WATER SUPPLY
Ultraviolet Disinfection - Practical Aspects

By Michael Gundry, P.Eng.
Totten Sims Hubicki Associates

As more designers become familiar with ultraviolet disinfection systems, they understand some of their critical operational features.

Following the Walkerton water tragedy in 2000, the Ontario Ministry of the Environment developed the Drinking Water Protection Regulation, which was followed by the Safe Drinking Water Act and its associated regulations. This legislation required that water supplies which were surface water, or groundwater under the direct influence of surface water, be treated using a multi-barrier approach consisting of treatment equivalent to chemically assisted filtration and enhanced Cryptosporidium, Giardia and Virus inactivation/removal. Since that time, UV disinfection has been used widely in the Ontario to meet the goals of these regulations. In addition, UV disinfection of potable water is also practiced in many of the other Provinces in Canada.

Ultraviolet light disinfection involves irradiating the potable water with UV light at a specific wave length. The UV light interrupts the DNA of the micro-organisms, rendering the micro-organism unviable. The UV disinfection process is relatively simple, with very little process control or operator intervention required, depending upon the nature of the raw water and pre-treatment. The UV reactors can be configured with the lamps oriented parallel to the water flow or in a cross-flow mode with the lamps perpendicular to the flow.

As UV disinfection has become more widely used, it has shown itself an effective tool for water treatment. Professionals are becoming much more familiar with this technology, they are also becoming aware of different practical aspects involved in designing and operating these systems. Some of these practical issues are outlined in this article.

Regulations require continuous monitoring

UV disinfection first gained acceptance as a water supply disinfection method in June 2000 when the United States Environmental Protection Agency allowed its widespread use as a potable water disinfectant.

In Ontario, the Ministry of the Environment requires UV disinfection systems to operate with an applied UV dose of 40 mJ/cm^2, providing for a 1.0 log (99%) credit for inactivation of Cryptosporidium and Giardia. Actually, microbial inactivation research has shown that this dose is approximately 10 times higher than that required to achieve an actual log inactivation of 1.0.

In order to ensure the integrity of the UV disinfection system, most Certificates of Approval for UV disinfection systems in Ontario require that the UV dose applied to the water supply be continuously monitored and recorded. In addition, the monitoring and recording systems are required to notify and alarm the operator, if there is a UV lamp or system failure. In addition, the UV transmittance of the raw water must be monitored continuously or tested on a frequent basis to ensure that the UV reactor chosen is delivering the appropriate UV dose.

The Ontario Ministry of the Environment requires that UV reactors be third-party validated from an organization such as the DVGW German Technical and Scientific Association and National Science Foundation. This third party validation is typically done with a reactor based upon a specific flow rate and even though the UV dose is a function of contact time and electrical energy applied, the validation requirements typically limit the flow rate to a UV reactor.

Knowing the UV transmittance (UVT) of the raw water is critical

The use of UV as a disinfectant requires a specific UV intensity be transmitted to the water being treated. The amount of UV applied is a function of the transmittance of the raw water. As the transmittance of the raw water decreases, the energy required to be inputted into the water must be increased to ensure the appropriate UV dose is received. Thus, knowing the UV transmittance (UVT) of a water supply is critical.

In designing and selecting a UV disinfection system, the UV transmittance of the water supply must be actually tested. Many groundwaters and surface waters can be subject to changes in raw water UVT over time, or seasonally, depending upon the aquifer or water body characteristics. In order to ensure that the appropriate UV dose is chosen, UVT testing must be undertaken on water supply seasonally and monitored frequently once the UV disinfection system is installed and operational. An alternative to seasonally UVT testing for a new water supply is to specify a conservative UVT so that more UV energy is applied to the water supply to mitigate the risks.

Lamps and sensors require cleaning

Over time, the lamps in a UV disinfection system can become fouled with scale or other minerals within the water supply. This scaling occurs as a result of plating of these minerals on the lamp surface from the heat or from the natural scaling tendencies of the water supply. A UV reactor typically includes a UV intensity sensor which provides the operator with guidance with respect to lamp fouling or changes in UV intensity. The sensor that registers a low UV dose can actually be the result of fouled lamps, changes in the raw water quality or fouling of the sensor itself.

