Ultraviolet Disinfection

Edstrom Industries
www.edstrom.com
819 Bakke Ave.
Waterford, Wisconsin 53185

4230-MI4178

Edstrom Industries, Inc.
819 Bakke Avenue
Waterford, WI 53185-5913
(262) 534-5181
(800) 558-5913
(262) 534-5184 – FAX

Ultraviolet (UV) sanitizing units are used in many water purification systems to control bacteria and have certain applications in animal drinking water systems. UV units can be effective water treatment tools, but it is important to recognize what UV can do, what its limitations are, and what maintenance is required.

If you have any further questions or concerns about UV disinfection, contact Edstrom Industries at 800-558-5913.

How Does UV Work?

Ultraviolet or UV energy is found in the electromagnetic spectrum between visible light and x-rays and can best be described as invisible radiation. In order to kill microorganisms, the UV rays must actually strike the cell. UV energy penetrates the outer cell membrane, passes through the cell body, and disrupts its DNA, preventing reproduction. UV treatment does not alter water chemically; nothing is being added except energy. The sterilized microorganisms are not removed from the water. UV disinfection does not remove dissolved organics, inorganics or particles in the water.

The degree of inactivation by ultraviolet radiation is directly related to the UV dose applied to the water. The dosage, a product of UV light intensity and exposure time, is measured in microwatt second per square centimeter ($\mu ws/cm^2$). The accompanying table lists dosage requirements to destroy common microorganisms. Most UV units are designed to provide a dosage greater than 30,000 $\mu ws/cm^2$ after one year of continuous operation. Notice that UV does not effectively disinfect some organisms (most molds, protozoa, and cysts of Giardia lamblia and cryptosporidium) since they require a higher dose.

UV Units for Water Treatment

Special low-pressure mercury vapor lamps produce ultraviolet radiation at 254 nm, the optimal wavelength for disinfection and ozone destruction. The UV lamp never contacts the water. The lamp is either housed in a quartz glass sleeve inside the water chamber or it is mounted out of the water, and the water is forced through UV-transparent Teflon tubes. Some ultrapure water systems use 185-nm UV units for reducing TOC (total organic carbon).

Important Factors for Successful Disinfection

Although 100% destruction of microorganisms cannot be guaranteed, it is possible to achieve a 99.9% reduction in certain applications with proper maintenance. In order for a UV unit to successfully disinfect water, it is important to have adequate water quality and a sufficient flow rate.

Water quality

Certain contaminants in water can reduce the transmission of UV light through the water, which reduces the UV dose that reaches the bacteria. These UV-absorbing contaminants include turbidity, iron, and humic and fulvic acid (which are common to surface water supplies). Suspended particles are a problem because microorganisms buried within particles are shielded from the UV light and pass through the unit unaffected.

Figure 2, below, lists common contaminants or characteristics of water and the corresponding maximum recommended concentration levels that can be treated by UV disinfection. If the water has levels of contamination that are greater than the maximum levels listed in the chart, it means the water is not a good candidate for UV disinfection. UV disinfection is most effective for treating high-clarity, purified reverse osmosis or distilled water.

Water Contaminant / Water Characteristic Name	**Maximum level allowed for water to be treated using UV radiation**
Turbidity	5 NTU (Nephelometric Turbidity Units)
Suspended Solids	10 mg/l
Color	None*
Iron	0.3 mg/l
Manganese	0.05 mg/l
pH	6.5 – 9.5
Hardness	< 6 grains
* the color of water does not affect disinfection by UV.	

Figure 1. Maximum levels of contaminants that can be treated using UV Disinfection.

Flowrate

All UV units have a maximum flowrate capacity and some have a minimum flowrate as well. If the flow is too high, water will pass through without enough UV exposure. If the flow is too low, heat may build up, causing damage to the UV lamp. The water flow in an animal drinking water system is usually low and intermittent, so a UV unit with minimum flow requirements should not be placed on the water line supplying pressure stations in a non-recirculating system. UV units are most often used in constant-flow recirculating systems.

