APPLICATION NOTE

APPLICATION: TOC Reduction

Aquafine® Ultraviolet Treatment Systems for TOC Reduction

Total Organic Carbon (TOC)

Organic compounds are among the most difficult contaminants to remove in an ultrapure water (UPW) or high-purity water (HPW) treatment system. An important step in producing UPW or HPW is the removal of total organic carbon (TOC). Organics are polar and weakly ionize which poses a considerable challenge to ion exchange and electro-deionization (EDI) systems. The removal of TOC can be cost-effectively achieved by using ultraviolet (UV) irradiation to oxidize organic molecules, followed by ion exchange to remove the resulting ionic species from the water.

Aquafine TOC reduction units coupled with ion exchange systems or EDI will oxidize trace organics into smaller ionic species, carbon dioxide and water, which are more readily removed by ion exchange resins, EDI, and/or degasifiers.

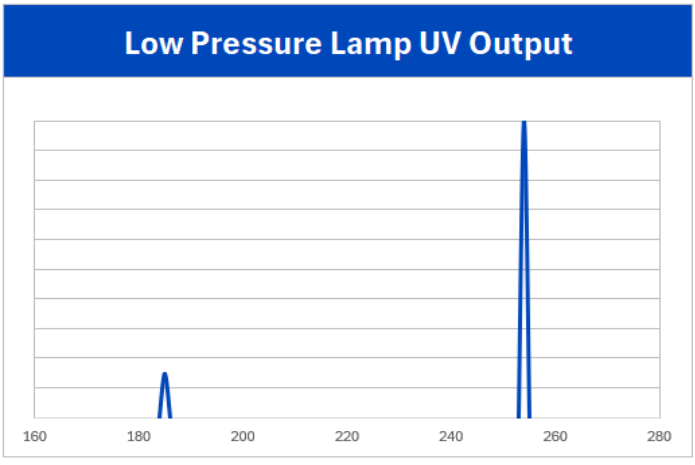
Photolysis

When water is exposed to a specific wavelength of UV light, the energy breaks down the water molecule in a process is known as photolysis.

A 185 nm emission is critical for efficient TOC degradation. Although some TOC compounds can be degraded through direct photolysis by 254 nm photons, most TOC reduction is initiated by photochemistry driven by the absorption of 185 nm photons in the water itself. These energetic photons photolyze the water molecule, resulting in highly reactive and short-lived hydroxyl radicals (OH·). These radicals can ionize or otherwise rapidly break down most TOC compounds. Therefore, the most important predictor of TOC reduction performance is the amount of 185 nm light absorbed into the water.

Ultraviolet Lamp Types

Mercury lamps are the only economical sources of the short light wavelengths required for TOC destruction. There are two general types of mercury lamps: medium-pressure and low-pressure lamps. While medium-pressure lamps are more powerful, their higher heat output, shorter lifetimes, and lower electrical efficiency



Aquafine low-pressure TOC lamps emit both 185nm and 254nm wavelengths, effectively breaking down organic molecules while simultaneously inactivating any microbiological contaminants.

make them less preferred for TOC destruction. Low-pressure mercury lamps are ideal for TOC reduction because of their high efficiency at generating two useful emission lines, 185 nm and 254 nm.

Today, LED emitters cannot be used for TOC reduction because of their very low efficiency at the required UV wavelengths – this is in sharp contrast to their high efficiency in producing visible light in general lighting applications.

