TECHNOLOGY UPDATE

By Tom Schaefer, Aquionics

Ultraviolet for Disinfection

The science, selection and applications

Disinfection—the killing of potentially harmful microorganisms—in our water and air is critical to public health and industrial process reliability. Historically, industry has relied on hazardous chemicals such as chlorine and expensive processes such as pasteurization to rid its water supplies of pathogens. Currently, though, the use of ultraviolet (UV) light, the same as the portion of the electromagnetic spectrum of sunlight responsible for killing microorganisms, is providing a safe, reliable and highly effective method of getting the job done.

Traditionally, the primary industrial markets for UV technology have been food, beverage, pharmaceutical, aquaculture and wastewater treatment. However, sales are expanding into more than three-dozen new industries concerned with microbiological control. This rapid expansion in UV application continues due to regulatory and quality requirements for reducing chemical use, lowering costs and improving processes and water quality.

UV is a highly effective way to address bacteria, viruses, yeast and mold including pathogens resistant to chemical treatment. It is used often to reduce microbiological levels by greater than 99.99 percent.

This rest of this article will cover

- The science of UV technology,
- Description of common systems and typical options,
- Common applications within industry, and
- Parameters to address when selecting a system.

UV Light

UV light is part of the electromagnetic spectrum. It is a “color” just as blue, yellow and even infrared are colors. UV is the portion of the spectrum at higher energy (shorter wavelength) than visible light. It most commonly is experienced as the energy from the sun that causes tanning. At even higher energy, the UV-C and vacuum UV wavelengths arise. It is these wavelengths of light between 180nm and 300nm that have the desired effects.

Disinfection. Every living organism contains DNA within its cells. Single cell organisms such as bacteria, protozoa, viruses and molds can survive and become pathogenic only if they can reproduce. Wavelengths from 200nm to 320nm will react with all cellular DNA and prevent replication, hence killing a single-cell organism. This germicidal effectiveness peaks around 265nm and covers the output of germicidal UV lamps. Generally, the larger the organism, the more “protected” the cell nucleus, the more UV is required to inactivate the cell. All cellular life can be affected by UV, but size matters, and spores of yeasts and molds require much more energy to disinfect.

UV Dose. There are widely accepted charts showing the amount of UV required to inactivate a variety of organisms. These “D-10” charts show the UV dose required for a single-log or 90 percent reduction in the number of colony-forming units. Of course, application of two times this dose would result in a 99 percent reduction and so on.

Dose is a function of the UV intensity reaching the organism multiplied by the exposure time. Factors affecting dose include energy of the UV lamp, clarity or transmission of the water or fluid being treated, flow rates and residence time in the treatment chamber. Typically, UV systems are rated at different flow rates based on fluid UV transmission to deliver doses of 30 mW-s/cm^2 (which is equal to 30,000μW-s/cm^2 or 30 mJ/cm^2). This dose delivers a 5 to 6 log reduction in many common pathogens but will deliver at least 99.9 percent reduction to most organisms of concern.

Photolysis and advanced oxidation. In addition to disinfection, UV light is very effective in breaking down certain chemical compounds through processes know as photolysis and UV advanced oxidation. Both vacuum and UV-C are effective in breaking down a variety of chemicals. UV systems can remove ozone, chlorine, chloramines and organic compounds by directly breaking the chemical bonds (photolysis) or by creating OH$^-$ radicals directly from water or another oxidant such as peroxide. These applications typically require UV doses of three to four times up to as much as 20 to 40 times the dose required for disinfection.

UV Treatment Systems

A typical piece of equipment used for UV treatment of water is made of three main components: a treatment chamber, the UV lamps and a power and control cabinet. In addition, there are a number of specialty features and options that enhance the system’s performance and capabilities.

UV lamps. There are two primary types UV lamp technologies used in these applications: low pressure (LP) and medium pressure (MP). The “pressure” refers to that of the lamp’s internal gas but

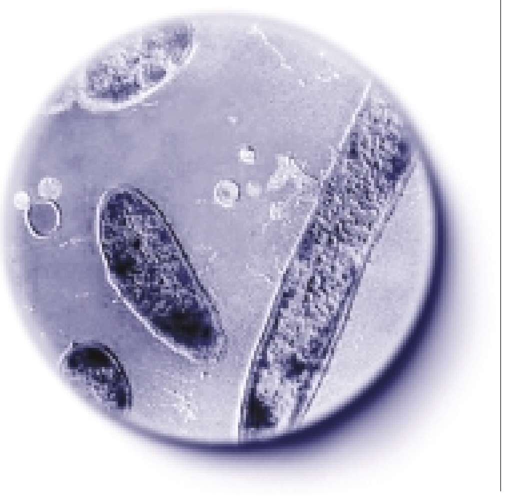
the main difference lies in the power of the lamp. All of these lamps excite a mercury vapor inside of a quartz tube. Mercury emits UV light, and quartz—unlike regular glass—is transparent to UV wavelengths. LP lamps range from 40 watts to the new 160- or 180-watt bulbs. They essentially are identical to the fluorescent lights found in most offices. LP lamps emit UV wavelengths at 185nm and 254nm, which have become the standard nomenclature for UV emission. MP lamps emit wavelengths across the entire UV spectrum and range from 500 watts to more than 7 kilowatts. Due to this energy difference, the less-costly LP lamps can treat far less fluid than a single MP lamp. MP lamps can deliver very high doses, treat very large or poor quality flows and operate at temperature extremes of hot and cold fluids. LP systems are broadly accepted and are relatively less expensive.

