APPLICATION NOTE

APPLICATION: Monochloramine Reduction

Aquafine® Ultraviolet Treatment Systems for Chloramine Reduction

Chloramine vs. Chlorine

For over a century, most U.S. public water supplies have used chlorine to meet the standards of the Safe Drinking Water Act of 1974, but over 40% of utilities now use chloramine for its longer-lasting residuals and fewer by-products.

Chloramine — a mixture of chlorine and ammonia — is commonly used as a residual disinfectant in municipal drinking water. Although it is a weaker disinfectant than chlorine, it is more stable, which extends its disinfectant benefits throughout a water utility's distribution system.

Although chloramines can exist as mono-, di-, and tri-chloramine, municipalities increase the pH to avoid production of dichloramine and trichloramine because of serious health concerns. Therefore, chloramination processes are optimized for monochloramine production.

A concern with chloramine is it remains active longer in the water and does not dissipate by itself, which can cause damage to downstream membranes by the oxidizing power of chloramines (as well as chlorine). For municipal water utilities now using monochloramine as a residual in the distribution, this has a negative impact on membrane performance and lifetime.

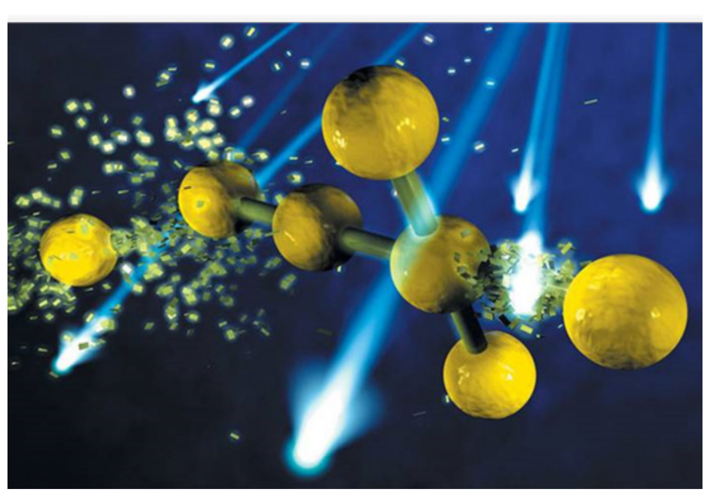
Unfortunately, chloramines come with many disadvantages. Though they help treat water for pathogens, they are also known to be challenging to remove and are a known irritant with corrosive properties.

Common Methods for Chloramine Removal

Ultraviolet Water Treatment

Ultraviolet (UV) technology using low-pressure lamps is a highly effective, versatile, and reliable method to address numerous requirements in industrial water purification applications, including chloramine reduction. Studies have demonstrated conclusively that chloramine residuals up to 4 ppm can be successfully reduced to <0.02 ppm by the application of UV light.

Ultraviolet treatment using photolysis is rapidly growing in popularity. The breakdown products from treating monochloramine with UV are primarily non-hazardous ionic species and subsequently removed by the downstream RO system. At typical pH and dissolved oxygen levels in municipal treated waters, ammonia formation is negligible.



Granular Activated Carbon (GAC)

Carbon adsorbers need to operate continuously to avoid stagnant water to minimize biogrowth. Monochloramine removal by activated carbon is a chemi-adsorptive process. Monochloramine is adsorbed to the surface of the carbon where a chemical reaction occurs. This reaction produces the hydronium (hydrogen) ion, chloride ion, and ammonia. The ammonia reacts with water in an equilibrium reaction producing ammonium ion and the hydroxide ion. Subsequently, the products of monochloramine by activated carbon always produce ammonia. Water purification systems with monochloramine specifically employ "polishing" water softening after activated carbon to remove ammonia (as the ammonium ion) since ammonia, a gas, will pass through downstream RO membranes.

With the high concentration of organics in the carbon bed, the surface of the carbon provides an ideal environment for the growth of bacteria. It is a known fact that carbon units grow bacteria. There must be no stagnant conditions for a carbon unit since this significantly increases bacteria proliferation.

An activated carbon unit should completely remove the residual disinfectant from the municipality and reduce the concentration of Natural Organic Matter (NOM), although NOM is removed by relatively weak physical adsorption. For new activated carbon media the reduction of NOM through the carbon bed may be as low as 30–40%. Activated carbon media is replaced based on breakthrough of monochloramine with the spent carbon removed discarded or returned to the manufacturer.

