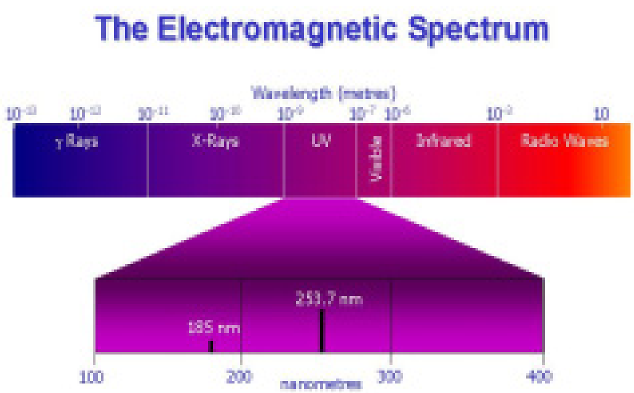
AQUIONICS
World Leader
in Ultraviolet Technology

ULTRAVIOLET TECHNOLOGY

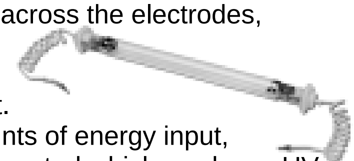
What is Ultraviolet Light?

Close to a century ago, scientists first identified that part of the electromagnetic spectrum responsible for the bactericidal effect of sunlight. The most biologically disruptive frequencies causing this well-known effect are the shorter wavelengths within ultraviolet (UV) light known as the UV-C spectrum. This form of light ranges from 200nm to 300nm where a nanometer (nm) is one-billionth of a meter. Such energy can now be produced commercially by electrical discharge devices. UV technology is harnessed for a range of applications from disinfection to oxidizing organics.

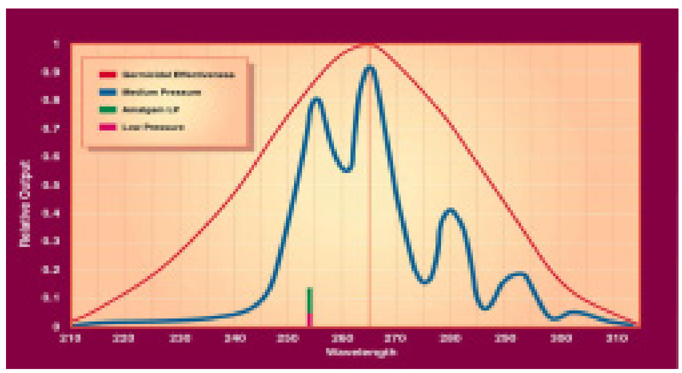


How is UV Light Generated?

The UV lamp, a quartz tube similar to a standard fluorescent bulb with electrodes at each end, is filled with an inert gas and a minute amount of mercury. Electrical energy, applied across the electrodes, provides the initial discharge and means of exciting the gases present. With relatively small amounts of energy input, a "Low Pressure" glow is created which produces UV



emissions at 185nm and 254nm. As the electrical input energy is increased, the lamp heats up rapidly; causing the internal pressure to increase, producing the characteristic "Medium Pressure" spectrum shown. The high output of the medium pressure lamp is as a result of a complex combination of atomic spectral, continuum and absorption lines characteristic of mercury vapor.



Low Pressure UV …

Typical Low-Pressure (LP) lamps operate between 120V and 240V, similar to standard fluorescent bulbs. These lamp types obtain power outputs ranging from 40 to over 100 Watts with current draws of less than 500mA. These low-pressure UV lamps are manufactured of quartz with two electrodes. They operate with very low (vacuum) internal pressures between 10^{-3} to 10^{-2} Torr and optimum operating temperatures of 110°F at the lamp surface. The mercury inside is partially vaporized raising the mercury atoms to low orbital energy states with subsequent emission of two distinct wavelengths within the UV spectrum, 185nm and 254nm.

Medium Pressure UV …

Medium Pressure (MP) lamps have higher (nearly atmospheric) operating pressures between 10^2 and 10^4 Torr with surface temperatures up to 1500°F. Under these conditions the mercury completely vaporizes creating a plasma with temperatures that can reach 10,000°F. In this hot plasma, mercury atoms are excited to multiple high orbital levels which, upon collapse, produce the characteristic broad spectral emission. Many of the performance features of MP lamps are derived from these fundamental differences in operation. Medium pressure lamps are stable under all temperature conditions. In addition, the broad spectral output results in a diverse range of applications not possible with low pressure.

Specifying Ultraviolet Equipment

To specify the most appropriate UV system for each application and ensure that the correct UV dose is applied, there are a number of critical parameters that must be determined.

UV Dose

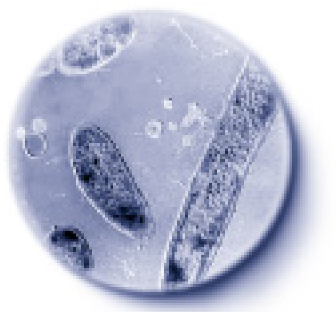
The UV dose is the energy delivered to a given surface area for a given period of time and can be calculated by the formula:

Dose (µW-sec/cm^2) = Intensity (µW/cm^2) x Time (sec)

The intensity is determined by the UV lamp power and time is determined by the period which the process fluid is exposed to the UV (residence time). Aquionics will recommend the appropriate UV dose for each application, taking into account all critical factors including: water quality, temperature, and lamp life.

