Although successful, the system could not be scaled-up.
- In 1978, one of the first gravity flow UV systems in North America was developed using lamps arranged perpendicular to the flow. This system also included an in-place chemical cleaning system and a UV intensity sensor. This system required 100 percent standby if the quartz sleeve or lamps needed to be replaced.
- An open channel system using horizontal lamps arranged perpendicular to the flow and equipped with automatic cleaning was developed in 1983. The close spacing of the lamps overcame issues related to low UV transmission. However, the perpendicular to the flow configuration of the lamps resulted in debris accumulation, which disturbed the alignment of the cleaning system causing the quartz sleeve and lamps to break. Because of this, the use of automatic cleaning systems disappeared until the 1990s. The system had to be taken out of service to replace the quartz sleeve or UV lamp.
- In 1984, a US patent was issued for an open-channel, horizontal lamp, parallel to the flow configuration. This milestone UV system design involved the use of UV lamps arranged in modules. This allowed a set of lamps to be removed for servicing without shutting down the UV system, which eliminated the need for 100 percent standby. In addition, the UV system was configured so that it could be installed in an existing channel. These features have rendered the UV system cost competitive with chlorine.
- In 1989, the single-ended sleeve design replaced the double-ended design, thereby preventing flooding of all UV lamps in the module when one seal or quartz sleeve broke.
- Ballasts used in UV systems generate heat and must be cooled. Air used for cooling also is a source of moisture, dust, and insects. This required the use of filters, which require frequent maintenance. In order to correct this situation, a submerged ballast was developed in 2001. In this design, the ballast is attached to the UV lamp and submerged in the effluent.

Key Impacts of	
Wastewater Industry on UVDGM	**UVDGM on the Wastewater Industry**
• UV lamp technology • Ballast technology • Concepts of UV equipment validation • Sleeve cleaning mechanisms • CFD modeling of open channel reactor • Basis for O&M requirements	• Dose requirements for reclaimed water use • Advancements in UV equipment validation • UV sensor reliability • Power quality • Enhanced mercury safety

- Historically, low-pressure lamps have been used in wastewater disinfection. In 1995, a medium pressure system was introduced, which reduced the number of UV lamps required significantly. A few years later, in 1998, the low-pressure high output technology was unveiled incorporating the advantages of both low and medium pressure technologies.

- Effective cleaning of the quartz sleeve surrounding the UV lamp has always been a challenge. Since the first reported use of a cleaning mechanism in 1935, several materials have been used including felt, rubber, metal, plastic, and Teflon. In addition, brushes, ultrasonic, air scouring, and chemicals have also been used for the purpose.



STATUS OF WASTEWATER UV DISINFECTION

In wastewater treatment, UV light is the preferred disinfection alternative to chlorine. Presently, approximately 15 to 20 percent of the municipal wastewater treatment plants in the USA use UV disinfection and the number is rising. The most common secondary fecal coliform discharge standard is a 30-day geometric mean of 200 MPN/100 mL. The typical UV dose required to achieve this limit at an activated sludge facility is 25 - 35 mJ/cm2.

With respect to reuse of wastewater application, California Title 22 requires 5-logs poliovirus inactivation and a 7-day median total coliform of 2.2 MPN (Most Probable Number)/100mL. In Florida, the requirements are total suspended solids of less than 5 mg/L and non-detectable fecal coliform in 75 percent of all samples. Depending on the filtration technology used, the National Water Research Institute (2003) guidelines specify the following minimum UV dose criteria (in addition to turbidity limits) for meeting the above reuse standards:

- Media Filtration: Design UV dose of at least 100 mJ/cm2 under maximum day flow at filtered effluent UVT of 55 percent or greater at 254 nm.

- Membrane Filtration: Design UV dose of at least 80 mJ/cm2 under maximum day flow at filtered effluent UVT of 65 percent or greater at 254 nm.

- Reverse Osmosis: Design UV dose of at least 50 mJ/cm2 under maximum day flow at filtered effluent UVT of 90 percent or greater at 254 nm.

KEY DIFFERENCES BETWEEN DRINKING WATER AND WASTEWATER UV SYSTEMS

Wright et al (2002) compared the UV systems used in drinking water application with those used in wastewater disinfection. The following are some of the key differences:

- Unfiltered wastewater effluents contain dispersed and particle-associated microbes, while filtered drinking waters contain mostly dispersed microbes. Particle association results in dose-response curves with a tailing effect, indicating the need for higher UV doses for inactivation due to shielding of the microbes by the particles.

- Wastewater regulations are based on meeting not-to-exceed levels of the indicator organism, such as fecal or total coliforms, which are used as surrogates for the pathogens of interest. In the case of drinking water treatment, regulations require non-detectable levels of the target pathogens in the finished water. Consequently, compliance monitoring in wastewater entails measuring the concentration of the indicator organism (typically 7 or 30-day geometric mean). In drinking water disinfection, primacy agencies are likely to require a target UV dose to be delivered.

- Validation testing in drinking water provides proof that the UV dose indicated by the UV reactor's on-line monitoring system is equal to or greater than the required dose. In wastewater treatment, validation often is used to assess the performance of a UV reactor under extreme operating conditions or to compare the performance of different UV systems.

CONCLUSIONS AND A LOOK INTO THE FUTURE

The past 20 to 30 years have witnessed a tremendous growth in the UV market and a phenomenal increase in state of knowledge. The ability of UV light to meet proposed drinking water regulations continues to generate a wellspring of interest in the technology. Likewise an increasing number of wastewater treatment facilities are converting to UV disinfection in an effort to enhance public health and safety. As the UV disinfection technology for water and wastewater matures over the next several years, the following trends may be anticipated, which could result in reduced design and validation safety factors and lower capital and O&M costs:

- Enhanced germicidal efficiency of input power
- UV lamps containing minimal or no mercury
- Improved UV sensor performance
- Increased UV reactor efficiency
- Improved sleeve material with reduced tendency to foul
- Longer UV lamp life
- Improved ballast life
- Enhanced monitoring and control capability
- Availability of off-the-shelf validated reactors for standard conditions

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