Treatment chamber. The treatment chamber consists of a 316L stainless steel, pressurized vessel with a single or multiple UV lamps mounted either parallel to or perpendicular to flow. Lamps are located inside the chamber and are isolated from the process fluid by a quartz sleeve.

Power and control cabinet. The power and control cabinet consists of a typical electrical cabinet that houses the lamp power supplies, the control electronics and user interface. They are available in polycarbonate, epoxy-coated steel and 304 stainless steel. Standard cabinets carry a NEMA 12 environmental protection rating. NEMA 4 (waterproof) and NEMA 4X (waterproof and corrosion resistant) also are available. LP systems are powered by ballasts while MP systems require transformers. Cabinet cooling is a concern and typically accommodated by fans or cabinet coolers. User interfaces and controls vary by product line and range from membrane keypads with digital displays to simple switches and LED's. All power and instrument wiring from the cabinet to the chamber is included with the system.

UV Treatment Systems (Options)

UV monitor. The monitor detects the UV output of the lamp(s) at the interior wall of the treatment chamber. Monitoring is valuable in tracking lamp and system performance. A monitor is recommended in all disinfection applications in fresh, reverse osmosis/deionization (RO/DI) and other clean water.

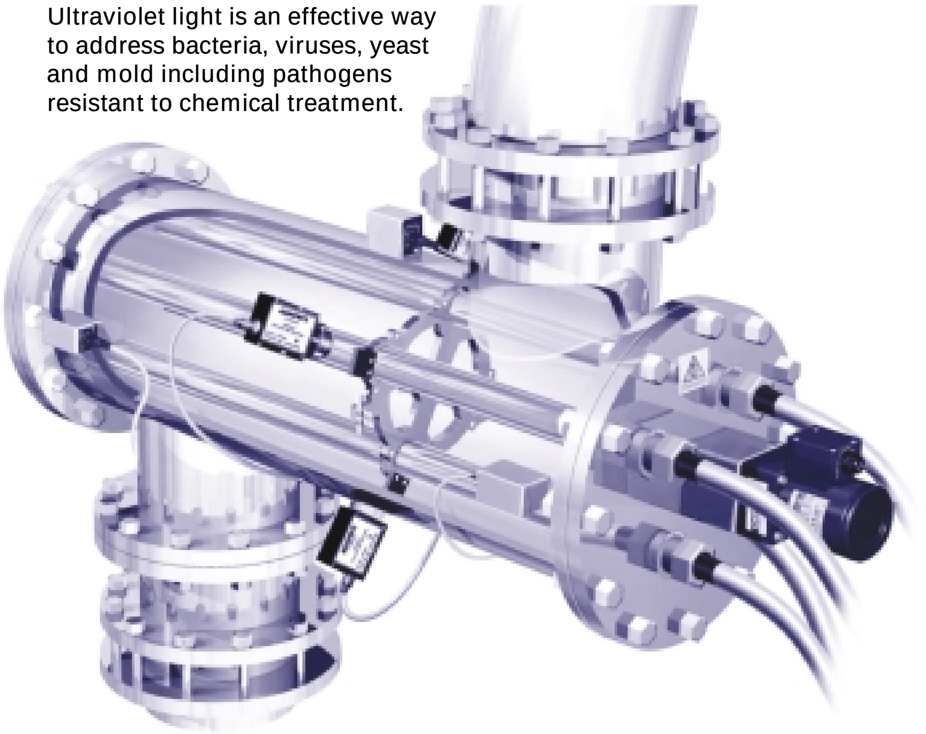


Quartz sleeve cleaning. The cleaning mechanism removes deposits that may accumulate on the quartz sleeve, which would block the emission of UV light. It is recommended for use in applications where the water is high in organics or dissolved iron or manganese. The wiper can be actuated automatically or manually with automatic being preferred to ensure regular cleaning and maintain system performance.

High purity finish. Chambers may be electropolished and passivated to better than Ra25 or Ra15 interior surface finishes. These highly polished finishes eliminate any microsurface texture where organisms be retained. This option is preferred in pharmaceutical, electronics and often food and beverage applications.

Specialty quartz. In addition to standard quartz for lamps and sleeves, ozone-free quartz options are available to eliminate the production of ozone in the system. This is critical in deozonation, recirculated indoor, high iron content and air applications. A special high purity quartz, which accentuates high-energy vacuum UV, is used in TOC destruction and other photolytic applications.

