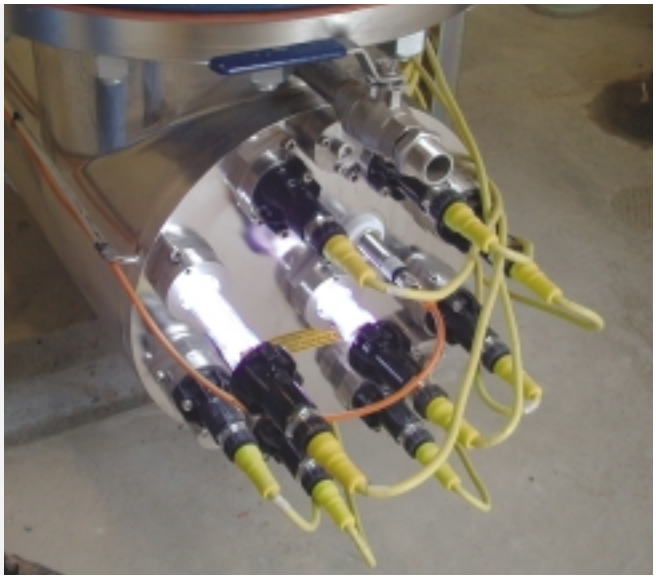

Ultraviolet light inactivates microbes by damaging their DNA, thereby preventing the microbes' ability to replicate. Unlike chemical disinfectants, UV disinfection leaves no harmful byproducts and does not impart any taste or odor to the water supply.

Ultraviolet Disinfection of Drinking Water
A Growing Trend

By Richard G. Protasowicki, P.E.

The use of ultraviolet (UV) light for the treatment of drinking water is becoming more acceptable by both the public and regulatory agencies as an alternative disinfectant. Water suppliers that are developing new water treatment facilities or modifying existing ones now commonly investigate this technology to determine its applicability to their treatment processes.

What is UV and How Does it Work?

UV light lies within the region of the electromagnetic spectrum between visible light and x-rays (between 100 to 400 nanometers [nm]). This region is further subdivided into four sub-regions; vacuum UV (100–200 nm), UVC (200–280 nm), UVB (280–315 nm), and UVA (315–400). Its disinfection effectiveness comes primarily from the UVC and UVB portions of the light.

Whereas chemical disinfectants destroy or damage a microbe's cellular structure, UV light inactivates microbes by damaging their DNA, thereby preventing the microbe's ability to replicate (or infect the host).

The dosage for a chemical disinfectant typically is expressed in milligrams per liter (mg/L). However, a UV dose is expressed as energy per area. It is calculated by multiplying irradiance by time (i.e., Dose = I × T). Irradiance is defined as the total radiant power incident from all upward directions on a surface area divided by that area. The units for irradiance are milliwatts per square centimeter (mW/cm^2) and the units for time are seconds. Therefore, the units for dosage are milliwatt-seconds per square centimeter ($mW\text{-}s/cm^2$) or millijoules per square centimeter (mJ/cm^2).

What are the Pros and Cons of UV?

UV light disinfection offers many advantages.

- It does not impart any tastes or odors to the water as chlorine does.
- It does not form harmful disinfection byproducts that can result with chlorine and other chemical disinfectants.
- It does not increase bacterial regrowth potential in distribution systems.
- It can effectively inactivate biological pathogens such as *Giardia* and *Cryptosporidium*.

Some drawbacks also should be noted. For example, UV light does not leave a disinfectant residual in the disinfected water as a chlorinated disinfectant would, should one be desired or required. Additionally, recent research suggests that UV light may not effectively inactivate the Adenovirus at the same doses that are effective for other microorganisms. Should either of these items be of concern, additional disinfection with chlorine could be practiced to create a multiple disinfectant barrier approach.

