Water Treatment NOTES

Cornell Cooperative Extension, College of Human Ecology

Ultraviolet Radiation for Disinfecting Household Drinking Water

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Ultraviolet (UV) rays are part of the light that comes from the sun. The UV spectrum is higher in frequency than visible light and lower than x-rays. As a water treatment technique, UV is known to be an effective disinfectant due to its strong **germicidal** (inactivating) ability. UV disinfects water containing bacteria, viruses, and *Giardia lamblia* and *Cryptosporidium* cysts.

UV has been used commercially for many years in the pharmaceutical, cosmetic, beverage, and electronics industries. It was used for drinking water disinfection in the early 1900s but was abandoned due to high operating costs, unreliable equipment, and the expanding popularity of disinfection by chlorination. Recently, the safety of chlorination has been questioned and UV has experienced increased acceptance in both municipal and household systems. There are few large-scale UV water treatment plants in the United States although there are several such plants in Europe.

Municipal systems use UV in conjunction with chlorine, thus reducing the amount of chlorine necessary for disinfection. Likewise, **disinfection byproducts** (DBPs), the chemicals associated with chlorination, are also reduced. Certain DBPs, such as trihalomethanes, have been linked to increases in certain cancers. UV treatment's main advantage is that no chemical input is required. However, UV treatment lacks **residual** (remaining) disinfection in the water delivery system, such as that available with a chemical treatment system like chlorination. Therefore, a secondary disinfection method, such as chlorine or ozone may be a requirement for a UV system.

Uses of UV disinfection

UV radiation has disinfection properties that **inactivate** bacteria, viruses, and some other microorganisms. It effectively treats *Giardia lamblia* and *Cryptosporidium* cysts, which may also be removed from water by filtration. UV is not recommended if the untreated water contains very high levels of coliform, the indicator organism that is the basis for bacteriological water tests, or if there is substantial color or turbidity (cloudiness) in the water. UV is effective only if the light intensity reaches the organism in question; therefore, nothing should be present in the water that shields the organism from the radiation.

Household UV treatment could conceivably be used for chlorinated water from a public supply if the home has a treatment device, such as an activated carbon filter, that removes chlorine (and thus allows bacterial growth). In this case, UV provides a final disinfection of the water supply.

Principles of UV disinfection

UV radiation has three wavelength zones: UV-A, UV-B, and UV-C, and it is this last region, the shortwave UV-C, that has germicidal properties for disinfection. A low-pressure mercury lamp resembling a fluorescent lamp produces the UV light in the range of 254 **nanometers** (nm). A nm is one billionth of a meter (10^{-9} meter). Since most microorganisms are affected by radiation around 260 nm, UV radiation is in the appropriate range for germicidal activity. There are UV lamps that produce radiation in the range of 185 nm that are effective on microorganisms and will also reduce the total organic carbon (TOC) content of the water.

In a typical UV system, approximately 95 percent of the radiation passes through a special quartz glass sleeve and into the untreated water that flows in a thin film over the lamp. The glass sleeve keeps the lamp at an ideal temperature of 104 °F. UV radiation affects microorganisms by altering the DNA in the cells and impeding reproduction. UV treatment *does not* remove organisms from the water, it merely inactivates them. The effectiveness of this process is related to exposure time and lamp intensity as well as general water quality parameters. The exposure time is reported as "milliJoules per square centimeter" (mJ/cm^2), and the U.S. Department of Health and Human Services has established a minimum exposure of 16 mJ/cm^2 for UV disinfection systems. Most manufacturers provide a lamp intensity of 30-50 mJ/cm^2. Coliform bacteria, for example, are destroyed at 7 mJ/cm^2. Since lamp intensity decreases over time with use, lamp replacement is a key maintenance consideration with UV disinfection. In addition, UV systems should be equipped with a warning device to alert the owner when lamp intensity falls below the germicidal range.

Used alone, UV radiation does not improve the taste, odor, or clarity of water. UV light is a very effective disinfectant, although the disinfection can only occur inside the unit. There is *no residual disinfection in the water* to inactivate bacteria percentage of microorganisms destroyed depends on the intensity of the UV light and the contact time. If material builds up on the glass sleeve, the light intensity and the effectiveness of treatment are reduced.

Either sediment filtration or activated carbon filtration should take place before water passes through the unit. Particulate matter, color, and turbidity affect the transmission of light to the microorganisms and must be removed for successful disinfection.

UV is often the last device in a **treatment train** (a series of treatment devices), following reverse osmosis, water softening, or filtration. The UV unit should be located as close as possible to the point-of-use since any part of the plumbing system could be contaminated with bacteria. It is recommended that the entire plumbing system be disinfected with chlorine prior to initial use of a UV system.

Types of UV disinfection devices

The typical UV treatment device consists, of a cylindrical chamber housing the UV bulb along its central axis (Fig. 1). A quartz glass sleeve encases the bulb; water flow is parallel to the bulb, which requires electrical power. A flow control device prevents the water from passing too quickly past the bulb, assuring appropriate radiation contact time with the flowing water. It has been reported that turbulent (agitated) water flow provides more complete exposure of the organism to UV radiation.

A UV system housing should be made of stainless steel to protect any electronic parts from corrosion. To assure they will be contaminant-free, all welds in the system should be plasma-fused and purged with argon gas. The major differences in UV treatment units are in capacity and optional features. Some are equipped with UV emission detectors that warn the user when the unit needs cleaning or when the light source is failing. This feature is extremely important to assurance of a safe water supply. A detector that emits a sound or shuts off the water flow is preferable to a warning light, especially if the system might be located where a warning light would not be noticed immediately.

