NEW ADVANCES IN UV WATER TREATMENT

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SUMMARY: *Once tagged as a relatively unknown and potentially expensive water treatment, UV has gained a firmer place in the industry through education and certification. Moreover, advances in the field have made it a more attractive option for many water treatment professionals.*

Ultraviolet (UV) disinfection has long been recognized as one of the most effective, least complicated and least expensive technologies to use for water purification. Recent advancements in UV technology for rural residential, commercial and small community water treatment applications have shown to dramatically improve UV water disinfection effectiveness and safety.

For decades, the industry has relied on conventional UV technologies for water purification. Unfortunately, the design of these systems hasn't changed all that radically and there's risk with problems inherent in conventional, small-scale, drinking water purification systems (see Table 1). Today, a next generation system technology is being introduced to eliminate the risk associated with conventional UV systems.

Below is a discussion of the two distinct technologies, how UV systems that treat drinking water are becoming increasingly advanced, and how safety is taking priority.

CONVENTIONAL SYSTEM DESIGN

The conventional design of pressurized UV systems relies on a single UV lamp or group of lamps installed in a pipe. Each lamp is enclosed in a watertight quartz sleeve. The sleeve is used to protect the lamp from the flowing water for it to operate at its design temperature. The design of these conventional UV systems has some challenges (see Table 1) and this, unfortunately, means safety isn't always completely assured. The system may be "on" but not working, which could put health at risk. Plus, maintenance may be difficult at best.

By enclosing the lamp inside the quartz sleeve in the water flow, 100 percent of the light may enter the water – but efficiency of the UV chamber has been a major challenge for UV manufacturers. The problem of getting as many of the produced UV photons to hit a pathogen in the water requires complicated flow dynamic calculations, and any UV light that gets through the water and hits the side walls of the chamber is absorbed by the walls. The quartz sleeve in a conventional system is inherently strong from the external water pressure and allows for very thin quartz to be used; however, the delicate quartz tubes often break during even routine maintenance. Discoloration, or solarization, is very slow with low-pressure UV lamps and considered insignificant over the life of the system. In addition, small municipal applications raise what they consider to be legitimate concerns regarding precautions that need to be taken in the event that the quartz sleeve and lamps break, and the mercury from the lamps enter into the water stream (regardless of how negligible the amount).

SITUATIONS BY DESIGN

Single-lamp design also seems attractive at first for low-annualized usage costs. Still, dangerous pathogens can clump together and escape UV rays entirely or, alternatively, small particles in the water could shade the pathogens from the light and lead to UV "shadowing" to prevent complete UV disinfection in many of these units. This affects proper transmittance of the UV dose to effectively inactivate targeted microorganisms. Unless this pretreatment is very fine (less than 2 microns), viruses can still be shielded by much larger contaminants.

Since the UV lamp in conventional systems is mounted inside the quartz tube, the lamp overheats when water flow has stopped (overnight, for example) and causes the UV output to drop to unsafe levels. Many systems have been designed to recirculate flows to prevent this from happening. Recirculation loops are complicated and expensive, especially in a home environment. The severe drop in UV output can remain low for several minutes even after water flow starts again. This also limits the system's ability to effectively inactivate targeted microorganisms. Most systems don't have a shut-off valve controlled to a UV sensor because the drop in UV on no-flow conditions would shut off water flow and make it impossible to restart the flow. Systems that turn off lamps on no-flow conditions would rely on flow switches that aren't fail safe. Plus, a homeowner wouldn't like to wait a few minutes every time they wanted water. Finally, lamp on/off cycles cause reduced lamp life.

Table 1. *New generation/conventional UV comparison*

RISK OR PROBLEM	CONVENTIONAL UV	NEW GENERATION
Minerals coat the quartz tube	Low UV treatment, difficult to access and clean, and possible quartz breakage	Automatic cleaner keeps quartz clean, UV always high, and no maintenance required
Power loss to UV system	No UV or alarms, water still flows	Water shuts off by automatic solenoid valve
UV sensor alarms	Four possible problems, cannot be identified	Problem easy to diagnose, two UV sensors
Particles cause UV shadow	Pathogens can survive in shadow, low treatment	360 UV irradiance, no shadowing
No flow, lamps overheat	Low UV output for several minutes until flow established	Lamps air cooled, no loss in UV

Other systems lack sensors or alarms entirely, and have no fail- safe, shut-off valves. As a result, unsafe water can enter the water system with no prevention or warning.

UV sensors cannot distinguish between low UV lamp output, quartz and sensor fouling, and low water transmittance to UV light. Small municipal applications are increasingly requiring UV transmittance readings. For example, the Ontario (Canada) Ministry of Environment's new proposed guidelines require continual, water transmittance monitoring for community systems.

In addition, conventional system design also necessitates UV sensors be mounted in watertight enclosures prone to fouling. Those systems with UV sensors suffer from false alarms due to sensor fouling caused by suspended particles, minerals and metals (1).

Since the lamp is mounted in a quartz sleeve, changing a lamp takes a long time and may require system drainage and removal of the quartz tube. Fouled quartz tubes need to be removed and cleaned periodically with acid or scrubbed to remove mineral build-up. Some systems employ moving wiping assemblies that must be powered by expensive linear actuators or air cylinders. Others use a hand-powered wiper that the owner pulls back and forth to clean the quartz.