Cleaning of the UV system is therefore critical to the operation of any UV system and must be considered during the design and installation stages. Typically, the engineer must review the quality of water to be treated by the UV and its tendency to scale or plate minerals on the UV lamps.

Raw water supplies with high alkalinity, iron and/or manganese are especially prone to fouling the lamp and UV transmittance sensor. Effective pre-treatment of these waters with an appropriate cleaning system can ensure that the system operates properly with out needing excessive maintenance and manpower.

Cleaning systems include manual lamp cleaning, as well as various wiping systems installed within the reactor, either manual or automatic. In some cases, chemical cleaning solutions are also used within the reactors.

The sensor can also become fouled, similar to the UV lamps, and must be cleaned.

Depending upon the cleaning system employed, the wipers and cleaning of the UV lamps can scratch the lamp outer quartz sleeve, which results in reducing the transmittance of the UV light through the lamps, reducing its effectiveness.

UV reactor must stay submerged

Depending upon the configuration of the UV disinfection system, the UV lamps can be relatively long, up to 2 metres. Consideration must be made to ensure that adequate space is available for removing them, either for cleaning or replacement. Water bubbles within a UV disinfection system can affect the readings experienced by the UV intensity sensor so the piping upstream of the UV reactor must be designed to minimize air bubbles. In addition, the UV reactor must be submerged at all times as air pockets within the system can result in cooling issues and interfere with the UV intensity sensor's operation.

The UV reactor must not overheat

The application of electrical energy in the form of ultraviolet light to a water supply results in heating of the UV lamps. The UV reactor must continuously receive flow while it is on to ensure that the reactor does not overheat. Some UV reactor designs include valves that will bleed water from the system once the reactor heats to unacceptable levels.

The ballast for a UV disinfection system can measure up to 1 square metre and generates a considerable amount of heat. The design of a UV disinfection system therefore must take into account the physical space of the UV ballasts and control panels. It must also provide adequate clearances to allow sufficient cooling air to ensure the operation of the control panel and the ballast.

Another method to minimize the lamp heating is to turn the system off during periods of no flow. This, however, requires a lamp warm up time when the system is restarted. When a UV disinfection system is started, there is a period of time while the UV lamps are warming up before the full UV dose is being generated by the system. The warm-up period varies depending upon the type of lamps. It can vary from lamps that are almost instantly at full power when turned on to approximately eight minutes until the lamps are at full power. Thus, the design of a UV disinfection system must take into account this lag from when the reactor is first called to service until it is at full power and able to effectively disinfect the water supply. Strategies to mitigate the lamp warm up period, include running the water to waste, or providing delays to the start of the upstream water supply pumps.

Output declines as lamps age

UV lamps and ballasts have a finite life. As the lamps age, the power output from the UV system declines and this decline must be considered in the selection of the UV reactor lamp design. As the lamps and ballasts age they must be replaced. Typical UV disinfection lamp life is approximately three years, while ballasts have a lifespan of approximately 10 years.

