Foul No More:

Controlling Maintenance and Energy Costs in UV Disinfection

ABSTRACT

Driven by the accumulation of fouling at the sleeve-water interface, maintenance time and costs remain a significant challenge in the application of ultraviolet (UV) disinfection. Studies of the mechanism of quartz sleeve fouling have identified the key factors involved which are categorized as rate of water flow, source water quality, and elevated water temperatures. Existing solutions all have associated challenges albeit they have decreased the manual sleeve cleaning cycle times. Solutions have either focused on mechanizing the sleeve cleaning process or moderating the water temperature within the chamber by releasing hot water. An alternative approach is to avoid the water temperature increase by controlling the actual heat source – the UV lamp. While it is not recommended and often impractical to repeatedly turn off the lamp, it is possible to dim the lamp without prematurely degrading it, while maintaining an appropriate UV dose, reducing heat transfer and thus sleeve fouling. Lamp dimming not only substantially extends the sleeve-cleaning cycle, it also reduces energy consumption generating even more cost savings for the water treatment operation.

KEY WORDS

Ultraviolet disinfection, sleeve fouling, maintenance, lamp dimming

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INTRODUCTION

Minimizing maintenance time and costs is a primary objective in any water treatment operation. With the application of ultraviolet water treatment, the critical factor to control is quartz sleeve fouling. Fouling is the accumulation of mineral compounds on the sleeve, and is influenced by a combination of hydraulics, heat, and water quality effects. Water quality factors like hardness, alkalinity, iron concentration, and pH are all important and site specific. UV transmittance (UVT) of the quartz sleeve is rapidly diminished by fouling, along with disinfection efficiency. Sleeve fouling is exacerbated when there are regular or extended periods of no-flow conditions. During times of no water flow, heat transfers to the water resident in the UV chamber resulting in elevated temperatures within the reactor chamber; compounds exhibiting decreasing solubility with increasing temperatures (like $CaCO_3$, $CaSO_4$, $FeCO_3$) are more readily deposited on the sleeve[1].

In order to maintain complete disinfection, regular manual cleaning maintenance of the quartz sleeve is required. UV manufacturers have responded with product enhancements designed either to facilitate intermittent sleeve cleaning without disassembly or shutdown of the UV system or to moderate the water temperature within the chamber. The latter is typically achieved by releasing some water either in a slow, drip-wise manner or in a cyclical purge. Each approach has some inherent drawbacks.

A novel approach to controlling the water temperature is to control the actual heat source- the UV lamp. Dimming the lamp during periods of no flow conditions decreases power consumption and reduces the amount of heat transferred to the water, thus the rate of sleeve fouling is significantly slowed. This inherently will extend the sleeve cleaning maintenance cycle considerably, allowing for as much as twice the operating time between required cleanings.

BACKGROUND/ PROBLEM STATEMENT

In the US alone, there are well over 19,000 non-transient, non-community water systems (NTNCWS), most of which are small or very small operations relying on private water supplies. For years, ultraviolet disinfection has provided a safe, effective technology to meet jurisdictional water quality requirements. However, there is an inherent challenge for NTNCWSs. Facilities like daycares, churches and schools, or smaller healthcare and elder care operations experience extended periods when the building is vacant, like evenings and weekends or overnight periods where water demand is minimal or non-existent. While actual water usage can vary significantly in a 24-hour period, no-flow periods can account for as much as 60% of the time or more. This can exacerbate one of the most critical challenges in effective UV disinfection – sleeve fouling.



Fouling is the accumulation of mineral compounds on the lamp sleeve. These mineral deposits absorb UV light which decreases the UV transmittance of the sleeve and thereby negatively impacts the intensity of UV light penetrating into the water to be treated. Thus fouling can rapidly and significantly decrease the UV dose the water receives resulting in reduced disinfection performance.