Bacteria growth occurs because the disinfecting agent (i.e. monochloramine) has been removed. Increased bacteria growth results in the production of bacterial endotoxins with resulting biofilm. Most plants take precautions to control these populations via regular hot water or steam sanitization of the GAC bed; however, bacteria levels quickly return (2–3 days) to the same level as before hot water sanitization.

While well-known for its ability to remove chlorine, regular activated carbon is less effective for chloramine removal, requiring the water to have an extended contact time with the carbon bed.

Catalytic GAC

The transition to chloramine has led to the production of a modified carbon called catalytic carbon. Catalytic carbon is a higher-cost, specialty carbon designed to greatly enhance carbon's natural ability to remove chloramines. Although catalytic carbon is more effective than standard activated carbon for chloramine removal, the challenge of biofouling, increased maintenance and regular carbon changeout remains.

Regardless of the type of carbon used for chloramine removal, it requires a larger physical footprint and water footprint (for sanitization, backwashing and rinsing the carbon) than UV. Additional challenges arise when "Net Zero" directives need to be met with the use of carbon beds.

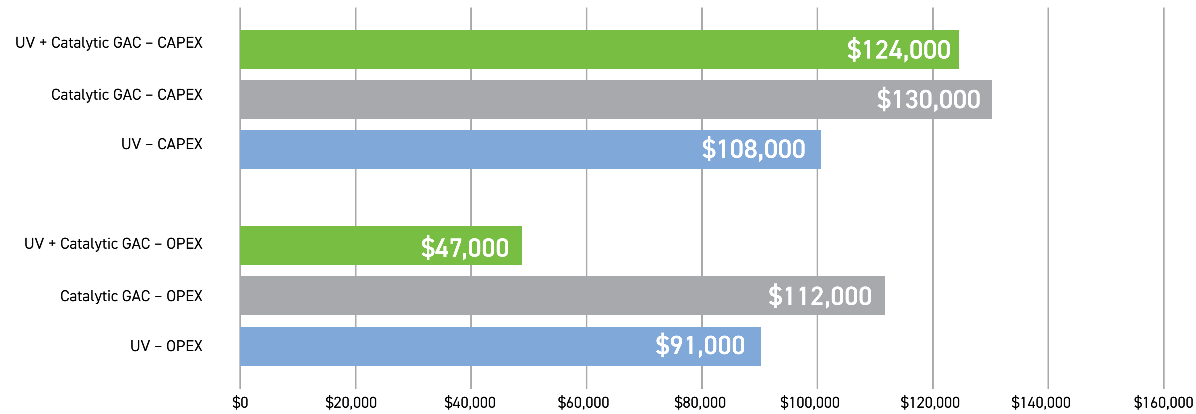
Dechlorination Chemicals

To dechlorinate water, a reducing chemical such as sodium bisulfite can be used but is less common in life science applications. Sodium bisulfite is a dechlorination agent that can remove or neutralize chloramine in water, and effectively eliminates chlorine residuals.

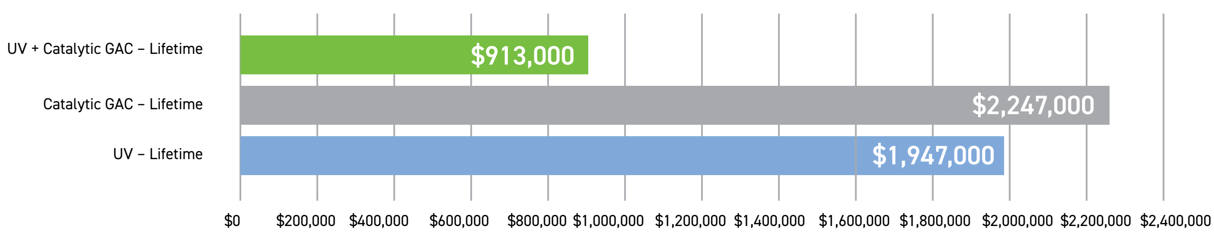
Sodium bisulfite in solid form is mixed to form a solution, or as liquid form, is employed in industrial processes via chemical dosing pumps and metering skids where chloramine removal is necessary. Accurate process control and monitoring of sodium bisulfite delivery is critical, as significant overdosing leads not only to excess operating costs, but sulfate formation, suppressed dissolved oxygen content, and lower pH of the finished effluent. These can have an adverse effect on downstream processes. Furthermore, the addition of chemicals will burden the downstream membranes (if present) and reduce the membrane flux and potentially its longevity.

For compendial water applications, anything injected during the purification process is considered a "Foreign Substance or Impurity". Tests must be performed to demonstrate that anything added is removed. Furthermore, a "Certificate of Analysis" is required for chemicals that are introduced.