Types of UV Reactors

Commonly available UV reactors use low pressure (LP), low pressure high-output (LPHO) and medium pressure (MP) UV lamps. The pressure reference relates to the mercury vapor pressure within the lamp. The germicidal UV light produced by the LP and LPHO lamps is monochromatic at approximately 254 nm and is polychromatic from approximately 200 to 320 nm for the MP lamp types. In general, as you move from the LP to the MP lamp systems, fewer lamps are needed to disinfect greater flows of water at the same dose. Correspondingly, a higher power input also is required.

A basic rule of thumb for lamp type selection is that LP and LPHO lamp systems would be suitable for flows up to 2 to 3 million gallons per day (mgd) and that MP lamp systems would be suitable for flows above that range. However, a detailed life cycle cost analysis should be performed for each system to select the most economical lamp type.

Current UV Projects

Dufresne-Henry has been implementing UV technology in drinking water supplies in the Northeast for several years. Among the states that are demonstrating a strong interest in UV technology is the Commonwealth of Massachusetts. Some of the most recent projects in Massachusetts to use UV are listed in Table 1.

Of the five locations cited, a common reason for selecting UV for disinfection has been its ability to not impart any tastes or odors to the disinfected water. For these locations, the consumers and/or water suppliers specifically asked that chlorine not be used. At the outset of the project in Norfolk, Water Superintendent

Table 1: Recent and Ongoing UV Projects

Location	Design Capacity (mgd)	Water Type		Facility Type		Lamp Type		Project Status			Reason for UV Selection			
		GW[1]	GWUDI[2]	New	Modification	LP		LPHO	Design	Construction	On-Line	Disinfection		GWUDI[2]
Multiple Barrier/Taste & Odor														
Mashpee	1.0	✔		✔		❊		✔			✔			
Norfolk	0.86	✔			✔		✔			✔	✔			✔
Plainville	1.0		✔		✔	❊		✔			✔	✔	✔	
West Bridgewater	1.0	✔		✔		❊		✔			✔			✔
Westford	2.0 and 3.0		✔	✔		✔			✔		✔	✔	✔	✔

1. GW = Ground Water.

3. UV was selected for the avoidance of the potential tastes and odors

James Martin asked that an innovative technology be selected to provide disinfection to an aerated water so that chlorine would not have to be used. Similarly, West Bridgewater Superintendent Rick Krugger specifically requested that UV be used so that his consumers would not have to experience the tastes and odors typically imparted by chlorine. In both of these communities, the municipal wells typically are not chlorinated.

A similarity among the water suppliers who have been classified as GWUDI is the use of UV disinfection in a "multiple barrier" approach for providing safe drinking water. Both the Plainville and Westford projects are pressurized greensand filtration plants that will use UV disinfection as a third barrier in their treatment processes.

Following are some important questions to ask in designing a UV system for your treatment facility.

- Is pilot testing required?
- What is the maximum flow rate (present or future) to be treated?
- What dosage is needed?
- What type of lamp system will be most cost effective?
- Will a wiper system (to remove precipitate from lamp sleeves) be required?
- How will the UV reactor be validated to confirm it is applying the required dose?
- What type of monitoring will be required by the regulatory agency?

Looking Ahead

Although not yet accepted by the United States Environmental Protection Agency as an approved technology for drinking water disinfection under the Surface Water Treatment Rule (SWTR), studies conclude that UV light can be an effective disinfectant for *Giardia*, *Cryptosporidium* and other microorganisms at varying doses. This does not preclude water systems from using UV; it just does not allow the granting of removal/inactivation credits for microbial contaminants by the regulatory agencies. However, state regulatory agencies have approved UV instead of other forms of chemical disinfection on a case-by-case basis.

At this time, observers within the water treatment industry anticipate that regulations pertaining to the use of UV disinfection for compliance with treatment requirements will be contained in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). This rule is expected to be proposed in late 2002 or early 2003 and likely will include stipulations on UV doses to achieve different levels of inactivation credits for various microbial contaminants. Additionally, the EPA will publish a UV Guidance Manual concurrently with the proposed LT2ESWTR.

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An operator receives training during UV system startup.