Various chemical and physical characteristics of the water determine the rate at which fouling occurs. It has been demonstrated that the reduction in UV light transmittance through a quartz sleeve occurring in as little as 24 hours can be dramatic[2]. It is influenced by a combination of hydraulics, heat, and water quality effects. Mechanisms of fouling include heat-induced precipitation of metal ions onto the sleeve, gravitational settling or impaction, organic fouling, or photochemical reactions. Key site-specific water quality factors are hardness, alkalinity, iron concentration, and pH. With hard or iron-bearing waters, carbonate compounds (like $CaCO_3$,

$CaSO_4$, $FeCO_3$) that exhibit decreasing solubility with increasing temperature are affected at that sleeve-water interface and deposit on the sleeve. Because this type of fouling is temperature dependent, it will be intensified by periods of no-flow. During these times, heat is transferred by the UV lamp, resulting in water temperatures increasing to as high as 55˚C (131˚F) in the chamber, significantly increasing the rate of sleeve fouling. Fouling necessitates the need for cleaning of the quartz sleeves to maintain optimal system efficiency and performance and the rate of fouling determines the site's maintenance schedule.

SOLUTION

The need for frequent maintenance drives costs for a water treatment operation. The UV industry has responded with approaches that either limit fouling or facilitate sleeve cleaning.

Cleaning strategies for water-side surfaces of the quartz sleeve are either physical or chemical. They include off-line chemical cleaning, on-line mechanical cleaning, and on-line mechanical-chemical cleaning. Performance and cost-effectiveness of these options vary. Although it is labor intensive, off-line chemical cleaning remains the mainstay of the industry. Shutting down the UV system and manually giving the sleeve a thorough cleaning remains both an effective and necessary approach. Visual inspection of the sleeve can occur concurrently. As noted, the sleeve maintenance cycle will be dependent on site-specific fouling.

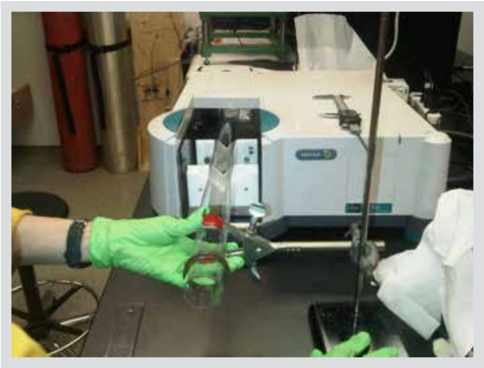
Mechanical cleaning systems facilitate routine cleaning of the quartz sleeve without service interruption or disassembly of the UV system. These accessories may consist of stainless steel brushes, rubber-type wipers, and/or Teflon rings that physically remove foulants from the sleeve. Operated manually, these mechanisms allow cleaning of the quartz sleeve without the need to disassemble the unit, though manpower is still required. They can be automated and once programmed, unattended cleaning of the quartz sleeve can be achieved. Mechanical cleaning systems have shown varying degrees of success in removing scale accumulation. Frequent passes of the wiper over the quartz sleeve may impede the build-up of scale, but ultimately a chemical cleaning will likely still be required. Over time, the wipers of cleaning systems may damage the quartz, creating scratches to which fouling materials may more readily adhere. Consideration needs be given to the maintenance of the wiper system and associated labor cost. Lastly, wiper jams have been known to contribute to lamp breakage. Nevertheless, the sleeve maintenance cycle can be extended with this approach.

The use of mechanical-chemical cleaning systems is typically reserved for larger, high-cost UV installations accommodating very high flow rates.

The alternative approach is to limit fouling by moderating the water temperature in the UV chamber. Configuring the UV installation with a "high heat dump valve" or "purge valve" allows hot water to dump to waste when a temperature threshold is exceeded. Cooler water then enters the chamber. These devices are typically incorporated to manage "low UV" alarms but may also effectively limit fouling. Some UV systems are available with a built-in purge valve or specially equipped to allow a small amount of water to continue to flow through the UV system in periods of no water demand. The downside of these devices is the water wastage which can be considerable over the longer term.