Chloramine Reduction Comparison - CAPEX and OPEX



Chloramine Reduction Comparison - Lifetime Cost



Note: Carbon results from third party model developed with Pharmaceutical Water Specialists, LLC (Worcester, MA).
Note: GAC opex includes backwash water, rinse-to-drain water, media changeout, labor, steam for hot water sanitization, and cool down water displacement

Benefits:

Benefits of Using Only UV

When it comes to reducing chloramines in municipal supplies, there are a few options. UV technology has been successfully demonstrated in the industrial segment for being an ideal solution for chloramine destruction, given the following benefits:

- Small physical footprint
- Lower capex and opex compared to GAC
- Achieving chloramine levels down to parts per billion
- No biogrowth; biofouling mitigation extends flux and life of membranes
- Meeting sustainable and/or "Net Zero" objectives
- Drastically reduced downtime

Benefits of Using UV with Catalytic Carbon

Using UV technology in tandem with activated carbon provides a powerful and efficient approach to chloramine reduction. UV handles the bulk of the treatment, reducing chloramine residuals by 99.5% while carbon acts as a polishing step. This not only lowers the amount of carbon required, but also extends its lifespan by up to four times, reducing maintenance frequency and cost. The combination improves water quality by decreasing organics like THMs and mitigates bacterial contamination risks in carbon beds, saving time and resources on sanitations.

Assumptions	
Flow Rate	60 gpm
Water Source	Municipal tap water
Incoming Cl^2 Concentration	2ppm <0.2 ppm chloramine
Operation	24 hours/day, 7 days/week, 50 weeks/year
Electrical Power Cost	$0.15/kWh
Municipal Water Cost	$11.50 /1000gal
Sewer Charges	$16.70/1000gal
Steam Cost	$4.00/1000lb (saturated)
Catalytic GAC Cost	$300/$ft^3$
Carbon Replacement	Every 6 months
Sanitization Frequency	1/week
Backwash Frequency	1/week

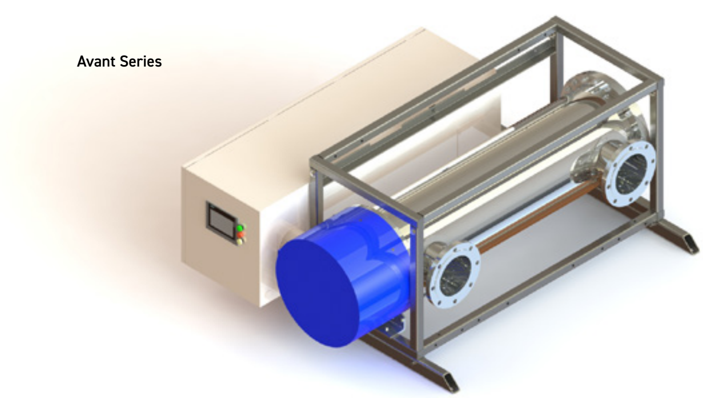
CHLORAMINE REDUCTION

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 Series

Avant Series



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

The OptiVenn Series is used for low flow applications to break down chloramines 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.
- **Flexible:** Can be installed in different positions to adapt to existing pipes and layout constraints; available in ANSI flange or sanitary connection.
- **Proven, Robust Components:** UV sensors, lamps, drivers, and panels have demonstrated reliability worldwide in thousands of installations.

Avant: Advanced UV systems for mid/high flow applications

The Avant Series is a cutting-edge system that delivers efficient destruction of chloramine using a smaller footprint, saves energy and increases flexibility for skid-mounted designs, including the capacity to mount eight reactors in a 3/4 smaller footprint.

The Avant Series includes top-of-the-line components, which lowers the overall cost of ownership and dramatically reduces maintenance.

Features and benefits include:

- **Intelligent Control System:** PLC-based controller with 7" HMI touchscreen to display operating status, alarms, and enhanced lamp and driver diagnostics.
- **Reduced Maintenance:** The control system optimizes reactor operation and monitors the lamps individually while alerting plant operators to replace the lamp before failure, thereby decreasing unplanned maintenance and downtime.
- **Multiple lamp configurations:** Supports a wide flow rate range depending on lamp count.
- **Compact installation:** Multiple UV reactors can be stacked to minimize footprint; available in ANSI flange.