Most UV systems on the market which use automatic quartz cleaning incorporate a reciprocating device with a Teflon or Viton scraper that moves along the outside circumference of the quartz tube. If the coating is slightly covering the quartz tube, this type of cleaner works well. If the minerals have had time to bake onto the quartz surface, however, they become much more difficult to remove with this type of wiper. Other systems use a stainless steel brush instead of Teflon, and yet another uses a container of acid enclosed in a movable capsule to clean the quartz. Without cleaning assemblies, maintenance is difficult and must be done frequently, particularly if the treated water has high mineral content.

NEXT GENERATION UV DESIGN

New advances in UV treatment have emerged that differ radically from conventional UV system design. By turning existing UV system design inside-out, water is pumped inside the quartz tube for treatment instead of outside the tube. In addition, UV lamps are mounted outside the quartz in air.

It has also been found that a higher UV dose can be obtained by using two lamps in conjunction with elliptical reflectors. This technique of mounting the lamps outside the quartz tube has proven to be a very efficient use of UV light since 95% of the UV light will reflect back into the quartz tube for a second or third time. Light is, therefore, maintained by hitting a non- reflecting wall as in conventional design. A comparison of efficiencies between the two technologies shows a more-than-double UV dose for each watt of electrical power consumed.

Automatic quartz cleaning devices have also been introduced to minimize and, in most cases, eliminate quartz fouling completely. The unique advantages of passing the water inside the quartz tube make the automatic cleaning device both affordable and effective. By using a built-in mechanical device consisting of a simple central turning shaft and stainless steel wiping blades, the necessity for the complicated reciprocating motion used in conventional systems is eliminated.

An additional innovation in UV system design includes use of multiple sensors capable of monitoring both UV lamp output and water UV transmittance separately. UV sensors also can be mounted in air to prevent fouling and need for high-pressure housings. Percentage of UV transmittance can be calculated with assistance of a microprocessor to compare sensor readings of one UV lamp output with output of the second lamp sensor readings as seen through the water and quartz tube.

Having the lamps mounted outside the quartz tube ensures lamp output isn't dependent on water temperature. The lamps are cooled by natural convection, which means water is always treated at the maximum dose from the first glass in the morning until the last one at night. Lamp changing becomes a quick two-minute task requiring only a screwdriver; and the quartz tube doesn't have to be removed or water drained.

Next generation UV system technologies also eliminate the need for a water softener. Water doesn't need to be pretreated to remove iron, manganese, total dissolved solids (TDS) or reduce hardness since the automatic quartz cleaner works for most water conditions. As required by all UV systems, however, the water must be checked for low UV transmittance. If the water has been found to have less than 75% transmittance, then UV may not be a good choice for disinfection or a pretreatment device must be installed to remove the cause of low UV transmittance. Most drinking water supplies in North America are in the range of 85-95% transmittance.(2).

SAFETY FIRST

Given dramatic advancements in UV technology, how does one begin the process of researching how to obtain the safest, most reliable system available? All UV systems should be tested and certified so their dose and UV transmittance sensors meet NSF Standard 55A — Ultraviolet Microbiological Water Treatment Systems. This standard ensures the UV system will deliver a minimum dose of 40 milliJoules per square centimeter (mJ/cm^2) – 40 milliwatt-seconds per square centimeter ($\mu W\text{-}sec/cm^2$) – at the end of lamp life, and the UV sensor will detect if the transmittance in the water drops below safe levels. Next generation systems have been tested by NSF under Standard 55A and found to exceed dose requirements by 60% at a flow rate of 13 gallons per minute (gpm).

Any UV system that's used to protect people from drinking contaminated water must have a method to detect when the water isn't being treated with sufficient UV dose. Preferably, the system should incorporate a normally closed electric solenoid valve that shuts off the water if a problem occurs with the UV system. A normally closed valve is one that closes on loss of power. This is called a "fail safe" valve since its mode of failure is in the safe condition.

Most conventional systems rely solely on a visual and/or audio alarm to warn if a problem occurs. A blown fuse in the UV system or a loss of power to the UV system, however, would shut down both lamps and warning devices, but still allow the water to flow untreated. It's also possible a system owner may not hear the alarm if it's coming from a remote part of a home. Some UV monitor devices utilize a current or voltage sensor that ensures the lamp is powered. Yet, this type of lamp detector device doesn't take into account quartz fouling, low UV output or low UV transmittance of the water. Water could still be passing through a UV system with this kind of lamp monitor with little or no treatment.

CONCLUSION

Today, UV is the only NSF-certifiable biological water purification system. With increasing awareness of NSF standards and a related new U.S. Environmental Protection Agency ruling on groundwater for release in spring of 2003 (see www.epa.gov/safewater/gwr.html and www.epa.gov/safewater/-mdbp/-alternative_disinfectants_guidance.pdf), the adoption of UV will continue to flourish as an integral component of a multi-barrier water purification system. Undoubtedly, we will continue to see increasing developments in UV technology for even greater safety and performance.

References

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