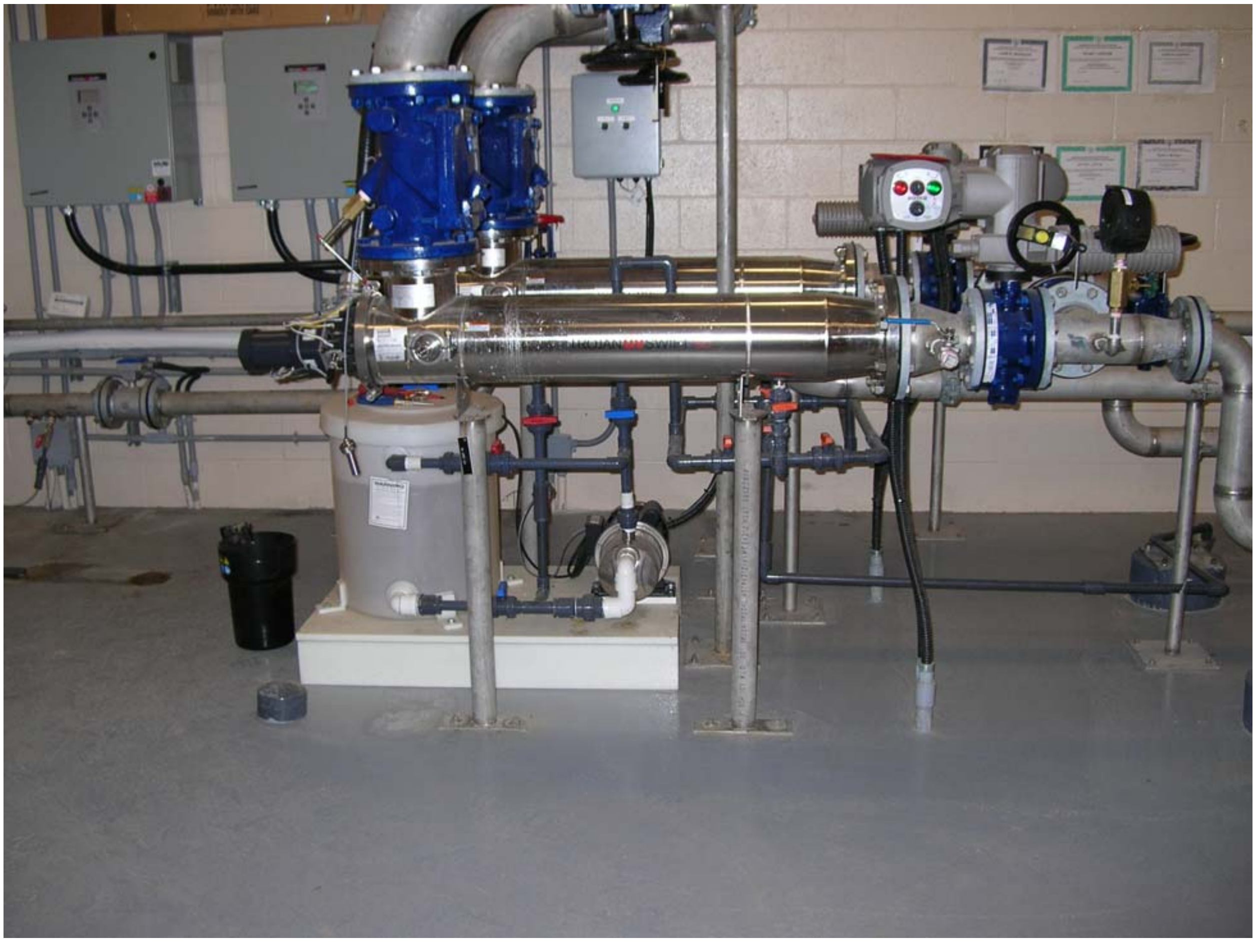
If the power supply is interrupted for any reason, the UV disinfection system will not function. Thus, in order to ensure that a proper UV dose is being applied at all times, provisions are required to cease the flow to the reactor when the power is interrupted, or to power the system with an uninterruptible power supply.

Emerging uses for advanced oxidation

UV can also be used in the Advanced Oxidation Process (AOP) for enhancing the oxidation and treatment of endocrine disrupting compounds and taste and odour compounds. In the advanced oxidation process, hydrogen peroxide is added upstream of a UV reactor. The UV light converts the hydrogen peroxide into super oxides which are powerful oxidants. Typically, a higher UV dose is required for an advanced oxidation process than for disinfection alone.

In conclusion, UV disinfection is an effective method for providing enhanced primary disinfection of potable water. Chlorine is required for secondary disinfection and as part of the multi-barrier approach. As outlined above, in order to ensure effective operation of a UV disinfection system, good design and operational practices are required, but we anticipate that UV disinfection will continue to be an effective tool in the water supply treatment tool kit.

Michael Gundry, P.Eng. is the manager of the environmental engineering department at Totten Sims Hubicki Associates in Whitby, Ontario.



Ultraviolet (UV) disinfection reactors with a chemical clean in place system at Havelock, Ontario

UV disinfection reactors in Cardinal, Ontario