

# Disinfection:

By Paul Overbeck

## Why Do We Need It?

The use of ozone and ultraviolet technologies for primary disinfection

In a broad definition, disinfection is “any process in which most or nearly all microorganisms (pathogenic or not) in a given article are killed or inactivated to prevent or cease infection.”

That “given article” may be just about anything: a liter of water, the surface of a carrot moving to the ready-to-eat packaging line, a semiconductor wafer or the interior surface of pipes used to carry treated water into anything from electronics and pharmaceutical plants to that new subdivision down the street. Disinfection is a way of life in so many arenas, but for the purposes of this article, I’m going to focus on water.

### Why Do We Need It?

Disinfection of drinking water and wastewater is critical to the protection of public health. All water and wastewater systems should use some form of disinfection process to remove or inactivate microorganisms (pathogens) that can cause disease in humans and animals. (Yes, water treatment and disinfection are critical to agriculture, cattle, swine and poultry farms, too. All life as we know it thrives on clean water.)

Just think—if not for the specialized aquatic life-support systems featuring highly refined disinfection processes, the general public would never get to experience the array of natural aquatic beauty seen at aquariums around the world. Water parks would otherwise be a complete impossibility, as would fountains, grocery stores and space stations. Think about the many uses of water you experienced just on your way to work this morning: a shower, morning coffee, clean streets, etc. None of these things would be possible without some form of disinfection along the way.

### How To Disinfect?

Both the U.S. Environmental Protection Agency’s (EPA) LT2 Enhanced Surface Water Treatment Rule and the Ground Water Rule require public water systems to disinfect water obtained from surface water supplies, groundwater sources under the influence of surface water and protected groundwater sources.

Primary methods include but are not limited to:

- Enhanced filtration (physical removal of larger organisms—parasites, *Cryptosporidium* and *Giardia*);
- Disinfection with oxidizing biocides (inactivation of microorganisms)—for instance, chlorine (gas or liquid), chloramination, chlorine dioxide and ozone; and
- Other disinfection methods such as ultraviolet (UV) light.

### Enhanced Filtration

Conventional filtration of surface water is designed to account for the variability of the water sources used and balance the effects of seasonal weather storm runoff and source blending on turbidity and total organic compounds. Systems employed may include flocculation, sedimentation, clarification and filtration. The nature of these filtration processes allows for the removal of a majority of particles above a certain size and shape; this is not an absolute removal process due to the variability of the media size and packing density.

To aide in particle reduction, it has been determined

that specific chemicals (e.g., alum and ferric chloride), cationic or anionic polymers and oxidation processes help to improve process efficiency and the ability to remove smaller particles. Enhanced filtration, therefore, can increase the removal of smaller particles, including *Cryptosporidium* and *Giardia*, from surface water supplies, leaving a lower load for oxidizing biocides or UV for primary disinfection.

Figure 1 shows the decrease in finished water turbidity when ozone, as an example, is used as a preoxidant.

### Oxidizing Biocides

All oxidizing biocides work in a similar fashion by attacking the cells of microorganisms to which they are exposed. This oxidative interaction changes cell permeability, protoplasm or enzyme activity because of a structural change in enzymes. In some cases, the exposure results in lysing of the cell membrane, thereby opening it up to its environment. In other cases, the surface oxidation allows for diffusion of the oxidant through the cell membrane to attack RNA and DNA. Oxidation either kills or inactivates the organism, stopping its ability to multiply.

Microbial inactivation is a function of oxidant type, residual level, contact time, system temperature and pH. The EPA and other government agencies globally have researched the reactions of the various oxidizing biocides on target organisms important to public health. Figure 2 compares the Ct (residual concentration multiplied by exposure time) values for several oxidants for three-log inactivation of *Giardia* and four-log inactivation of Enteric Virus. You can see that ozone treatment inactivates 99.9% of *Giardia* at a 1.9 Ct compared to a 122 Ct for free chlorine. This difference is less significant when comparing inactivation of the example virus.

### UV Light

UV light has been used successfully in wastewater disinfection, but it has grown most significantly in drinking water applications over the past 10 years due to the discovery that it is effective at low dosage for inactivation of *Giardia* and *Cryptosporidium*.

UV disinfection performance is tied to the First Law of Photochemistry, which says only the light (photon) that is absorbed by a organism can be effective at producing photochemical change in the organism. If photons are not absorbed as they pass through a medium, nothing can happen and no photochemical reaction can be induced. In order to inactivate microorganisms, UV energy must be absorbed. It turns out that cellular DNA and RNA absorb light in the UVC range with the greatest inactivation efficacy between 245 and 275 nm. The absorbed UV energy causes damage to these nucleic acids and prevents cell replication by dimerization of thymine nucleotides, stopping the ability to multiply.