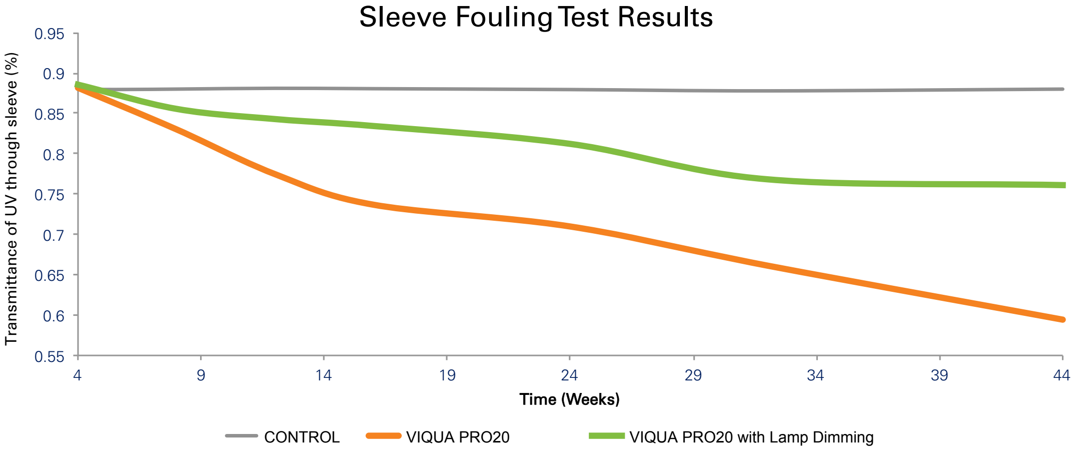
A novel approach to managing the water temperature in the chamber without water wastage is to avoid the temperature rise during no flow conditions. This is achieved by adding technology in the controller that reduces the lamp power or "dims" the lamp during periods of no-flow. By adjusting lamp power to 50%, the water temperature is maintained below 40˚C (104˚F) and the rate of sleeve fouling is significantly reduced. This can only be achieved in UV systems equipped with a flow meter.

To demonstrate the impact on fouling and associated sleeve maintenance requirements, two pairs of VIQUA PRO20 UV systems (equipped with flow meters) were operated side-by-side in a facility mechanical room. The first pair was conventional systems operating at 100% power at all times. The second pair was operated at 50% power throughout, simulating the full dimming condition. Performance was evaluated using UV transmittance (254 nm) through the quartz sleeves compared to a new clean reference quartz sleeve. At timed intervals, the sleeves were removed from the system, visually inspected, and UVT measured by spectrophotometry at the University of Guelph. The rate of quartz transmissibility (UVT) degradation was significantly reduced in the lamp-dimming systems (Figure 1). A distinct visual difference was also observed.



Sleeve fouling testing at the University of Guelph.

Figure 1: Impact of Lamp-Dimming on UVT Degradation



A typical low-UV alarm set point that would trigger sleeve maintenance is 65% UVT. On this basis, the VIQUA PRO20 would have required sleeve-cleaning by week 32 while the VIQUA PRO20 enabled with lamp-dimming would not have required sleeve cleaning until week 72. Thus the sleeve maintenance cycle has been extended by more than 2 times. As discussed, fouling rate is highly site-specific and actual results will vary with water quality. Nevertheless, a similar relationship should hold true. Water treatment facilities incorporating UV lamp-dimming technology can expect up to 60% less sleeve maintenance.