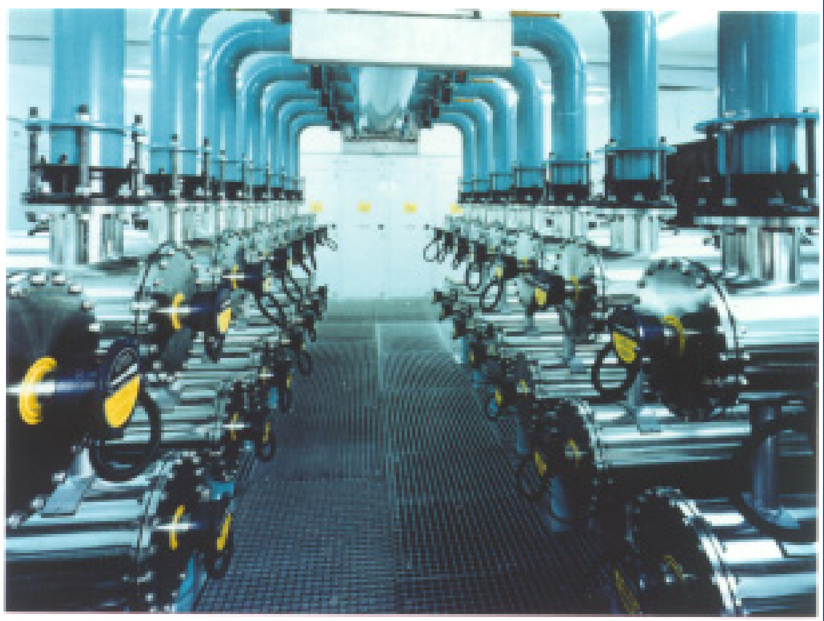
UV Dose (µW-sec/cm^2)	Reduction in CFUs
5,400	90.00% (1-log)
10,800	99.00% (2-log)
16,200	99.90% (3-log)
21,600	99.99% (4-log)

Dose/Kill-Rate Relationship for E. Coli in Water. A commonly used indicator organism for measuring contamination of municipal water supplies.



Flow Rate

Flow rate is a critical factor effecting the residence time, or exposure to UV, that an organism undergoes. There is a linear relationship between dose and flow rate. Typical disinfection systems are rated at the *maximum* flow which will deliver a 30,000 µW-sec/cm^2 dose at the end of a lamp's usable life.



Water Temperature

Low pressure UV lamps have an optimum operating temperature of 105ºF which is maintained when process water in the chamber is approximately 70^{o}F. Low pressure UV output drops rapidly if process water temperature rises above, or drops below this optimum temperature. The UV output of medium pressure lamps remains unaffected by water temperature due to its higher operating temperature.

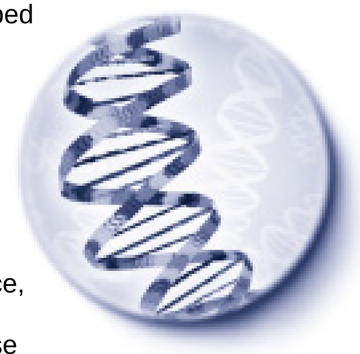
Water Quality

Effective UV dose is dramatically effected by water quality and constituents of water that absorb ultraviolet light. UV transmission through water decreases as the level of organic and inorganic contamination increases. Consequently, additional UV energy is required to treat the fluid. The most important factors in determining water quality and UV transmission are color, metals, organic matter, suspended and dissolved solids, and turbidity.

How Does UV Destroy Microorganisms?

High-energy ultraviolet light will pass easily through cell walls, cytoplasm, and nuclear membranes. Here, the photons are readily absorbed by the cellular DNA (the reproductive material). This UV energy causes permanent, irreparable, inactivation of the microorganism by fusing together and forming dimmers within portions of the DNA strands prohibiting replication. The microorganism becomes unable to maintain metabolism or reproduce itself and subsequently perishes. All cells, when subjected to germicidal UV, undergo a similar processes:

- Ultraviolet light penetrates the cell wall
- UV photons are absorbed by cellular DNA.
- DNA is permanently altered ceasing any capability for reproduction.
- Organisms, unable to metabolize or reproduce, perish and become unable to cause disease or spoilage.



The D10 Concept

The *D10* value for a microorganism is defined as the UV dose necessary to effect a 90% reduction in Colony Forming Units (CFUs). The relationship between dose and kill-rate is logarithmic. For example, if a 99.99% kill-rate of a particular organism is desired, the necessary dose is determined by multiplying the *D10* value by 4.