Ultraviolet Dosage Required For 99.9% Destruction of Various Organisms (μW-s/cm^2 at 254 nm)

Bacteria		Mold Spores	
Bacillus anthracis	8,700	*Aspergillus flavus*	99,000
B. enteritidis	7,600	*Aspergillus glaucus*	88,000
B. Megatherium sp. (vegatative)	2,500	*Aspergillus niger*	330,000
B. Megatherium sp. (spores)	52,000	*Mucor racemosus A*	35,200
B. paratyphosus	6,100	*Mucor racemosus B*	35,200
B. subtilis (vegatative)	11,000	*Oospora lactis*	11,000
B. subtilis (spores)	58,000	*Penicillium digitatum*	88,000
Clostridium tetani	22,000	*Penicillium expansum*	22,000
Corynebacterium diphtheria	6,500	*Penicillium roqueforti*	26,400
Eberthella typhosa	4,100	*Rhizopus nigricans*	220,000
Escherichia coli	7,000		
Leptospira interrogans	6,000		
Micrococcus candidus	12,300	**Algae / Protozoa**	
Micrococcus sphaeroides	15,400	*Chlorella vulgaris* (algae)	22,000
Mycobacterium tuberculosis	10,000	Nematode eggs	92,000
Neisseria catarrhalis	8,500	Paramecium	200,000
Phytomonas tumefaciens	8,500		
Proteus vulgaris	6,600		
Pseudomonas aeruginosa	10,500	**Virus**	
Pseudomonas fluorescens	6,600	Bacteriophage (*E. coli*)	6,600
Salmonella enteritidis	7,600	Hepatitis virus	8,000
Salmonella paratyphi	6,100	Influenza virus	6,600
Salmonella typhimurium	15,200	Polio virus	6,000
Salmonella typhosa (Typhoid)	6,000	Rotavirus	24,000
Sarcina lutea	26,400	Tobacco mosaic	440,000
Serratia marcescens	6,200		
Shigella dysenteriae (Dysentery)	4,200		
Shigella paradysenteriae	3,400		
Spirillum rubrum	6,160	**Yeast**	
Staphylococcus albus	5,720	Baker's yeast	8,800
Staphylococcus aureus	6,600	Brewer's yeast	6,600
Streptococcus hemolyticus	5,500	Common yeast cake	13,200
Streptococcus lactis	8,800	*Saccharomyces cerevisiae*	13,200
Streptococcus viridans	3,800	*Saccharomyces ellipsoideus*	13,200
Vibrio cholerae	6,500	*Saccharomyces sp.*	17,600

Figure 2. Dosage Requirements to destroy various common microorganisms.

Limitations of UV Treatment

Under ideal conditions, a UV unit can provide greater than 99% reduction of all bacteria. Even with this performance, however, ultraviolet disinfection has some limitations.

"Point" disinfection

UV units only kill bacteria at one point in a watering system and do not provide any residual germicidal effect downstream. If just one bacterium passes through unharmed (100% destruction of bacteria cannot be guaranteed), there is nothing to prevent it from attaching to downstream piping surfaces and proliferating.

Cells not removed

Bacteria cells are not removed in a UV unit but are converted into pyrogens. The killed microorganisms and any other contaminants in the water are a food source for any bacteria that do survive downstream of the UV unit.

Due to these limitations, the piping in a watering system treated by UV disinfection will need to be periodically sanitized with a chemical disinfectant.

Maintenance Requirements for UV units

Lamp replacement

UV lamps do not burn out as normal florescent lamps do. Instead, the UV lamps will solarize, reducing their intensity to about 60% of a new lamp after about one year of continuous use. When lamps are new, they will generate a dosage level near 60,000 μw-s/cm^2. When the dosage level drops to 30,000 μw-s/cm^2 (the minimum dosage needed to effectively kill bacteria) lamps should be replaced. Lamp life will be shortened significantly if the lamp is turned on and off more frequently than once every eight hours.

Monitoring performance

Water should be sampled and tested for bacteria counts regularly. Sample before and after the UV unit to test its performance. Water should also be sampled in the animal rooms, since bacteria re-growth can occur downstream of the UV unit.

Cleaning

As water passes through the UV unit, minerals, debris, and other material in the water will leave deposits on the quartz or Teflon sleeve. This will limit the penetration of UV rays through the sleeve and into the water. To maintain high clarity, the glass around the lamp must be cleaned regularly. Cleaning frequency depends on the water quality and will be minimal with RO, distilled, or deionized water.