NSF International, a non-profit standard-setting organization, has developed standards for these UV light systems. NSF-approved systems can be found on the NSF website at www.nsf.org.

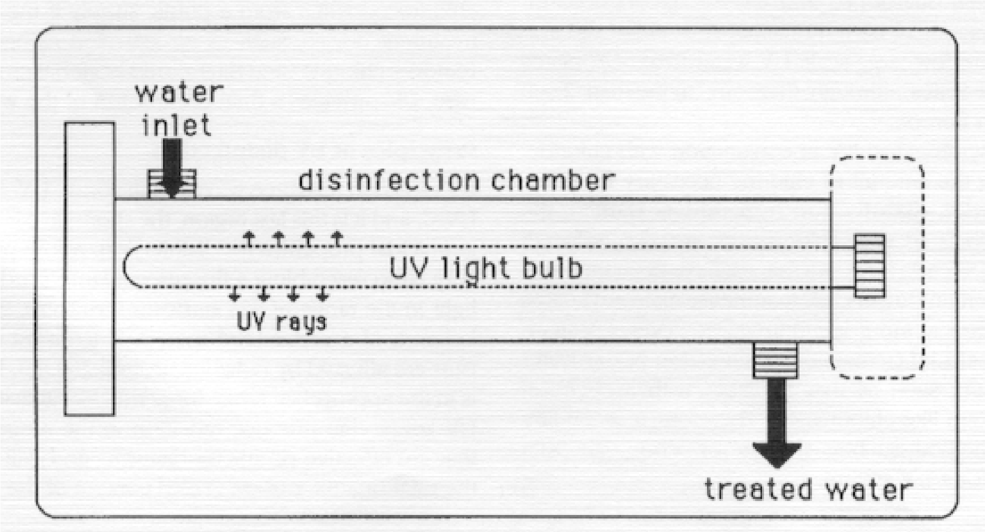

Figure 1. Cross section diagram of a typical UV disinfection unit

Maintenance of a UV system

Since UV radiation must reach the bacteria to inactivate them, the housing for the light source must be kept clean. Commercial products are available for rinsing the unit to remove any film on the light source. An overnight cleaning with a solution of 0.15 percent sodium hydrosulfite or citric acid effectively removes such films. Some units have wipers to aid the cleaning process.

UV systems are designed for continuous operation and should be shut down only if treatment is not needed for several days. A few minutes for lamp warm-up is needed before the system is used again following shut-down. In addition, the plumbing system of the house should be thoroughly flushed following a period of no use. Whenever the system is serviced, the entire plumbing system should be disinfected with a chemical such as chlorine prior to relying on the UV system for disinfection.

Because UV lights gradually lose effectiveness with use, the lamp should be cleaned on a regular basis and replaced at least once a year. It is not uncommon for a new lamp to lose 20 percent of its intensity within the first 100 hours of operation, although that level is maintained for the next several thousand hours. As stated previously, units equipped with properly calibrated UV emission detectors alert the owner when the light intensity falls below a certain level.

The treated water should be monitored for coliform and heterotrophic bacteria on a monthly basis for at least the first 6 months of the device's use. If these organisms are present in the treated water, the lamp intensity should be checked, and the entire plumbing system should be disinfected with a chemical such as chlorine.

Quick Facts about UV Water Treatment

- UV disinfection does not add chemicals to the water
- UV is effective against bacteria, viruses, *Giardia lamblia* and *Cryptosporidium*
- UV disinfection has no residual disinfection
- Minimum lamp exposure of 16 mJ/cm^2
- UV often last device in a treatment train of water treatment devices
- UV device should have audible UV emission detector to notify user when lamp intensity is inadequate
- Regular maintenance and lamp replacement is essential

Capacity of UV disinfection systems

UV is an in-line, **point-of-entry** system that treats all the water used in the house. The capacities range from 0.5 gallons per minute (gpm) to several hundred gpm. Certain **point-of-use** devices (treating water from a single tap) may include UV as a final disinfection method, as when used with reverse osmosis, for example. (For more information on reverse osmosis systems, consult Water Treatment Notes No. 4, *Reverse Osmosis Treatment of Drinking Water.)* Since bacteria may be shielded by particles in the water, pretreatment to remove turbidity may be required. There is also a limit to the number of bacteria that can be treated. An upper limit for UV disinfection is 1,000 total coliforms/100 mL water or 100 fecal coliforms/100 mL.

Special considerations

Prefiltration is required to remove color, turbidity, and particles that shield microorganisms from the UV source. Water that contains high mineral levels can coat the lamp sleeve and reduce the treatment effectiveness. Therefore, pretreatment with a water softener or phosphate injection system may be necessary to prevent build-up of minerals on the lamp. Table 1 lists the maximum levels of certain contaminants that are allowable for effective UV treatment. It is extremely important to remember that UV provides no residual disinfection of the water. Microorganisms that have been shielded from the UV light by components such as particulate matter or color, may not be completely exposed to the radiation and may be reactivated if they come in contact with oxygen. Therefore, storing UV-treated water for any period of time could result in recontamination.

Table 1. Recommended maximum contaminant levels in water entering a UV treatment device.

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

*Nephelometric Turbidity Units

Source: Voitle, Robert. Water Technology. Oct. 1992.

UV water treatment is an effective way to disinfect home drinking water supplies; it is becoming increasingly popular as an alternative to chlorine disinfection systems because it adds no chemicals to the water. There are, however, specific water quality parameters that must be met for the UV system to produce adequate amounts of bacteriological safe water. In addition, adherence to a regular maintenance routine is essential.

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