Sample, drain and bleed systems. Taps and controls are available to sample fluid, drain and bleed the UV systems. Bleeding may be required in intermittent flow MP systems to maintain lamp cooling.



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FDA validation. Packages are available that include a wide range of test and documentation such as component validation and testing, material certifications and certification to standards. This is valued in pharmaceutical applications.

Cabinet upgrades. Options include upgrading material to 304 stainless steel and upgrading environmental protection rating to NEMA 4 or NEMA 4X. Frequently used in outdoor installations and food and beverage applications.

Power and control upgrades. Options include variable power control to increase power to maintain consistent dose over the life of the lamps, data logging to allow data downloads of all system parameters and dose monitoring to measure and control the actual, absolute UV dose.

Applications of Ultraviolet Technology

Water disinfection. The most common application of UV systems is in the disinfection of water. Most industrial uses of water require removal of microorganisms to protect the product being made, industrial process, environment or worker health and safety. For consumables such as foods and beverages, water used in the process must not contain any biological contamination that would result in human health hazards and product liability. In many processes water of exceptional purity is needed as a process fluid.

RO, activated carbon filtration and DI commonly are employed with UV being an integral part of these processes. Industrial wastes must be treated to protect the environment, and many process waters including cleaning and rinse fluids must be free of contamination as well.

Often, chemicals such as chlorine are used to disinfect water. UV eliminates or greatly reduces the use of disinfection chemicals along with their cost, storage, environmental and worker hazards and potential to damage other process equipment.

Removing ozone. Ultraviolet systems are highly effective at deozonation. Ozone commonly is used as a disinfection chemical and as an oxidant for organic compounds. Often, residual ozone can cause harm to process equipment or cause health hazards. Typically, UV doses of three to four times that of disinfection are required.

Removing chlorine. Chlorine and chloramines commonly are used to provide residual disinfection of water. Chlorine will damage RO membranes and other process equipment or otherwise affect a product or process. UV provides a reliable, cost-effective alternative to activated carbon or bisulphite injection or other chlorine removal systems that can cause microbiological problems and high maintenance costs. These applications require extremely high doses of UV.

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Destruction of organics. Many large or nonpolar organic molecules contaminating water can be broken down by UV light and become harmless or easily removed by activated carbon or DI. High purity, RO/DI water requires very low organics. UV also can break down many organic contaminants that pose environmental or health hazards.

Disinfecting air. Ultraviolet light provides a very effective means of disinfecting air. Hospitals, food processors and clean rooms require air that is free from living organisms that may cause harm. Tanks for storing sweeteners, syrups, ingredients and other fluids must allow air to vent when draining or filling. UV can protect these fluids from contaminated air.

Selecting the Right UV System

UV transmission. The first factor to consider is transmission of the water or fluid to germicidal wavelengths. To determine transmission, a 10 mm (T10) or 40 mm (T40) quartz cell is filled with the fluid, and UV light is passed through it measuring the amount not absorbed. Typical fresh water has a transmission of 80 percent in a 40 mm cell (T40 = 80 percent), RO/DI water usually is T40 = 95 percent, and typical prefiltered wastewater is T10 = 60 percent. Many fluids less than T10 = 50 percent cannot be effectively treated with UV unless there is a high rate of recirculation. Estimates of transmission are common, and fluids should be tested for their UV transmission when selecting a system.

Flow rate. Every UV system will have a maximum flow capacity at each transmission value. Typically, the higher the transmission, the greater the capacity. Each system will be limited as to how low a T-value it can treat based on its design. Some high-power systems hydraulically are limited in that the lamps can treat more water than chamber velocities allow.

UV dose. Most rated flow capacities are for a 30 mJ/cm^2 (or one times the disinfection) dose at the end-of-lamp-life (8,000 hours continuous operation). All UV lamps gradually become more opaque due to use and are oversized initially to compensate. Other applications require much higher doses. A deozonation dose of three times disinfection would reduce a system's capacity by a factor of three.

LP. It is important to understand when LP or MP lamps should be used. LP lamps relatively are inexpensive, but cannot treat as much fluid per lamp. For typical fresh water disinfection with no unusual conditions, LP is much more cost effective at flow less than 250 to 350 gpm. As transmission falls, dose requirements increase or other factors come into play such as the equal-price flow rate becomes lower. Also, since LP systems output only 185nm and 254nm wavelengths, many fluids besides water, which may be harmed by other wavelengths, can be treated.

MP. At higher flow rates, fluid temperatures above 70° C or below 40° C, high dose requirements or where added features are critical, MP systems are more economical. MP systems are available with a broader range of options. Above 250 to 350 gpm (or less for low transmission fluids or higher dose requirements), the use of a single high power lamp is more cost effective due to fewer lamps, fewer chambers and controls, decreased installation and piping costs, and greatly reduced maintenance and service costs. Also, temperature extremes have no effect on MP lamps. For MP systems, the use of a single lamp with a single monitor allows for greatly increased monitoring, control and process security. There is no uncertainty with one lamp. WQP

About the Author

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