

Whitepaper

Addressing Point-of-Entry Water Disinfection with UVC LEDs

The use of ultraviolet (UV) mercury lamps in point-of-entry water disinfection has provided homeowners with microbially safe water throughout their homes.

However, as concerns loom around bans on mercury lamps, either from the Minamata Convention or consumer sentiments, more OEMs have been investigating UVC LEDs as a potential way to access the UV spectrum for their products.

UVC LEDs have several advantages over traditional UV lamps. They make the system more energy-efficient, have a longer lifespan, and are less likely to break or malfunction. In addition, UVC LEDs are safer than traditional UV lamps because they do not emit harmful mercury vapor or require hazardous waste disposal. As a solid-state technology, they can also be cycled on and off unlike the long warm up and cool down cycles for lamps. This means they offer a means for more energy efficient operation—increasing the effective system life roughly 5-10 times. By improving system life, the end user benefits from reduced maintenance and a lower total cost of ownership.

Understanding UV light sources

UVC LEDs are a safe, effective, and environmentally friendly ways to treat well and post-filtration municipal water. They can help to protect people from waterborne illnesses while having no adverse effect on the temperature or odor and taste of the treated water. They are incredibly compact—allowing for more design flexibility and provide a more optimal output for disinfection.

UVC LED technology has come far in recent years—now reaching a tipping point in many applications where the benefits of UVC LEDs create a compelling case for system redesign.

Table 1: UV Light Source Comparison

	Low Pressure Mercury Lamp	UVC LED
Heavy Metals	Mercury (20-200mg)	None
Warm Up Time	1-15 Minutes	Instantaneous
Wavelength	254 nm	250 nm - 280 nm (can tailor to application)
Voltage	110 - 240V AC	6 - 12V DC
Current	0.5 - 2.0 A	0.02 - 0.5 A
Lifetime	8,000 hours	> 10,000 hours

In UV disinfection, short wavelength ultraviolet (UVC) light in the range of 250 to 280 nm disrupts the DNA of microorganisms rendering them unable to reproduce. The action spectrum for bacteria is commonly reported as 200 to 300 nm with a peak between 265 to 267 nm wavelengths, with some variation across species (Figure 1). Low-pressure mercury lamps emit a discrete wavelength at 254 nm whereas UVC LEDs can be tuned by the manufacturer to emit in a specific wavelength range.

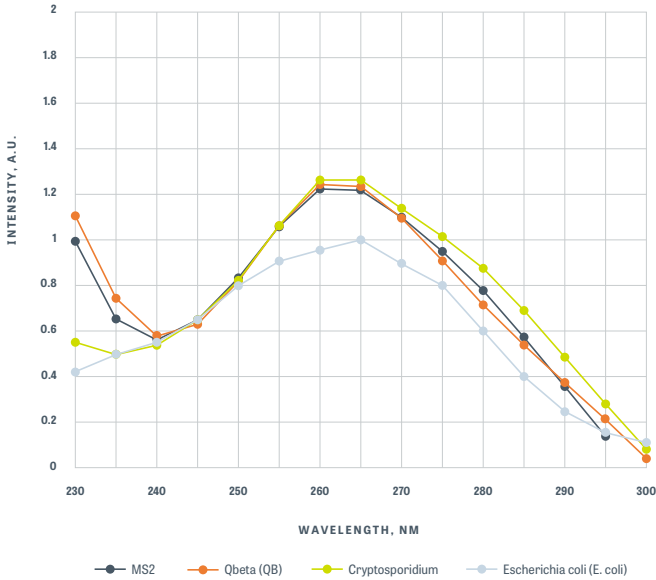


FIGURE 1: Absorption curves for common target microbes.

When selecting a UVC LED, it's important to understand the target microbe, or biosider, that is being used to design your system and its spectral response. A biosider is a surrogate microbe used to measure the performance of a system to ensure it delivers the disinfection performance for the application. These are often defined by industry standards such as NSF, or regional regulatory standards like the EPA, however some manufacturers may prefer to use a specific microbe based on their own application specific requirements.

Once the target microbe is selected, the system designer can consider the dosage required to meet the disinfection target. For example, with NSF 55 Class B the disinfection target is 2.0 LRV at beginning of product life for the surrogate Q-Beta.

Dosage is the energy required to reach a specific log reduction of a target microbe. Dosage is a function of UVC energy over time, and thus it depends both on the energy at the specific wavelength and the time of exposure. It's possible to use a lower power LED, or one of a less ideal wavelength, if you have more time allowed for disinfection—or a lower flow application. In water disinfection, the power at the specific wavelength will directly relate to the ability to disinfect higher flows of water.

