

## Ultraviolet Disinfection

### Summary

Using ultraviolet (UV) light for drinking water disinfection dates back to 1916 in the U.S. Over the years, UV costs have declined as researchers develop and use new UV methods to disinfect water and wastewater. Currently, several states have developed regulations that allow systems to disinfect their drinking water supplies with UV light. Running a UV light system requires a basic level of operator skill and relatively clean source water. On the down side, however, UV offers no residual disinfection within the distribution system.

### What is UV disinfection?

UV light, which continues to be a reliable means of disinfection, involves exposing contaminated water to radiation from UV light. The treatment works because UV light penetrates an organism's cell walls and disrupts the cell's genetic material, making reproduction impossible.

A special lamp generates the radiation that creates UV light by striking an electric arc through low-pressure mercury vapor. This lamp emits a broad spectrum of radiation with intense peaks at UV wavelengths of 253.7 nanometers (nm) and a lesser peak at 184.9 nm. Research has shown that the optimum UV wavelength range to destroy bacteria is between 250 nm and 270 nm. At shorter wavelengths (e.g. 185 nm), UV light is powerful enough to produce ozone, hydroxyl, and other free radicals that destroy bacteria.

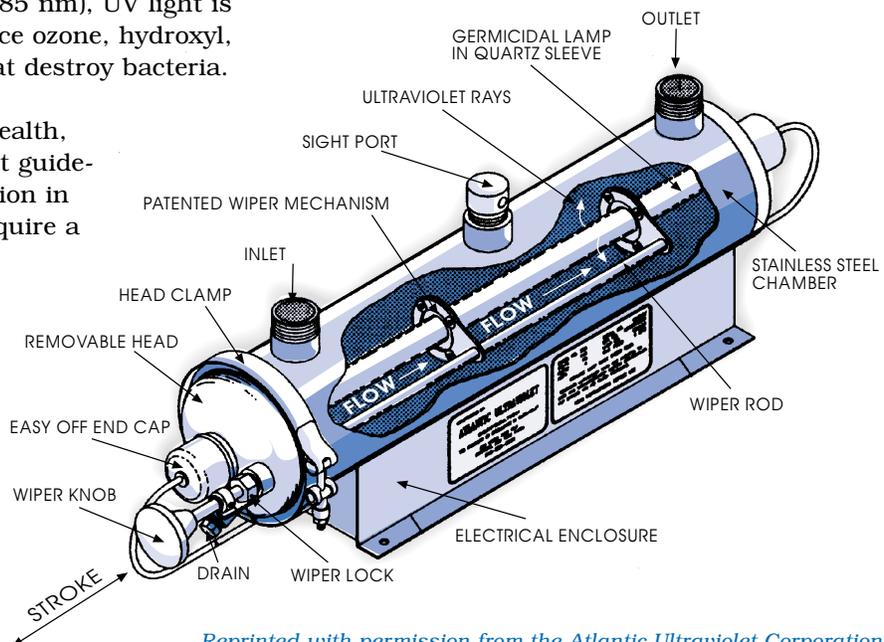
The U.S. Department of Health, Education, and Welfare set guidelines for UV light disinfection in 1966. These guidelines require a minimum dose of 16 mWs/cm<sup>2</sup> [milliwatt seconds per square centimeter] at all points throughout the water disinfection unit.

However, the American National Standards Institute and the National Sanitation Foundation

International set the minimum UV light requirement at 38 mWs/cm<sup>2</sup> for class A point of use (POU) and point of entry (POE) devices that treat visually clear water.

The U.S. Environmental Protection Agency (EPA) lists UV disinfection as an approved technology for small public water systems. In addition, EPA is considering the following variations of conventional UV treatment as "emerging" technologies: pulsed UV, medium-pressure UV, and UV oxidation (i.e., used in combination with

### Closed Vessel Ultraviolet Reactor



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peroxide or ozone).

## Advantages

Generally, UV is simple to install and requires little supervision, maintenance, or space. Improved safety, minimum service time, low operation and maintenance costs, and the absence of a chemical smell or taste in finished water are primary factors for selecting UV technology rather than traditional disinfection technologies.

UV treatment breaks down or removes some organic contaminants. UV achieves 1-log reduction of *Giardia lamblia* at an intensity of 80-120 mWs/cm<sup>2</sup>, and 4-log reduction of viruses at an intensity of 90-140 mWs/cm<sup>2</sup>. Only recently has the scientific community begun to accept UV as a highly effective tool for *Cryptosporidium* control.

UV light disinfection does not form any significant disinfection byproducts, nor does it cause any significant increase in assimilable organic carbon (AOC).

Research has confirmed that UV effectiveness is relatively insensitive to temperature and pH differences. In addition, researchers found that UV application does not convert nitrates to nitrites, or bromide to bromines or bromates.

Recent pilot studies show that UV-treated drinking water inhibits bacterial growth and replication in the distribution system; however, conditions within distribution systems, such as leaks, still require additional residual disinfection (e.g., free chlorine).

The advantages of using UV, rather than chemical disinfection, include:

- Has no known toxic or significant nontoxic byproducts;
- Has no danger of overdosing;
- Removes some organic contaminants;
- Has no volatile organic compound (VOC) emissions or toxic air emissions;
- Has no onsite smell and no smell in the final water product;
- Requires very little contact time (seconds versus minutes for chemical disinfection);
- Does not require storage of hazardous material;
- Requires minimal space for equipment and contact chamber;
- Improves the taste of water because of some organic contaminants and nuisance microorganisms are destroyed;

- Does not affect minerals in water; and
- Has little or no impact on the environment except for disposing of used lamps or obsolete equipment.