UV technologists and regulators often refer to UV inactivation dose in a similar fashion as those who would use a Ct value for oxidizing biocides like chlorine or ozone to control pathogens.

Specifically, UV dose equals UV intensity multiplied by the time the organism is exposed. In past years, North Americans used dose units of mW-sec/cm<sup>2</sup>.

Figure 1. Pre-coagulation Ozonation Effects on Turbidity During Startup (Mazloum, 2004)

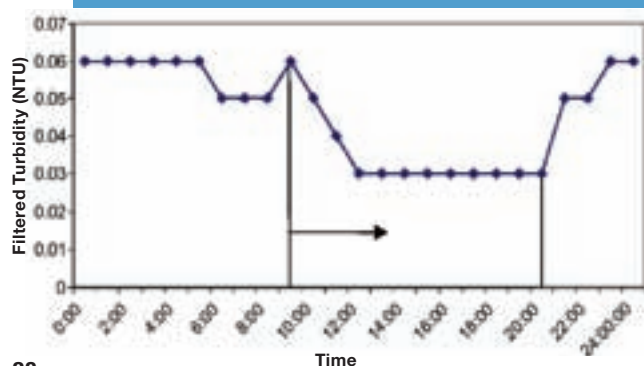
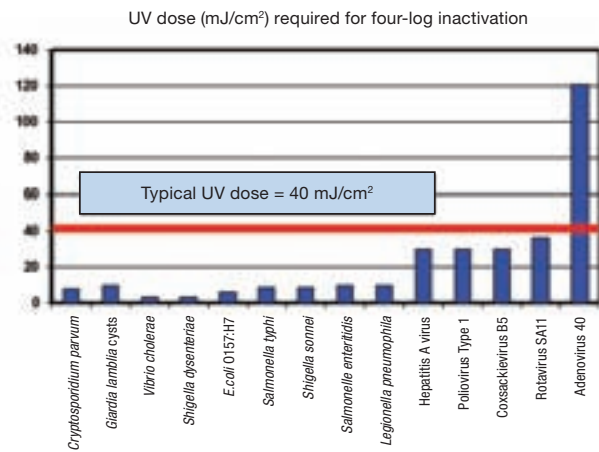


Figure 2. Ct Values (mg x min/L) for 99.9% *Giardia* and 99.99% Virus Inactivation

	Ct values (mg x min/L)			
	Free Chlorine (pH 6 to 7)	Chloramine (pH 8 to 9)	Chlorine Dioxide (pH 6 to 7)	Ozone (pH 6 to 7)
<i>Giardia</i>	122	2,200	26	1.9
Virus	8	1,988	33.4	1.2

Source: U.S. EPA - Data for 5°C, for each disinfection method in its optimum pH range.

Figure 3. Inactivation Comparison



Public water systems must disinfect water brought in from regulated sources.

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The more globally accepted terms for UV dose are J/m², commonly used in U.S. drinking water treatment units as mJ/cm².

Example: 400 J/m² = 40 mW·sec/cm² = 40 mJ/cm²

Target pathogen inactivation dosages have been well researched and recognized by global public health agencies. The identified UV dose for a four-log (99.99%) inactivation for various organisms is shown in Figure 3.

The EPA, U.S. Food and Drug Administration and most industries recommend or practice the use of multiple technologies to assure treatment goals are met. In many surface water treatment facilities, ozone preoxidation is used to enhance the flocculation and sedimentation process for improved turbidity and parasite reduction prior to UV reactors for primary disinfection and chloramination for distribution; this is referred to as a multi-barrier approach to disinfection.

High-purity industrial manufacturing operations, such as those in electronic and pharmaceutical production, practice a "multiple interventions" approach to operations—a different name, but the same disinfection goal. In these industries, conventional filtration is followed by membrane processes—for example, reverse osmosis, ultrafiltration or microfiltration with UV polishing, depending on the water quality specification.

**Resources**

The use of ozone and UV technologies for primary disinfection allows utilities to use lower chlorination levels for water distribution, which results in lower levels of chlorinated disinfection byproducts such as trihalomethanes and haloacetic acids in drinking water.

Oxidation, filtration and disinfection technologies are used as synergistic treatment processes to protect public health and support industrial production and efficiency. Selection of the best combination for an application may require consultation with industry experts and pilot testing.

The International Ultraviolet Association and the International Ozone Association are educational associations. Both act as repositories for detailed research, as well as operational and consultative contacts for these technologies, whether applied individually or as part of a systems approach to treatment. For more information, visit [www.iuva.org](http://www.iuva.org) and [www.io3a.org](http://www.io3a.org).

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