TOC Water Quality

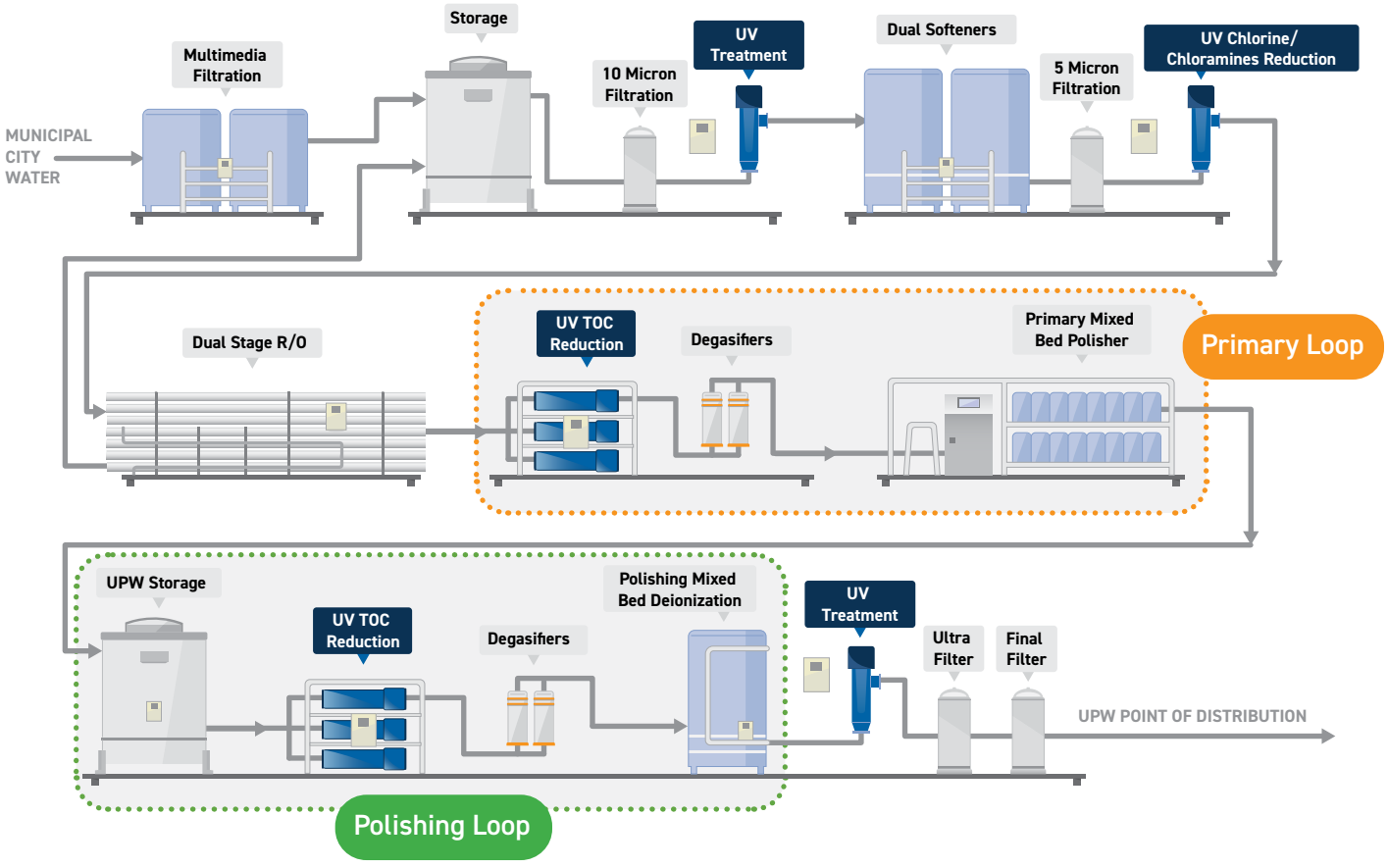
For effective TOC removal, water needs to have an ultraviolet transmittance (UVT) of 99%. UVT is the ratio of light entering the water to that exiting the water, measured with a 254nm wavelength and reported for a path length of 1 cm. The lower the UVT of the water, the more UV light is absorbed and cannot be used for TOC reduction. Pre-treatment technology, such as reverse osmosis (RO) and deionizers (DI), can be used to improve UVT to the 99% ratio required.

The power necessary for UV TOC reduction is determined by the amount of reduction desired and the type of organic compound. The higher the desired reduction, the more UV energy is required. Influent TOC concentration will also affect UV sizing. A concentration of 500ppb (or less) is common after RO pretreatment and TOC at this level are effectively treated with UV. In some cases, a two-stage approach with primary and polishing steps, will create a more efficient water treatment train. Effluent TOC down to <1 ppb has been successfully achieved with UV technology.

UV TOC Reduction Effects on Water

A fraction of organic compounds will be broken down to carbon dioxide (CO_2) and water (H_2O). The generation of CO_2 can be removed with a degasifier installed downstream of the TOC UV unit.

Other more resistant organic molecules are converted to ionic species. The ionic species may lead to a resistivity drop in the water. Downstream high-purity mixed



bed ion exchange resin or EDI can be used to remove ionic species and increase the water resistivity. This combination of UV and ion exchange, or EDI technology, has been successfully used to generate UPW in hundreds of facilities with a resistance of 18.2 M-Ohm water or better. The maximum resistivity of high purity water is approximately 18.3 M-Ohm, which means it is almost non-conductive and entirely free from dissolved cations and anions. 18.2 M-Ohm is categorized as Type 1 or Ultrapure water. It is the theoretical purity of water, used for demanding applications in semiconductor manufacturing, molecular biology, analytical chemistry (trace analysis), nucleic acid sequencing, chromatography, etc.