Monitoring UV dosage

UV light intensity meters are available that indicate the penetration of UV light through the glass sleeve and the water. These meters can indicate when cleaning or lamp replacement is needed.

UV Recirculation Systems

One application where ultraviolet disinfection is used is in recirculating delivery systems. In a recirculating system, water flows constantly from a storage tank, out to the pressure stations (or through the stations and through the piping in the animal rooms), then flows back to the storage tank. These installations use in-line UV units in the recirculating loop to provide control of bacterial growth.

However, one shouldn't assume that the UV unit would keep the water in such a system free of all bacteria. The UV unit may be working as specified, killing 99% or more of the bacteria passing through, but it can only kill bacteria at one point in the loop. If just one microorganism passes through the unit unharmed, there is nothing to prevent it from attaching to downstream piping surfaces and multiplying (see the Edstrom Industries document on Biofilms).

Case study example

The simplified drawing of a recirculation system in Figure 3 illustrates how bacterial levels can be high in the animal rooms even when the UV unit is operating properly. The total bacteria counts in the sketch are typical of water samples taken from an actual automated watering system. The UV unit reduces the total bacteria count from 2000 to 10 per milliliter, which is a 99.5% reduction.

By the time the water reaches the inlet to the first pressure reducing station, however, the count has increased due to the growth of bacteria that is attached to interior piping downstream of the UV unit. The bacteria count is even higher after the water has passed through the animal room, probably picking up bacteria from the animal cage piping.

Finally, the water is returned to the storage tank where it sits, allowing bacteria to continue multiplying. The UV unit is doing its job controlling bacteria, but only at one point in the loop. This example helps illustrate the following points:

1. Recirculating systems need to be periodically sanitized to disinfect the piping in the loop that cannot be disinfected by the UV unit.
2. Water should be regularly sampled and tested for bacteria counts to determine the performance of the UV unit and the frequency of sanitization.
3. The size of a storage tank in a recirculating system should be as small as possible to minimize the average time that water sits in the tank.

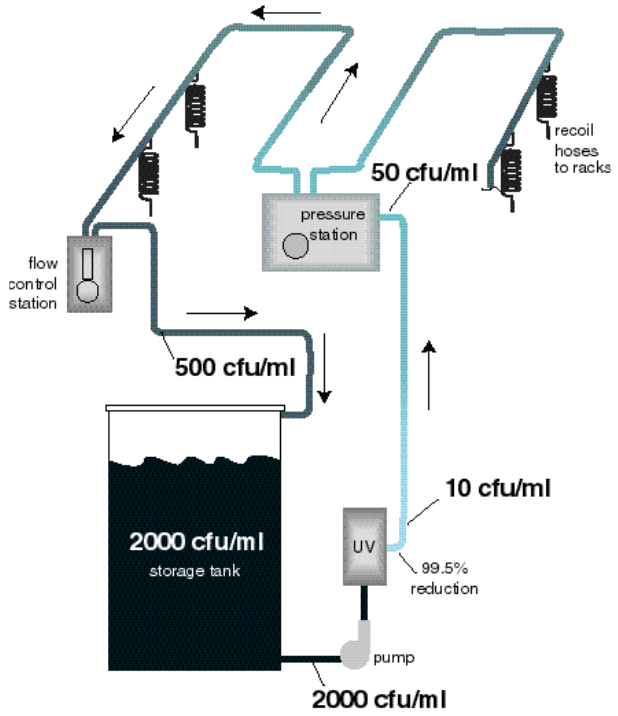

Figure 3. A typical recirculation system. The darkness of the piping in this recirculating loop indicates increasing bacteria levels in a recirculating system and illustrates how bacteria can build up to high levels even when the UV unit is doing its job. High bacteria levels signal a need to sanitize the system.

A UV disinfection unit, if it is properly operated and maintained, is one tool that can be used to control bacteria in a recirculating system. It is not a magic bullet, however. If a UV unit is installed and then forgotten (and no maintenance is performed), it cannot be expected to keep the drinking water bacteria-free.

References

Aquafine Corporation, “Ultraviolet Systems” brochure

Eccleston, B. May 1998. UV intensity levels affected by water quality. Water Technology 21(5):61-68.

Voitle, R. Ultraviolet Equipment for Potable Water Systems. Ideal Horizons, Inc. Rutland VT.