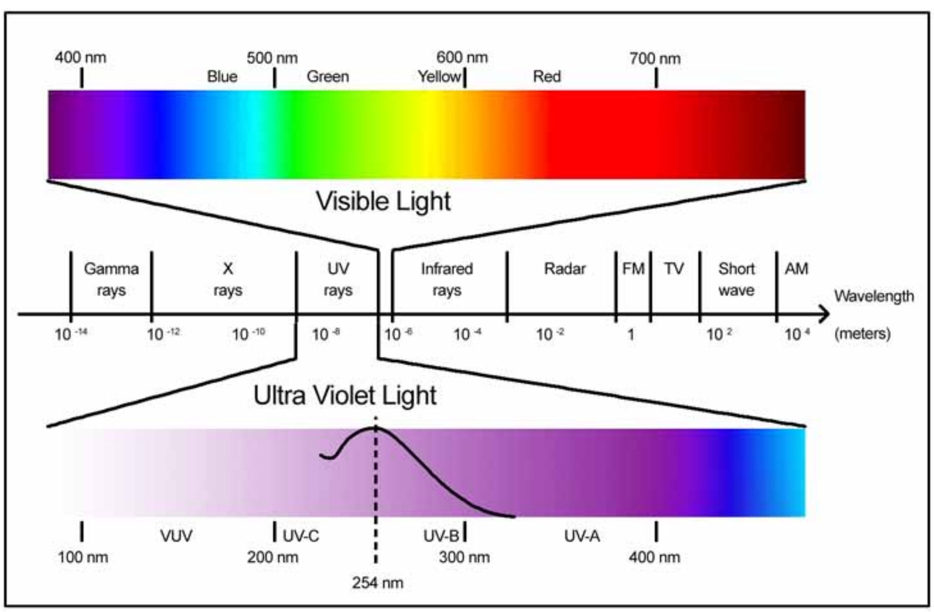
Ultraviolet Sterilization Technology

Ultraviolet disinfection systems are mysterious to many people – how can “light” kill bacteria? But the truth is it can. Ultraviolet (UV) technology has been around for more than 50 years, and its effectiveness has been well documented both scientifically and commercially. It is nature’s own disinfection/purification method. With consumers becoming more concerned about chlorine and other chemical contamination of drinking water, more dealers are prescribing the ultraviolet solution suitable for both small flow residential applications as well as large flow commercial projects.

Ultraviolet is a means of killing or rendering harmless microorganisms in a dedicated environment. These microorganisms can range from bacteria and viruses to algae and protozoa. UV disinfection is used in air and water purification, sewage treatment, protection of food and beverages, and many other disinfection and sterilization applications. A major advantage of UV treatment is that it is considered safer and more reliable for disinfection of water than chemical alternatives, while the level of disinfection is much higher. UV treatment systems are also extremely cost efficient and require less space than alternative disinfection systems.

What is UV and how does it work?

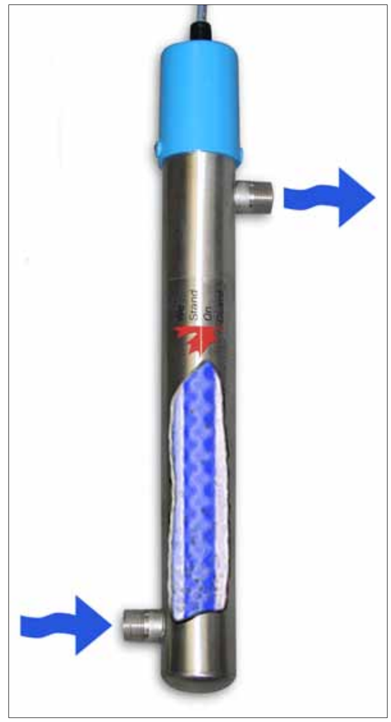
Ultraviolet light is one energy region of the electromagnetic spectrum, which lies between the x-ray region and the visible region. Wavelenghts of visible light range between 400 and 700 nanometers (nm). UV itself lies in the ranges of 200 nm to 390 nm. Optimal UV germicidal action occurs at 254 nm.



The Electromagnetic Spectrum

Since natural germicidal UV light from the sun is screened out by the earth’s atmosphere, we must look to alternative means of producing UV light. This is accomplished through the conversion of electrical energy in a low-pressure mercury vapor “hard glass” quartz lamp. Electrons flow through the ionized mercury vapor between the electrodes of the lamp, which then creates UV light.

The Filaments and Arc in a UV Lamp



Water flows through the chamber in an upward circular path

As UV light penetrates through the cell wall and cytoplasmic membrane of a microorganism that is in the water while it flows through the unit, it causes a molecular rearrangement of the microorganism’s DNA, which prevents it from reproducing. If the cell cannot reproduce, it is considered dead or “inactivated”.