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

TROJAN technologies

AVANT/OPTIVENN | CHLORAMINE REDUCTION

Model Name	OptiVenn 12DDL	Avant 20	Avant 36	Avant 44	Avant 48
Lamps					
Number of UV Lamps	12	20	36	44	48
Power Per Lamp (W)	155 W	155 W	155 W	155 W	155 W
Quartz Material	Natural				
Lamp Type	Low Pressure High Output				
Validated Lamps (Optional)	Yes				
UV intensity monitoring (Optional)	Yes				
Flow Rate					
Maximum Hydraulic Flow gpm (m^3/hr)	80 (18.18)				
Maximum treatment Flow gpm (m^3/hr) based on 90% UVT at 2" I/O	2 to 27 (0.45 to 6.2)				
Minimum Cooling Flow gpm (m^3/hr)	1.5 (0.34)	1.5 (0.34)	2.4 (0.55)	2.9 (0.66)	3.2 (0.73)
Skid option and Skid material	None	Standard			
For Application Specific Sizing, please contact Trojan Technologies					
Treatment Chamber					
Chamber Length Inches (cm)[1]	60 (152.4)	79 (200.6)			
Chamber Diameter Inches (cm)	8 (20.32)	12 (30.5)	14(35.6)	16 (40.6)	18 (45.7)
Standard I/O Size Inches (cm)	2 (5.08)				
I/O Type	Sanitary (Tri Clamp)				
Pressure Rating	Up to 150 psi [PN10]				
Chamber Weight (Dry) lbs (kg)	235 (107)	460 (209)	636 (288)	740 (335)	880 (399)
Chamber Weight (Wet) lbs (kg)	346 (157)	660 (299)	896 (406)	1090 (494)	1430 (649)
Chamber material	316L Stainless Steel				
Elastomer material	EPDM, FKM (VITON)				
Surface finish	RA15[1]				
Ports	Drain - 1" Sanitary Tri-Clamp	Drain - 2 1/2" Sanitary Tri-Clamp			
	Vent - 3/4" Sanitary Tri-Clamp; Sample - 3/4" Sanitary Tri-Clamp				
Hot water sanitization 0^F (0^C)	194 (90)				
Monitoring & Controls					
Base package	Lamp status indicator, System hours of operation, Lamp out alert and Remote start/stop				
Optional package	UV Monitoring Package with UV intensity sensor				

Electrical Requirements									
Electrical Supply	Standard: Single phase, 2 wire + gnd L-N 110V - 120V 50/60 Hz L-L 240V 60 Hz L-N 220V - 240V 50/60 Hz	System Power (kVA)	System Current (A)	System Power (kVA)	System Current (A)	System Power (kVA)	System Current (A)	System Power (kVA)	System Current (A)
208Vac, 3PH, 50/60Hz 3W + GND		3.9	12	6.8	19	8.3	24	9	25
220-240Vac, 1PH, 50/60Hz, 2W + GND		3.9	18	6.9	31	8.3	38	9	41
240Vac, 3PH, 50/60HZ, 3W + GND		4	11	6.9	17	8.3	21	9.1	22
380/220Vac, 3PH, 50Hz, 4W + GND		3.9	7	6.9	11	8.3	13	9	15
400/230Vac, 3PH, 50Hz, 4W + GND		3.9	6	6.9	11	8.3	13	9.1	14
415/240Vac, 3PH, 50Hz, 4W + GND		4	6	6.9	10	8.3	12	9.1	14
440Vac, 3PH, 50/60Hz, DELTA		4	7	6.9	12	8.3	15	9.1	16
480/277Vac, 3PH, 60Hz, 4W + GND		4.3	6	7.2	9	8.7	12	9.4	12

Control Power Panel - Modular (Standard)		
Material & Rating	Standard: Painted Carbon Steel (TYPE 1 - IP 51)	
Dimensions H×W×D Inches (cm)	22.9×22.0×9.2 (58.2×55.9×23.4)	23×66×23 (59×168×59)

AVANT/OPTIVENN | CHLORAMINE REDUCTION continued

Model Name	OptiVenn 12DDL	Avant 20	Avant 36	Avant 44	Avant 48
Control Power Panel - Stand Alone (Optional)					
Standard					
Material and Coating	Painted Carbon Steel (UL or CE TYPE 12 - IP 54)				
Cooling	Forced Air and Vent				
Installation Location	Indoor Only				
Conduit Length	7 feet	9 feet			
Optional					
Material and Coating	304 Stainless Steel (UL or CE Type 4X - IP 56)				
Cooling	Forced Air and Vent, With Shroud				
Installation Location	Indoor Only				
Conduit Length	18 feet	15 feet			
Dimensions H×W×D Inches (cm)	22.9×24.9×9.2 (582×632×234)	65×35×19 (166×90 ×50)			
Certifications	c UL us LISTED				

1. Applies to metal wetted components. Surfaces such a threads, removable components and weld areas will be <RA64.