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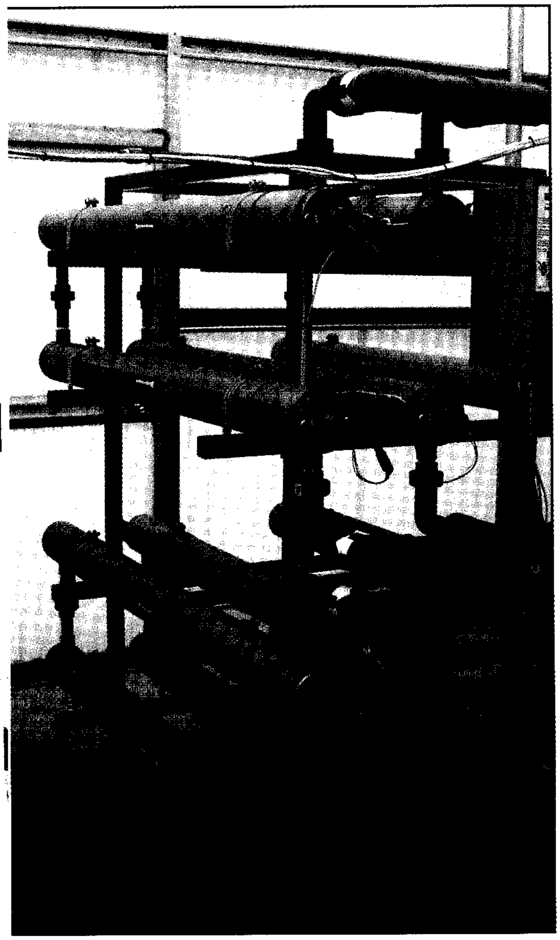
Using ultraviolet light for water treatment

Ultraviolet light treatment should be considered for recirculating water systems, or where growth of algae or disease organisms can cause problems.

By R. Peter Fynn, Paul Fisher, Anne Frances and Bill Argo



This ultraviolet light unit treats 100 gallons of water per minute and is equipped with high intensity bulbs (240 watts). Cost varies according to the water quality and the pre-treatment that is required. Operating costs depend on the price of power. This unit requires 7.5 kilowatts to run.

Ultraviolet (UV) light is a highly effective option to control pathogens and algae in irrigation systems. Ultraviolet light systems treat water passing through one point in an irrigation system. Because ultraviolet light lacks residual activity, it is combined with filtration, which removes organic matter and increases light transmission and residual sanitizing agents such as ozone or peroxide.

Differences in ultraviolet light

Ultraviolet light has a shorter wavelength than visible light, but a longer wavelength than X-rays. Ultraviolet light is invisible to the human eye. The electromagnetic spectrum of ultraviolet light is categorized according to wavelength,

Ultraviolet A (black light)	400 nm–315 nm
Ultraviolet B	315 nm–280 nm
Ultraviolet C (germicidal)	280 nm–100 nm

measured in nanometers (nm).

Not all ultraviolet radiation has the same sanitizing effect because different wavelengths have different properties. Only the UV-C wavelength is useful for killing microorganisms. The other ultraviolet light wavelengths (UV-A and UV-B) are ineffective.

Ultraviolet mode of action and dose

Ultraviolet radiation in the 240-280 nm (UV-C) range disinfects water through a purely physical, chemical-free process. An ultraviolet light bulb that emits a peak of 254 nm wavelength (UV-C) destroys the genetic information contained in bacteria, viruses and mold through a photochemical reaction. Bacteria lose their reproductive capability (become sterile) and are destroyed.

Increasing the ultraviolet light power increases the proportion of pathogens that are sterilized and killed. The ultraviolet light dosage required for a 99.9 percent reduction of microorganisms (known as a 3 log kill) varies according to the target microorganism.

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How ultraviolet light works

Ultraviolet light bulbs work by using an electrical ballast to form a discharge between two electrodes contained in a gas filled glass tube, similar to how fluorescent bulbs work. In an ultraviolet light bulb, the combination of the electrical discharge and the pressure