Dosage

UV dosage is the most critical function of UV disinfection, because the extent of inactivation is proportional to the dose applied to the water. As individual UV lamps emit a set amount of ultraviolet energy, it is important that a system be sized correctly. Flow rates are the determining factor and must not be overstated. Contact time, which is the time the water is within the sterilization chamber, is directly proportional to dosage, which is the amount of energy per unit area (calculated by dividing the output in watts by the surface area of the lamp), and thus the overall effectiveness of microbial destruction in the system. This product of intensity and time is known as the Dose and is expressed in microwatt seconds per centimeter squared (uWsec/cm^2). **Divide by 1000 to express the dose in mJ/cm^2, the preferred notation**.

$$\textbf{DOSE} = \frac{\text{time (sec) x output (watts)}}{\text{area (cm}^2\text{)}}$$

For maximum UV transmission a “hard glass” quartz sleeve is recommended for two main reasons. It isolates the lamp from the water to offer more uniform operating temperatures and allows for higher UV output into the water.

Optional Features

A variety of optional features may be added on to the UV sterilizers. They include UV monitoring devices that measure the actual UV output in real time, solenoid shut-off devices that will stop the water flow in the event of a system failure, flow control devices to properly limit the water flow in the units, audible and visual alarms (both local and remote) to warn of lamp failures, high temperature sensors to monitor excessive temperatures in the reactor chamber or control panel, and hour meters to monitor the running time of the UV lamps.

A solenoid valve shuts off the flow of water, if the intensity of the UV lamp goes down

Advantages of UV Sterilization

Following are the advantages of UV sterilization:

- Environmentally friendly, no dangerous or toxic chemicals to handle, no problem of overdosing (it's impossible), no need for specialized storage equipment, no WHMIS requirements.
- Low initial capital cost as well as reduced operating expenses when compared with similar technologies such as ozone, chlorine, etc.
- Immediate treatment process, no need for holding tanks, long retention times, etc.
- Extremely economical, hundreds of gallons may be treated for each penny of operating cost.
- No chemicals are added to the water supply – no chlorinated by-products are generated (i.e. chlorine + organics = trihalomethanes).
- No change in taste, odor, pH or conductivity or the general chemistry of the water, essential minerals and trace elements remain in the water
- Automatic operation without special attention or measurement, operator friendly.
- Simplicity and ease of maintenance, periodic cleaning (if applicable) and annual lamp replacement, no moving parts to wear out.
- Easy installation, only two water connections and a power connection.
- Compatible with all other water processes (i.e. RO, filtration, ion exchange, etc.)

Factors Affecting UV

Because UV does not leave any measurable residual in the water, it is recommended that the UV sterilizer be installed as the final step of treatment and located as close as possible to the final distribution system. Once the quality of your water source has been determined, you will need to look at things that can inhibit the UV from functioning properly (e.g., iron, manganese, TDS, turbidity, and suspended solids).

Iron and Manganese will cause staining on the quartz sleeve and prevent the UV light from transmitting into the water at levels as low as 0.3 ppm of iron and 0.05 ppm of manganese. Proper pretreatment is required to eliminate this staining problem.

Total Dissolved Solids (TDS) should not exceed 500 ppm. There are many factors that make up this equation such as the particular make-up of the dissolved solids and how fast they absorb on the sleeve, again impeding the UV energy from penetrating the water.

Turbidity is the inability of light to travel through water. Turbidity makes water cloudy and aesthetically unpleasant. In the case of UV, levels over 1 NTU can shield microorganisms from UV light, making the process ineffective.

Suspended Solids need to be reduced to a maximum of 5 microns in size. Larger solids have the potential of harboring or encompassing the micro-organisms and preventing the necessary UV exposure. Pre-filtration is a must on all UV applications to effectively destroy microorganisms to a 99.9% kill rate.

Additional Factors - UV levels fluctuate with temperature levels. The optimal operating temperature of a UV lamp must be below or near 40°C (104°F). Typically, a quartz sleeve is installed to buffer direct lamp-water contact, thereby reducing any temperature fluctuations. The UV dose applied to the water decreases significantly with temperatures over 40°C.

UV Applications

One of the most common uses of ultraviolet sterilization is the disinfection of domestic water supplies due to contaminated wells or surface water sources. Coupled with appropriate pre-treatment equipment, UV provides an economical, efficient and user-friendly means of producing safe potable water.