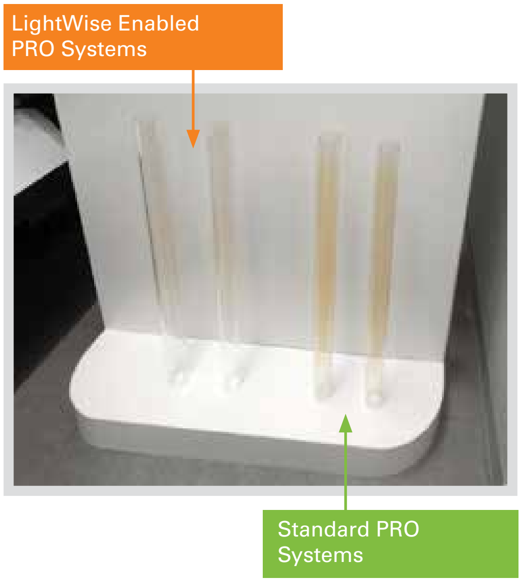


Figure 2: Sample Maintenance Shcedule

Sample Maintenance Schedule

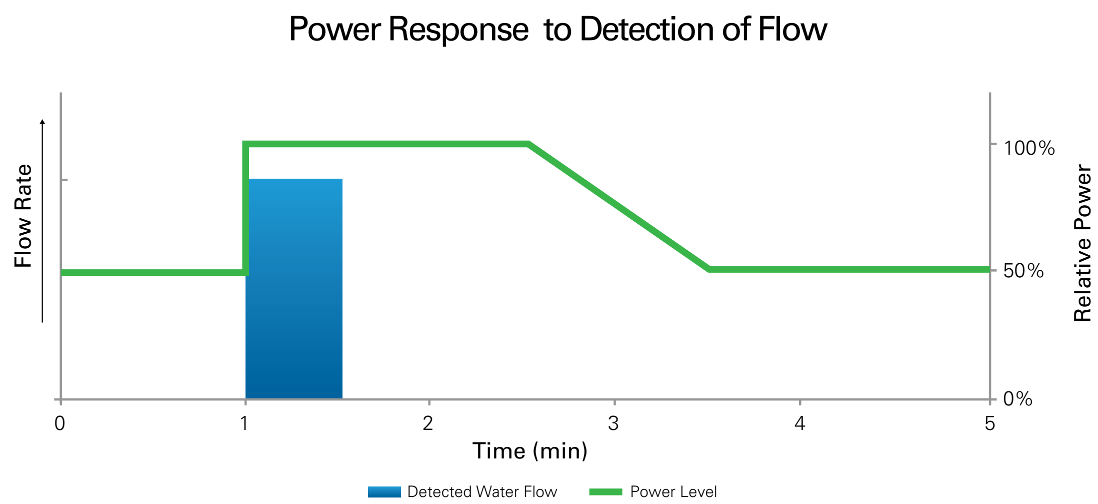
Time (Weeks)	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100
VIQUA PRO20	82%	79%	77%	74%	71%	68%	66%	63%	60%	58%	55%														
VIQUA PRO20 with Lamp-Dimming	84%	83%	82%	81%	79%	78%	77%	76%	74%	73%	72%	71%	69%	68%	67%	66%	64%	63%	62%	61%	59%	58%	57%	56%	55%

Maintenance-Free Period

Actual results may vary with water quality

The lamp dimming is automatically triggered when no flow has been detected for a period of one minute, and the power will have been reduced to the 50% level after another minute. However, when the flow meter once again detects water demand, the lamp immediately returns to full power (Figure 3). This happens with no interruption in disinfection and without the "hotshot" of water that typically occurs after an extended period of no flow.

Figure 3: Power Response to Detection of Flow



For many facilities experiencing extended periods of no flow, this can correspond to approximately 30% less power consumption or more. Facilities need to be guided by the system diagnostics to establish a sleeve cleaning cycle which optimizes energy savings.

CONCLUSION

Sleeve fouling is a constant challenge to the application of ultraviolet water disinfection. The rate of sleeve fouling is influenced by water temperature, water flow, and water quality – specifically the concentrations of calcium, magnesium, and iron in the water, which are the most common minerals that contribute to sleeve fouling. During periods of no flow, the water temperature in the chamber rises and accelerates sleeve fouling. This diminishes the UV transmittance of the sleeve and hence UV effectiveness, necessitating regular sleeve cleaning maintenance. Redress has focused on mechanized cleaning systems that allow cleaning without shut-down or disassembly of the UV system. These sometimes complex wiper systems can become yet another maintenance issue. Alternatively, work-around solutions like installing a hot water purge help control the temperature of the water in the chamber to reduce fouling. Unfortunately, these are wasteful of water – an increasingly important resource.

However, the water temperature can be very effectively managed by reducing the power to the UV lamp during no flow periods. This dimming technology can extend the sleeve cleaning maintenance cycle considerably and contribute to labor and power savings.

ADDITIONAL RESOURCES

1. Clarke, S.H. "Ultraviolet Light Disinfection in the Use of Individual Water Purification Devices," US Army Public Health Command Technical Information Paper #31-006-0211, 2011.

2. Salveson, A., Oliver, M., Bourgeous,K., Mahar, E., "Has Something Gone Foul with Your UV? The Impact of Sleeve Fouling on Delivered Dose," WEFTEC 2004: Session 11-20, pp. 484-495(12), 2004.

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