Summary

Aquafine's UV systems have been successfully demonstrated in the industrial segment for over 70 years. Aquafine systems are known for being an ideal solution for TOC reduction, with more than 500 installations in microelectronics facilities across the globe, given the following benefits:

- Small footprint using modular reactors with vertically-stacked configurations
- Low OpEX from high electrical efficiency UV lamps
- Simultaneous inactivation of microbiological contaminants
- Consistent high quality UPW and HPW achieving TOC levels down to <1 part per billion

The Trojan Technologies Solution

Aquafine, a Trojan Technologies brand of industrial UV water treatment systems, offers a portfolio of robust and flexible UV systems designed to meet the stringent requirements for Life Sciences, Food & Beverage, Microelectronics, and other industrial markets.

OptiVenn: Cost-effective and compact systems designed for low flows

The OptiVenn Series is used for low flow applications to break down TOC while providing simultaneous inactivation of microbiological contaminants.

The OptiVenn is a robust and versatile solution that offers the following features and benefits:

- **Multiple lamp configurations:** Supports a wide flow rate range depending on lamp count.
- **Proven, Robust Components:** UV sensors, lamps, drivers, and panels have demonstrated reliability worldwide in thousands of installations.
- **User-friendly HMI:** Intuitive interface enables at-a-glance check status of the system. Information displayed includes: individual lamp status, operational hours of the system and lamps, UV intensity and temperature condition of the chamber and control panel.

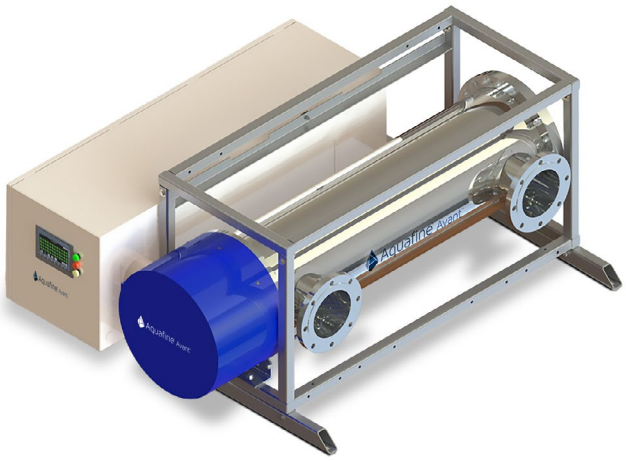
Aquafine®

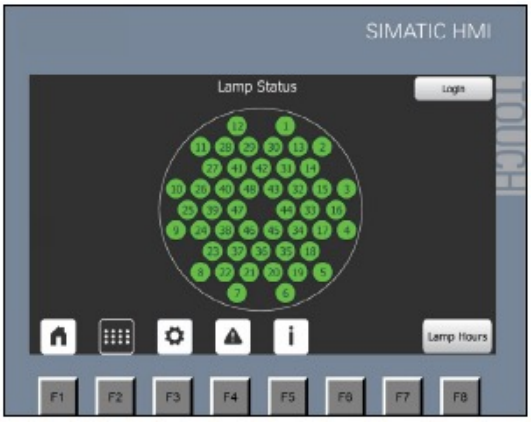
TOC REDUCTION

Avant: Advanced UV systems for mid/high flow applications

The Avant Series is a cutting-edge system that delivers efficient destruction of TOC. The Avant Series includes top-of-the-line components and offers the following features and benefits:

- Synthetic quartz systems that significantly decrease the required system size and power for polishing TOC reduction
- **Advanced Lamp Control:** the system can be operated in three modes; 100% On, Manual Dimming and Grouping. The Grouping mode allows a set number of lamps to be turned off, allowing treatment to be optimized under changing conditions. This enhanced power control allows operators to meet their treatment targets while minimizing their electrical consumption and operating expenses.
- **Preventative Maintenance:** The advanced controls and smart driver technology are combined for enhanced diagnostic capabilities and equipment protection in the event of a fault. The smart driver recognizes lamp failures, preventing the driver from being damaged by trying to turn on a lamp that is no longer operational. Individual lamp and driver monitoring, including power draw information, allows operators to better troubleshoot and stay ahead of unplanned failures.





To learn more about the brands and affiliates of Trojan Technologies, please visit www.trojantechnologies.com

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