The following list shows where ultraviolet technology is currently in use:

surface water	laboratories	bottled water plants
ground water	wineries	pharmaceuticals
cisterns	dairies	mortgage approvals
breweries	farms	electronics
hospitals	hydroponics	aquaria
restaurants	spas	boats and RV's
vending machines	canneries	printing
cosmetics	food products	butter processing
bakeries	distilleries	petro chemicals
schools	fish hatcheries	photography
boiler feed water	water softeners	swimming pools
cooling towers	sprinkler systems	bottling plants
and much more…		

Installation and Maintenance Guidelines

Once the application has been determined, you should find a location that offers easy access for service. You will need to have access to the pre-filters, to the

UV chamber for annual lamp changes and regular maintenance on the quartz sleeve. You will want to locate near an electrical outlet. *Note: Using a UV system and a pump on the same electrical line may cause problems and shorten the life of the UV lamp and ballast. A surge protector with a rating of at least 3600 Joules should be installed to protect the electronic ballast from damage due to power spikes or lightning strikes. UV units are installed on the cold water line before any branch lines and should be the last point of treatment. Clearance for lamp change has to be considered during installation. All points of the distribution system after the sterilizer must be chemically “shocked” to ensure that the system is free from any downstream microbial contamination. Lamp changes should be done at least once every year. Filter changes are done according to the condition of the feed water. If there is residue left, you may need to use a non-abrasive cleaner that does not scratch the surface and is formulated to remove iron and scale buildup. Do not leave fingerprints on the glass! It is imperative to follow the manufacturers guidelines on feed water quality and operational procedures.

Summary

The need for ultraviolet sterilization products can be found in virtually all areas in both residential and commercial applications alike. Its simplistic design, ease of maintenance and low capital and operating costs make UV disinfection the number one choice in contaminated water situations. Because of its advantages, UV irradiation is on the way to become the most popular choice for the disinfection of water supplies in the 21st century.

Next time, purify water *“natures way”*…use ultraviolet light.

UV Inactivation Chart[1] (in mJ/cm²)