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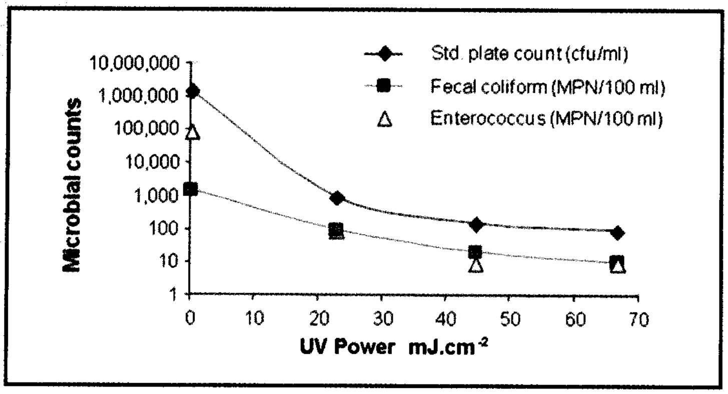


Increase in performance (bacteria kill) of an ultraviolet light system with an increase in the power (irradiation intensity) applied. Standard plate counts are measured as colony-forming units of bacteria per milliliter (cfu/mL). Estimated bacterial counts are presented as most probable number per 100 milliliters (MPN)/100 mL. Ultraviolet irradiance is expressed in energy per unit of surface area of water treated (milliJoules per square centimeter). Graph provided by Pure-O-Tech Inc.

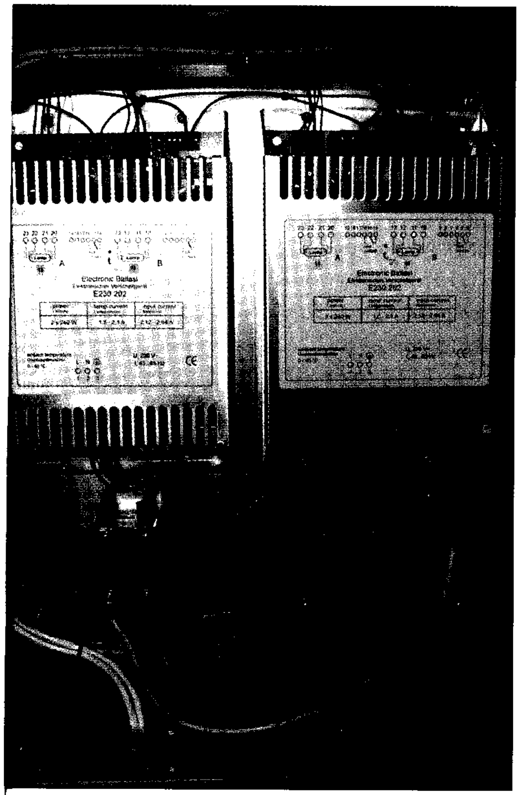
Microorganism	Power of ultraviolet light dosage (milliJoules per square centimeter)
Bacteria	3.5–26.5
Viruses	6.6–440

and formulation of the gases contained in the bulb defines the wavelength of the emitted ultraviolet radiation. Ultraviolet light bulbs also contain a small amount of mercury so proper disposal is always recommended.

Need for proper pretreatment

Ultraviolet light should be combined with filtration because suspended solids reduce the effectiveness of the ultraviolet treatment. Suspended solids (e.g., plant debris and algae) prevent radiation from penetrating throughout the enclosure in which irrigation water passes by the bulb. For this reason, it is essential that the water is pre-treated effectively.

The water entering ultraviolet light treatment should have a maximum turbidity of two nephelometric turbidity units (NTU is a common unit for turbidity). A value higher than two NTU will decrease ultraviolet light and reduce the effectiveness of the treatment.


o electrical ballasts, each drives two ultraviolet ht bulbs.

Microbes have to "see" the ultraviolet radiation in order for it to be effective. If suspended solids in the water stream prevent the penetration of the ultraviolet radiation throughout the water volume, then microbes will be "protected" from the ultraviolet radiation and will not be killed.

The California standard is the turbidity should be no greater than two NTU averaged over 24 hours, should not exceed five NTU for more than five percent of the time and should never exceed 10 NTU. In Florida the standard is a total suspended solids (TSS) maximum of 5 milligrams per liter as a single sample, but an average value is not specified.