As the power output, lifetime and wall plug efficiency of UVC LEDs improves, we're now seeing OEMs prefer to use these light sources in their designs as they can often meet or exceed existing lamp-based system performance.

Example Reactor Performance

To illustrate the operation benefits of a UVC LED over a mercury lamp in a POE water disinfection system, we will review a prototype reactor design and validation testing results. Traditional reactors using mercury lamps will place the lamp inside the reactor – using the water being disinfected to also function as a thermal management system. This can lead to a hot first glass of water as the water in the reactor chamber is being heated by the lamp before dispensing.

In the case of an LED-based design, the thermal management is handled as a separate system, not impacting the water inside the disinfection chamber. Two concept designs can be seen in Figure 2.

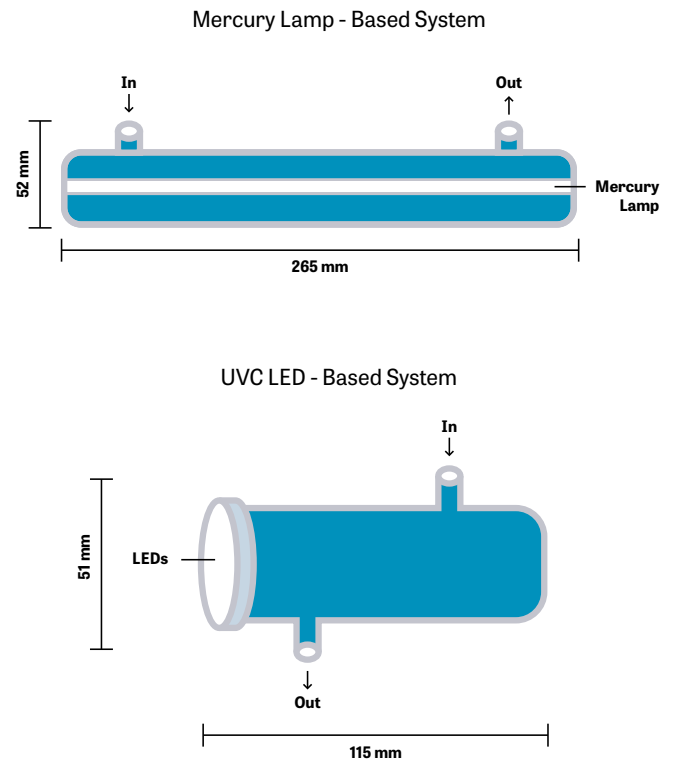


FIGURE 2: POE Reactor concept designs. Source: UVC LED Reactor for Point of Use Water Disinfection System, S. Otsuki, et al. Asahi Kasei Corporation, ICULTA 2023

The performance of these two systems – the mercury-based reactor and the UVC LED-based reactor were tested by Asahi Kasei (Fuji, Japan, www.asahi-kasei.com). The systems were operated using the experimental set up illustrated in Figure 2 to operate at a flow rate of 8 liters per minute with a UVT of 97% at 265 nm. The target microbe for disinfection in this experiment was e. coli. The lamp used in the lamp-based system was a 6-watt lamp, and the drive current for the LED was adjusted so that the power consumption was 6 watts to achieve a more equal performance comparison between the two systems. It’s important to understand that in this context, 6 watts refers to the input power driving the light source. This is different than the power output at the UVC wavelength—which is the emission intensity available for disinfection.

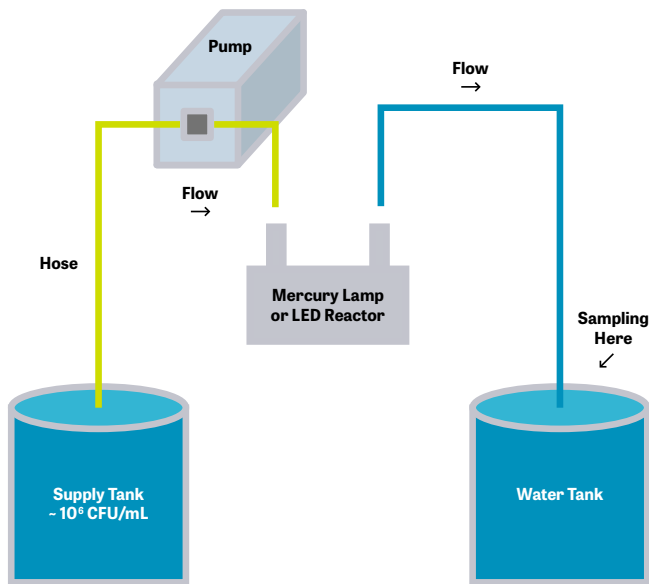


FIGURE 3: Experimental Set Up. Source: UVC LED Reactor for Point of Use Water Disinfection System, S. Otsuki, et al. Asahi Kasei Corporation, ICULTA 2023