Organism	Type	Affiliated Disease, Contamination, Toxin	Dose log 3	Reference
Agrobacterium tumefaciens	Bacterium	Crown Gall disease in Dicotyledons (Grapes, Berries, Fruits, Nuts)	8.5	
Aeromonas hydrophila	Bacterium	Tissue damage in humans (opportunistic pathogen)	3.9	Wilson, et al, 1992
Aspergillus flavus (yellow green)	Fungus (Mold Spore)	Aspergillosis of the lungs, corneal infections	99.0	
A. glaucus (blue green)	Fungus (Mold Spore)	Allergenic	88.0	
A. niger (black)	Fungus (Mold Spore)	Otomycosis, Black mold on fruits and vegetables	330.0	
Adenoviridae	Virus	Upper respiratory infections	90.0	Meng and Gerba, 1996
Bacillus anthracis	Bacterium	Anthrax	8.7	
B. anthracis (spores)	Bacterium	Anthrax	46.2	Pasteur Institute, Paris
B. megatherium (vegetable)	Bacterium	Infections, food poisoning	2.5	
B. megatherium (spores)	Bacterium	Infections, food poisoning	52.0	
B paratyphosus	Bacterium	non pathogenic	6.1	
B. subtilis (vegetable)	Bacterium	Ropiness in bread dough, food contamination	11.0	
B. subtilis (spores)	Bacterium	Ropiness in bread dough, food contamination	61.0	Chang et al, 1985, Sommer et al, 1998
Campylobacter jejuni	Bacterium	Food poisoning, gastroenteritis	4.0	Wislon et al, 1992
Chlorella vulgaris	Protist (algae)	Plant pathogen	22.0	
Clostridium Tetani	Bacterium	Tetanus	23.1	Pasteur Institute, Paris
C. botulinum	Bacterium	Produces Botulin toxin	11.2	
Coliphage	Virus	Bacteriophage that infects *E. coli*	6.6	
Corynebacterium diphtheriae	Bacterium	Diphtheria	6.5	
Coxsackie A	Virus	Hand, foot & mouth disease, conjunctivitis, herpangina	6.9	
Coxsackie B	Virus	Pericarditis, myocarditis, gastrointestinal distress	20.6	Battigelli et al, 1993
Cryptosporidium parvum	Protist	Cryptospiridiosis	25.0	Craik et al, 2001
Eberthella typhosa	Bacterium	Typhoid fever	4.1	
Escherichia coli	Bacterium	Food poisoning, gastroenteritis, meiningitis	8.6	Sommer et al, 1998; Wilson et al, 1992
Giardia lamblia (cysts)	Protist	Giardiasis (Beaver Fever, Traveller's Diarrhea)	10.0	Linden et al, 2002
Hepatitis virus	Virus	Hepatitis, jaundice	15.0	US.EPA, 1999
Influenza virus	Virus	Influenza, respiratory infections	6.6	
Legionella bozemanii	Bacterium	Pneumonia	3.5	
L. dumoffii	Bacterium	Pneumonia	5.5	
L. gormanii	Bacterium	Pneumonia	4.9	
L. longbeachae	Bacterium	Legionnaire's disease, pontiac fever	2.9	
L. micdadei	Bacterium	Influenza, Pittsburgh pneumonia	3.1	
L. pneumophila	Bacterium	Legionnaire's disease	3.8	
Leptospira interrogans	Bacterium	Leptospirosis (Weil's disease, canicola fever, canefield fever, 7-day fever)	6.0	
Micrococcus candidus	Bacterium		12.3	
M. sphaeroides	Bacterium		15.4	
Mycobacterium tuberculosis	Bacterium	Tuberculosis	10.0	
Mucor racemosus A	Fungus (Mold Spore)	Fungal plant pathogen, zygomycosis and fungal sinusitis in humans	35.2	
Neisseria (Moraxella) catarrhalis	Bacterium	Otitis media, sinusitis, laryngitis	8.5	
Nematode eggs (Roundworm)	Parasite	Ascariasis, Appendicitis, Loeffler's Syndrome	92.0	
Oospora lactis	Fungus (Mold Spore)	Fruit rot (rapid decay of ripe fruits, potatoes), mold in dairy products		
Paramecium spp.	Protist			
Penicillum digitatum (olive)	Fungus (Mold Spore)	Fungal spoilage in fruits and vegetables	88.0	
P. expansum (olive)	Fungus (Mold Spore)	Postharvest decay of stored apples	22.0	
P. roqueforti (green)	Fungus (Mold Spore)	Producing harmful secondary metabolites (alkaloids and other mycotoxins)	26.4	
Phytomonas tumefaciens	Bacterium	Crown Gall disease in Dicotyledons (Grapes, Berries, Fruits, Nuts)	8.5	
Polio virus	Virus	Poliomyelitis (Polio)	29.0	Snicer et al, 1998, Wilson et al, 1992
Proteus vulgaris	Bacterium	Infections (esp. sinus and respiratory, urinary tract)	6.6	
Pseudomonas aeruginosa (lab)	Bacterium	Hospital acquired infections, ear infection and dermatitis in pools & tubs	3.9	
Pseudomonas aeruginosa (env.)	Bacterium	Hospital acquired infections, ear infection and dermatitis in pools & tubs	10.5	
Rhizopus nigricans (black)	Fungus (Mold Spore)	Infections, allergetic reactions (known as breadmold)	220.0	
Rhodospirillum rubrum	Bacterium		6.2	
Rotavirus	Virus	Infections, severe diahorrea, gastroenteritis	26.0	Battigelli et al., 1993; Wilson et al., 1992
Saccharomyces sp.	Yeast		13.2	
Salmonella enteritidis	Bacterium	Egg-associated Salmonellosis (fever, abdominal cramps, diarrhea)	7.6	Tosa and Hirata, 1998
S. paratyphi	Bacterium	Enteric fever	6.1	
S. typhi	Bacterium	Typhoid fever	6.4	Wilson et al., 1992
S. typhimurium	Bacterium			
Sarcina lutea	Bacterium		26.4	
Serratia marcescens	Bacterium	Nosocomial (Hospital acquired) infections	6.2	
Shigella dysenteriae	Bacterium	Epidemic dysentery	4.2	Wilson et al., 1992
S. flexneri	Bacterium	Shigellosis, dysentery	3.4	
S. sonnei	Bacterium	Shigellosis	7.0	Chang et al., 1985
Staphylococcus aureus	Bacterium	Staph and nosocomical infections, toxic shock syndrome	7.0	Chang et al., 1986
S. epidermidis	Bacterium	Infections in catheters and prostheses	5.8	
Streptococcus hemolyticus	Bacterium	Strep throat	5.5	
S. faecalis	Bacterium	Endocarditis, bladder and prostate infection	8.0	Harris et al., 1987
S. lactis	Bacterium		8.8	
S.pyogenes	Bacterium	Scarlet fever, toxic shock syndrome, flesh eating disease	8.8	
S. viridans	Bacterium	Mouth or gingivial infections, endocarditis	3.8	
Tobacco mosaic virus	Virus	Mottling and discoloration in plants	440.0	
Vibrio cholerae	Bacterium	Cholera	2.2	Wilson et al., 1992
Yersinia enterocolitica	Bacterium	Yersiniosis (fever, abdominal pain, diarrhea	3.7	Wilson et al., 1992

Typical Wyckomar UV systems produce UV doses of 38 – 60 mJ/cm²

[1] UV energy levels required at 254 nanometer wavelength for 99.9% (log 3) destruction of organisms