

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 or drinking water quality, contact Edstrom Industries at **800-558-5913** or e-mail: [paula@edstrom.com](mailto:paula@edstrom.com)

## 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 ( $\mu\text{ws}/\text{cm}^2$ ). The accompanying table lists dosage requirements to destroy common microorganisms. Most UV units are designed to provide a dosage greater than 30,000  $\mu\text{ws}/\text{cm}^2$  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; it is either housed in a quartz glass sleeve inside the water chamber or mounted external to the water which flows through UV transparent Teflon tubes. Some ultrapure water systems use 185 nm UV units for reducing TOC (total organic carbon).

## Important variables for successful disinfection

Although 100% destruction of microorganisms cannot be guaranteed, it is possible to achieve 99.9% reduction in certain applications and with proper maintenance. In order for a UV unit to successfully disinfect water, the following variables must be considered:

### 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, 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. UV disinfection is most effective for treating high-clarity purified reverse osmosis or distilled water.

Recommended Maximum Concentration Levels for Water to be Treated By UV	
Turbidity	5 NTU
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

**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 which can damage 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.

<b>Ultraviolet Dosage Required            For 99.9% Destruction of Various Organisms</b> (µW-s/cm <sup>2</sup> at 254 nanometer)			
<b>Bacteria</b>		<b>Mold Spores</b>	
<i>Bacillus anthracis</i>	8,700	<i>Aspergillus flavus</i>	99,000
<i>B. enteritidis</i>	7,600	<i>Aspergillus glaucus</i>	88,000
<i>B. Megatherium</i> sp. (vegetative)	2,500	<i>Aspergillus niger</i>	330,000
<i>B. Megatherium</i> sp. (spores)	52,000	<i>Mucor racemosus A</i>	35,200
<i>B. paratyphosus</i>	6,100	<i>Mucor racemosus B</i>	35,200
<i>B. subtilis</i> (vegetative)	11,000	<i>Oospora lactis</i>	11,000
<i>B. subtilis</i> (spores)	58,000	<i>Penicillium digitatum</i>	88,000
<i>Clostridium tetani</i>	22,000	<i>Penicillium expansum</i>	22,000
<i>Corynebacterium diphtheria</i>	6,500	<i>Penicillium roqueforti</i>	26,400
<i>Eberthella typhosa</i>	4,100	<i>Rhizopus nigricans</i>	220,000
<i>Escherichia coli</i>	7,000		
<i>Leptospira interrogans</i>	6,000	<b>Algae / Protozoa</b>	
<i>Micrococcus candidus</i>	12,300	<i>Chlorella vulgaris</i> (algae)	22,000
<i>Micrococcus sphaeroides</i>	15,400	Nematode eggs	92,000
<i>Mycobacterium tuberculosis</i>	10,000	Paramecium	200,000
<i>Neisseria catarrhalis</i>	8,500		
<i>Phytomonas tumefaciens</i>	8,500	<b>Virus</b>	
<i>Proteus vulgaris</i>	6,600	Bacteriophage ( <i>E. coli</i> )	6,600
<i>Pseudomonas aeruginosa</i>	10,500	Hepatitis virus	8,000
<i>Pseudomonas fluorescens</i>	6,600	Influenza virus	6,600
<i>Salmonella enteritidis</i>	7,600	Polio virus	6,000
<i>Salmonella paratyphi</i>	6,100	Rotavirus	24,000
<i>Salmonella typhimurium</i>	15,200	Tobacco mosaic	440,000
<i>Salmonella typhosa</i> (Typhoid)	6,000		
<i>Sarcina lutea</i>	26,400	<b>Yeast</b>	
<i>Serratia marcescens</i>	6,200	Baker's yeast	8,800
<i>Shigella dysenteriae</i> (Dysentery)	4,200	Brewer's yeast	6,600
<i>Shigella paradysenteriae</i>	3,400	Common yeast cake	13,200
<i>Spirillum rubrum</i>	6,160	<i>Saccharomyces cerevisiae</i>	13,200
<i>Staphylococcus albus</i>	5,720	<i>Saccharomyces ellipsoideus</i>	13,200
<i>Staphylococcus aureus</i>	6,600	<i>Saccharomyces sp.</i>	17,600
<i>Streptococcus hemolyticus</i>	5,500		
<i>Streptococcus lactis</i>	8,800		
<i>Streptococcus viridans</i>	3,800		
<i>Vibrio cholerae</i>	6,500		

## Limitations of UV treatment

Under ideal conditions, a UV unit can provide greater than 99% reduction of all bacteria. Even with this performance, ultraviolet disinfection has the following 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  $\mu\text{W}\cdot\text{s}/\text{cm}^2$ . When the dosage drops to 30,000  $\mu\text{W}\cdot\text{s}/\text{cm}^2$  (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 regrowth can occur downstream of the UV unit.

### Cleaning

As water passes through the UV unit, minerals, debris and other material in the water will deposit out and onto 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 which indicate the penetration of UV light through the glass sleeve and the water. Low intensity means the UV dose is too low to provide adequate disinfection. This meter will 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 bacteria free. 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 bulletin on Biofilm).

## Case Study Example

The simplified drawing of a recirculation system illustrates how bacterial levels can be high out 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 99.5% reduction, but by the time the water reaches the inlet to the first pressure station the count has increased due to growth of bacteria attached to the interior piping downstream of the UV. The bacteria count is even higher after the water has passed through the animal room, probably picking up bacteria from the animal cage piping. Now this water returns 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 points out the following:

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 storage tank in a recirculating system should be sized as small as possible to minimize the average time that water sits in the tank.

A UV disinfection unit is one tool which can be used to control bacteria in a recirculating system if it is operated and maintained properly, but it is not a magic bullet which can be installed, forgotten, and 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

## Related Web Sites

- <http://www.hearinc.org/>  
Aquafine Corporation Ultraviolet Systems.  
<http://ourworld.compuserve.com/homepages/ottaway/ultrav.htm>  
Drinking Water Help Homepage: Ultra Violet Radiation  
<http://www.wqa.org/Technical/Improving-Water-Through-Disinfection.html#UV>  
Section on Ultraviolet Disinfection in a Water Quality Association technical paper titled "Improving the Quality of Water Through Disinfection"