Sample water was taken after two minutes of steady operation for both systems and the colony forming units of the sample water was counted before and after passing through the reactor. Three samples were taken from each system and the disinfection performance was evaluated. The results showed that the LED-based system provided an average of 6.3 log reduction across the three samples taken, while the traditional mercury-based system achieved a 3.6 log reduction. (Figure 4)

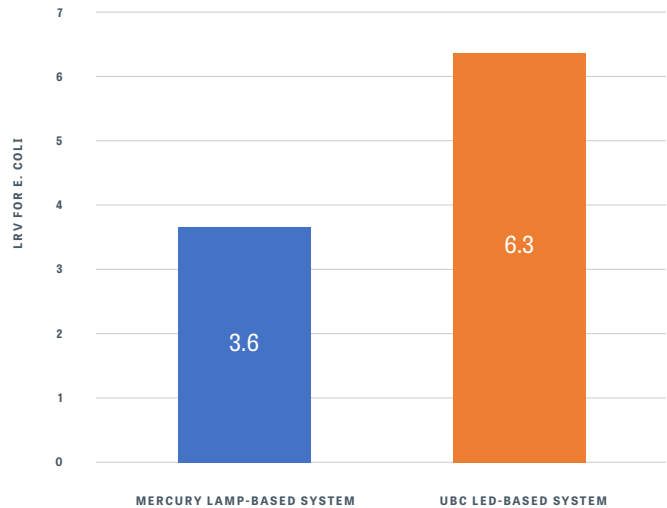


FIGURE 4: Log Reduction Value for e. Coli. Source: UVC LED Reactor for Point of Use Water Disinfection System, S. Otsuki, et al. Asahi Kasei Corporation, ICULTA 2023

Benefits of Designing with UVC LEDs

The experiment clearly shows that a 6 Watt UVC LED system can meet the performance of a 6 Watt mercury-based system when looking at e coli at 8 liters per minute. Not only does the LED system provide a performance benefit, but it can also provide other benefits to the OEM, service provider and consumer.

Just as with visible LEDs, consumers experience a reduced cost of ownership when switching to a UVC LED-based system. Legacy lamp systems typically employ lamp cycling during the idle mode to reduce the impact of lamp warm up time on the consumer.

A system using a 6-watt lamp may consume only 3 watts while in idle mode, operating at full power 10% of the time, and idle the remaining 90% of the time. At this rate, the system would consume just under 30 kWhr per year from the home electrical supply. According to the U.S. Department of Labor, the average electricity kWh in the US is 0.165 as of May 2023, making the operating cost just under \$5 for a typical year.

On the other hand, as LEDs reach full power in under a millisecond and the lifetime is not impacted by on/off cycles, the system can be designed to only operate while disinfecting water without the need for an idle mode. Thus the system would use less than 6 kWhr per year—costing the homeowner less than a dollar in energy costs annually.

If we look at the annual maintenance – service providers can continue maintenance contracts for filter changes and system checks, but they no longer will be required to replace light sources. The on-demand operation of a UVC LED-base system means that the typical UVC LED will last the full lifetime of the system — 5-7 years. This reduces the incidents of unplanned maintenance due to light source failure or the handling of hazardous waste from mercury bulbs. This enables OEMs to meet company sustainability goals for product designs and reduce their environmental impact.

As more OEMs commercialize POE systems based on UVC LEDs, this technology will extend to other areas in the POE ecosystem. For example, UVC LEDs are also be considered post-activated carbon treatment to address PFAS regulations while ensuring microbial safe water. The inherent benefits of UVC LEDs around on-demand operation, maintenance-free designs and alignment with sustainability goals will make this technology a staple in POE systems over the next 5 years.

WE INVITE YOU TO LEARN MORE ABOUT OUR UVC LEDs.



70 Cohoes Avenue, Green Island, NY 12183 U.S.A.
518.271.7375 | www.cisuvc.com | sales@cisuvc.com

©2023 Crystal IS, Inc. All rights reserved. Crystal IS, Klaran and the Crystal IS logo are trademarks of Crystal IS, Inc. and/or its affiliates. All other trademarks are the property of their respective owners.