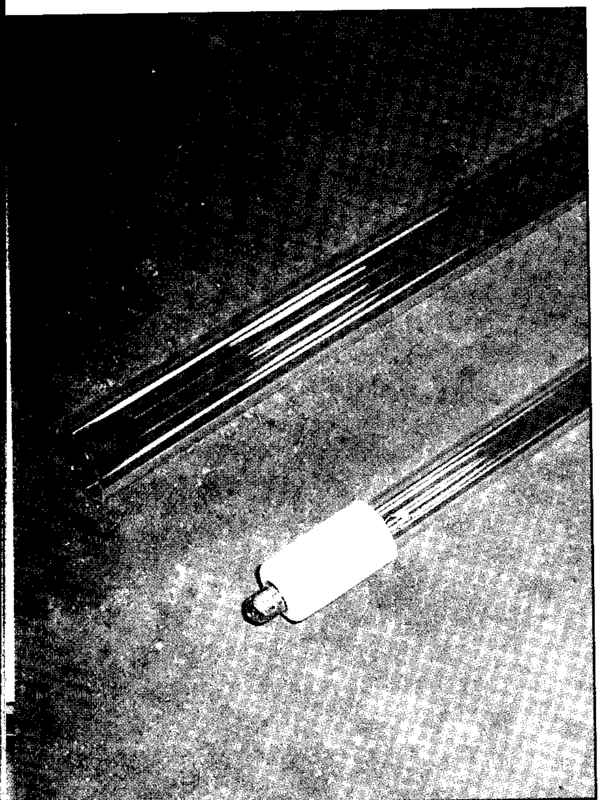
Using ultraviolet light in an irrigation system

Ultraviolet light should be considered for recirculating water systems, or where growth of algae or disease organisms can cause problems. By treating water passing through ultraviolet light at one point in the irrigation system, the light does not create a build-up of chemicals in the water. Ultraviolet light is often combined with a technology that has residual activity, such as ozone, peroxide or copper, to continue sanitizing the water as it travels through the irrigation system.

Ultraviolet light enhances the efficacy of ozone or peroxide through the advanced oxidation process (AOP). Ozone is a very strong sanitizer that directly oxidizes pathogen cell walls. As ozone decomposes, radical by-products are created that also are very active sanitizers. When ultraviolet light is combined with ozone or peroxide, the resulting reaction forms more of the highly unstable and active hydroxyl radical, thereby increasing the sanitizing effect.

System design

It is essential to use a professionally installed system from a company


An ultraviolet light bulb (bottom) and quartz sleeve.

familiar with the horticultural use of ultraviolet light. The major components of a ultraviolet light system include ultraviolet light lamps, lamp sleeves, piping and lamp cleaning, monitoring and control systems. When ultraviolet light is combined with ozone for advanced oxidation process, the system also includes an ozone generator and diffusers, ozone contactor, ozone off-gas decomposer, oxygen or air feed systems and supply and discharge pumps.

The two primary design variables that must be optimized in sizing an advanced oxidation process system are the ultraviolet light power radiation per unit volume of water treated — more commonly referred to as ultraviolet dose — and the concentration of ozone. Ultraviolet dose, when applied to an advanced oxidation process, is a measure of the total lamp electrical energy applied to a fixed volume of water. The units are measured in kilowatt hour (kWh)/1,000 gallons treated. This parameter combines flow rate, exposure time to ultraviolet light and light intensity into a single term. The dose of ultraviolet light and peroxide/ozone required per unit volume of water treated will vary depending on the quality of the water to be treated.

Maintenance and precautions

Ultraviolet light bulbs, quartz sleeves and the ballasts need to be properly maintained. Ballasts come equipped with alarms that indicate when bulbs need to be replaced.

Prompt replacement of bulbs is necessary to ensure continued treatment of the water stream. Bulbs can last up to 10,000 hours, but frequent on/off cycles can shorten bulb life dramatically. Inspection of the bulbs and quartz sleeves should be a regularly scheduled part of an ultraviolet light system maintenance plan.

For water disinfection, the

ultraviolet light bulb needs to be enclosed in a suitable vessel such as a tube with the ability to seal the ends around the bulb. This can be achieved by enclosing the bulb in a sleeve which is sealed to the vessel. However, the sleeve has to be made of quartz because glass filters release some ultraviolet radiation, whereas quartz is largely transparent to ultraviolet radiation. The bulbs should be shielded to block radiation from passing into the surrounding space.

The quartz sleeves require periodic cleaning, so the system design should allow the sleeves to be easily removed. A common problem is calcium deposits on the sleeve exterior. The quality of the water being treated affects how often the sleeves need to be cleaned.

Calcium deposits can be removed by placing the sleeves in an acid bath. Soak each sleeve in a vertical PVC pipe filled with acid. The sleeves should be handled with gloves to avoid contaminating the quartz.

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Chemical names and trade names are included in this publication as a convenience to the reader and to illustrate examples of technologies. The use of brand names and any mention or listing of commercial products or services does not imply endorsement by the University of Florida, nor discrimination against similar products or services not mentioned.

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Next month: A review of water treatment technologies and future research and education plans.