Other Pathogenic Organisms	***D10* Value (μW-sec/cm^2)**
Streptococcus viridians	2,000
Legionella pneumophila	2,000
Staphylococcus aureus	2,600
Listeria monocytogenes	3,400
Pseudomonas aeruginosa	5,500
Salmonella enteritidis	7,600
Bacillus subtilis (spores)	12,000
Bacillus anthracis (spores)	9,000
Polio Virus	6,500
Saccharomyces carlsbergensis	10,000
Cryptosporidium parvum	< 10,000
Aspergillus niger	130,000

Table 2 Typical D10 values of common microorganisms. Different types of organisms require different UV doses to achieve a 90% kill-rate.

Ultraviolet Light for PHOTOLYSIS

Disinfection is just one example of a broad range of photochemical effects of UV energy. Just as UV damages DNA in living organism, it also affects many other chemical bonds. Different bonds are affected at different UV wavelengths. The chemical effects of UV include:

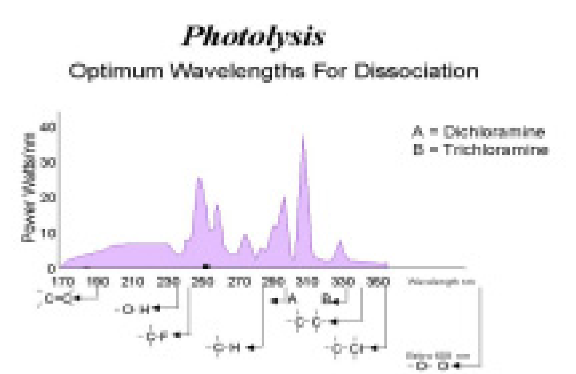
- Emission of high-energy photons which break molecular bonds.
- Conversion of non-Ionic organic molecules into charged species capable of ion exchange removal.
- Production of hydroxyl radicals (OH^-) which oxidize certain molecular bonds causing photochemical breakdown

The process of breaking chemical bonds with UV is called *Photolysis.* The principles of photolysis state that only light which is absorbed by a particular molecule can be effective in producing a photochemical change, and the photon energy absorbed must be sufficient to overcome the bonding forces to result in molecular photolysis.

Photolytic Applications

Possibilities for the use of UV to breakdown chemicals are limitless. Listed are several common applications:

- Total Organic Carbon (TOC) reduction for the production of high-purity water
- Destruction of pesticides or other contaminants in water supplies
- Chlorine and chloramine removal
- Destruction of residual ozone after disinfection and sanitation
- Destruction of chemical contaminants in industrial wastewater streams



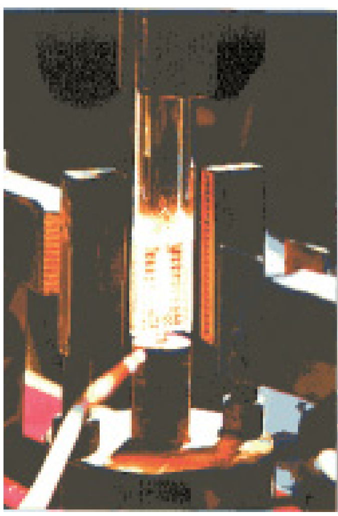
Why Choose Ultraviolet Technology for Disinfection and Photolysis?

The use of chemicals to disinfect and breakdown contaminants is declining because of the short and long term, damaging effects on humans, products, processes, and the environment. Traditionally, chemicals have been the accepted method of producing bacteria free process water for industrial use. Ultraviolet disinfection is chemical-free and does not alter the composition, resistivity, or pH of the water. Since nothing is added or removed from the water, it is unaltered in terms of taste, color, and odor. Advantages of UV include:

- Environmentally safe
- High-efficiency
- Low capital and operating costs
- Impossible to overdose
- Nothing added to alter fluid being treated

Important Factors	*Ultraviolet*	*Ozone*	*Chlorine*
Alters pH	No	Yes	Yes
Temperature Sensitive	No	Yes	Yes
Residual	No	Yes	Yes
Contact Time	Very Short	High	High
Operator Skill	Low	High	High
Maintenance	Low	High	Medium
Ammonia Interference	No	Yes	Yes
Water Chemistry	No Effect	Yes	Yes
Capital Cost	Low	High	Medium
Operating Cost	Low	High	Medium

Comparison of Common Disinfection Methods



Aquionics UV Systems Can Treat:

Liquids …

- Municipal or private drinking water
- Water for industrial processes
- Emulsions and brines for the food, beverage, and pharmaceutical industries
- In-line treatment of liquid sugar syrups
- Re-use and regeneration of process water
- Disinfection of waste streams

… And More

- Air for clean rooms, food processing, and tank ventilation
- Surfaces of packaging and for product contact

Why Choose Aquionics?

Aquionics is the world leader in Ultraviolet Technology…

- Aquionics, in conjunction with its global divisions in the UK and The Netherlands, offers experience since 1924 in the development, manufacture, and application of UV equipment supplied to all corners of the globe.
- Worldwide service and custom design capabilities
- All UV technologies available from a single supplier.

Aquionics is the only UV systems company in the world which manufactures its own UV lamps …

- Medium pressure lamps
- Low pressure lamps
- Each lamp is individually inspected
- Each system is factory tested before delivery

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