## Limitations

Microbial and chemical characteristics are two major water quality factors that affect the UV unit performance. Microbial characteristics of water include type, source, age, and density. Chemical water characteristics include nitrites, sulfites, iron, hardness, and aromatic organic levels.

UV radiation is not suitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. These materials can react with UV radiation, and reduce disinfection performance. Turbidity makes it difficult for radiation to penetrate water.

Disadvantages of UV disinfection include:

- No disinfection residual;
- No technical database exists on how well UV systems perform for various water quality conditions; and
- No standardized mechanism measures, calibrates, or certifies how well equipment works before or after installation.

Systems also should consider using different kinds of microbial testing. Laboratories typically test for total coliform to judge microbiological activity in drinking water—but coliforms are sensitive to UV light. Because of this sensitivity, microbial tests for UV treated finished water should include a Heterotrophic Plate Count (HPC) test. HPC microorganisms may provide a better disinfection assessment than the UV sensitive coliforms.

## Process Description

UV light effectively destroys bacteria and viruses. However, how well the UV system works depends on the energy dose that the organism absorbs. If the energy dose is not high enough, the organism's genetic material may only be damaged rather than disrupted.

An effective dose is measured as a product of the lamp's intensity (the rate at which photons are delivered to the target), including radiation concentration, proper wavelength, exposure time, water quality, flow rate, and the microorganism's type, and source, as well as its distance from the light source.

At a minimum, drinking water systems should install two UV units, which are both capable of carrying the amount of water the system was designed to handle. Having two units in place assures continuous disinfection when one unit is being serviced. Two units also can ensure operation during low-flow demand periods.

Modular units designed for small drinking water systems are easy to install and operate (two plumbing connections per unit and one electrical hook-up). They should be equipped with automatic cleaners and remote alarm systems. For systems in isolated areas, operators should maintain and store a set of spare parts onsite, and consider a telemetry system for monitoring treatment.

Typical UV light components include:

- A stable high-voltage source of electricity because low-line voltage would result in a lower UV dose;
- A chamber made of stainless steel or any other material that is opaque and will not corrode;
- UV lamps that are properly secured inside quartz sleeves, easing installation, replacement, and maintenance;
- Quartz sleeves with sufficiently high transmission rates to deliver the UV energy produced by UV lamps;
- Mechanical wipers to maintain optimum transmission between scheduled cleaning and maintenance work;
- Sensors to monitor the UV intensity passing through the water. These sensors need to be connected to alarm systems to alert the operator in case of low UV intensity. The operator must have easy access to these sensors for necessary installation, replacement, calibration, and maintenance;
- Safety control to shut off UV lamps in case of low-flow levels and elevated lamp temperature;
- Arc and lamp-out monitors to alert the operator of system failure; and
- Electronic ballasts.

UV units are currently used as stand-alone treatment systems or as part of a series of other drinking water treatment processes or multiple barrier system. A common treatment that uses UV light to remove and disinfect contaminants from groundwater sources involves a combined ozone or hydrogen-peroxide process along with UV application. So, it is common to find that

manufacturers of UV equipment also manufacture ozone equipment.

Furthermore, the drinking water treatment industry provides UV equipment (mainly closed chamber units) for short-term uses. Rental units are used in cleanup and emergency situations, such as if groundwater is contaminated by spilled toxic organic compounds.

### **Monitoring and Operation Requirements**

Factors that affect UV light system performance are: lamp output, lamp aging, and plating or fouling of unit surfaces. To better control these factors, operators must ensure continuous dose measurement (i.e., accurate intensity and flow-rate measurement) and proper maintenance (cleaning as well as lamp and sleeve replacement regimes).

Technological advances have eliminated many of the operation and maintenance problems that were associated with earlier UV applications. Current systems are equipped with mechanical cleaners, ultrasonic cleaners, or some self-cleaning mechanism (mandatory if water fouling agents, such as iron, are present in the water entering the unit); lamps that are easy to install and replace; and alarm systems that indicate minor and major failure.

To ensure continued system operation, a maintenance schedule needs to be in place. This schedule should include periodic site inspections; changing lamps annually or when light transmission efficiency has decreased to 70 percent; inspecting and cleaning surfaces; inspecting or cleaning the UV chamber interior every six months; and inspecting and replacing ballasts, O-rings, valves, and switches.

Furthermore, the operator should monitor water turbidity and color since they are natural barriers to UV light transmission. And some dissolved minerals, such as calcium, have a tremendous negative effect on UV absorbance.

Since it may not be practical to provide instantaneous stand-by power during power outages, the system should be designed to automatically stop water flow or provide an alternate means of disinfection as a backup. Where the system is dependent on electrically powered pumps, this measure may not be necessary because the pumps will shut off when the power goes out. However, gravity flow systems may be vulnerable.



UV disinfection should have the following minimum operational controls and procedures:

- A central display indicating alarms for power failure, lamp failure, hours of lamp operation, low UV dosage, high lamp temperature, high ballast temperature, and high system flows;
- Methods that monitor lamp temperature, ballast temperature, and system water flows;
- A minimum of two photodiode sensors per unit to monitor UV dosage at 254 nm. These sensors must be calibrated using approved standards each time the lamps are cleaned or replaced or the UV chamber is serviced;
- Automatic UV system by-pass or shutoffs, which are activated whenever the system exceeds peak design flow rates, when UV dosage is low, or when lamp or ballast temperatures are high; and
- Two UV units should be installed so flow is not interrupted when one unit is out of service.

#### Where can I find more Information?

Hargy, T.M., J.L. Clancy, and Z. Bukhari. 2000. "Shedding UV Light on the *Cryptosporidium* Threat." In *NSF Proceedings of the Small Drinking Water and Wastewater Systems*. International Symposium and Technology Expo: Phoenix, Arizona.

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