Proven And Effective Wastewater Disinfection … Why UV?

For the past few decades, and increasingly today, ultraviolet (UV) radiation has been successfully used around the world for municipal wastewater disinfection. As a growing alternative and a direct replacement technology to chemical (chlorine) disinfection, UV does not produce harmful by-products and is non-toxic to the environment. Furthermore, UV technology is recognized as the "green" disinfection solution with a low environmental impact.

TrojanUV is a global provider of UV disinfection systems, with decades of expertise behind them. Water Online spoke with Wayne Lem, TrojanUV market manager, to find out more about this important technology.

Utilities are tasked with protecting public health and the environment, and disinfection is critical for doing so. What are the most commonly used alternatives for disinfecting treated wastewater?

Traditionally, the use of chlorine gas was the most common method of wastewater disinfection. Chlorine gas itself is relatively inexpensive but is a highly toxic chemical that must be transported and handled with extreme caution. It is stored under pressure in large tanks and is released into the wastewater as a gas. Sodium hypochlorite is a diluted liquid form of chlorine that is also commonly used.

Today, UV disinfection is widely accepted for municipal wastewater disinfection around the world. UV is rapidly growing, given it's a safe and cost-effective alternative over chemical disinfection. Also, it produces no disinfection by-products or a chlorine residual, which is harmful to the environment. The UV disinfection process adds nothing to the water but UV light, and therefore, has no impact on the chemical composition of the water.

How effective is UV at destroying pathogens, as compared to chemical disinfection methods?

UV is a very cost-effective and a reliable technology that protects the public against pathogenic microorganisms, including protozoa, bacteria, and viruses. Chemical disinfection using chlorine is also effective against these pathogens; however, there

CHLORINE CONCERNS	UV SOLUTIONS
Safety of the environment and the public result in additional expenses for those who opt for chlorine.	UV disinfection does not require these extra expenses – cost-effective solution.
Some regulations require specially designed buildings for chlorine.	UV systems can be placed outdoors and does not require a building - UV is a physical, chemical-free process that adds no chemicals to the water.
Transportation and storage of the toxic chemicals used for chlorination/dechlorination.	UV disinfection is safe for operators and the community.

are pathogens such as *Cryptosporidium* and *Giardia* which are chlorine-resistant but can be disinfected by UV light.

Unlike chemical approaches to water disinfection, UV provides rapid, effective inactivation of microorganisms through a physical process. The retention time required to achieve disinfection ranges from a few seconds compared to several (>30) minutes for chlorine disinfection. This eliminates the need for large chlorine contact chambers, thereby reducing the required footprint and cost of installation.

Are there any employee safety issues involved with operating a UV disinfection system?

There should be safety plans in place for any disinfection technology used. The safety risks for operating a UV system, although low, are related to operator exposure to high levels of UV light and possible electrical hazards. The exposure to UV light is very low given that UV light is shielded from operators by channel grating and "light locks." As well, there are lock-outs in the power cabinets to ensure power is off, and lock-out/tag-out occurs when servicing a UV system. As with operating and working with any type of equipment, it is recommended that proper personal protective equipment (PPE) be worn and safety procedures be followed.

Owners and operators of UV disinfection systems should have operational practices in place. These are generally provided in the O&M manual from the UV system supplier and cover several items, including:

1. Procedure for lamp maintenance and replacement
2. Procedure for monitoring the system operation
3. Proper disposal of UV lamps, ballasts, quartz sleeves, and other components

What type of public safety concerns are associated with the use of UV disinfection versus chlorination?

The advantage that UV disinfection is a physical process and does not alter the quality of the water also makes it a perceived disadvantage, in that it does not leave a residual for monitoring. Without a residual, there may be a concern that the UV dose is low and pathogens are not being adequately disinfected, and/or pathogens can sometimes repair and reverse the destructive effects of UV through a "repair mechanism," known as photoreactivation, or in the absence of light known as "dark repair." Although these may be legitimate concerns, they can be overcome by working with a UV supplier with proper sizing tools and expertise in leading-edge controls and monitoring. Through proper sizing, an adequate UV dose can be delivered to prevent photo reactivation. Furthermore, through incorporating a robust and calibrated UV lamp intensity sensor for dose control, the real-time UV dose for the system can be monitored and controlled to ensure continuous adequate disinfection.

Another major advantage is the fact that with UV, the public has no possible exposure to the accidental release of hazardous chemicals.

TRAINING	Provide training on UV system components, theory, design, and O&M
	Teach operators how UV dose monitoring differs from chemical disinfection
	Provide training on criteria for UV sensor accuracy, calibration, and replacement
	Stress the importance of UVT and UVT monitor calibration on dose delivery
	Provide guidance on when to replace lamps, given that they continue to operate well beyond their warranted lives
	Teach operators how to quantify lamp aging and fouling and define cleaning frequencies
	Train operators on response procedures for broken UV lamps

How do employee training requirements compare for UV as opposed to chlorine gas or hypochlorite disinfection methods?

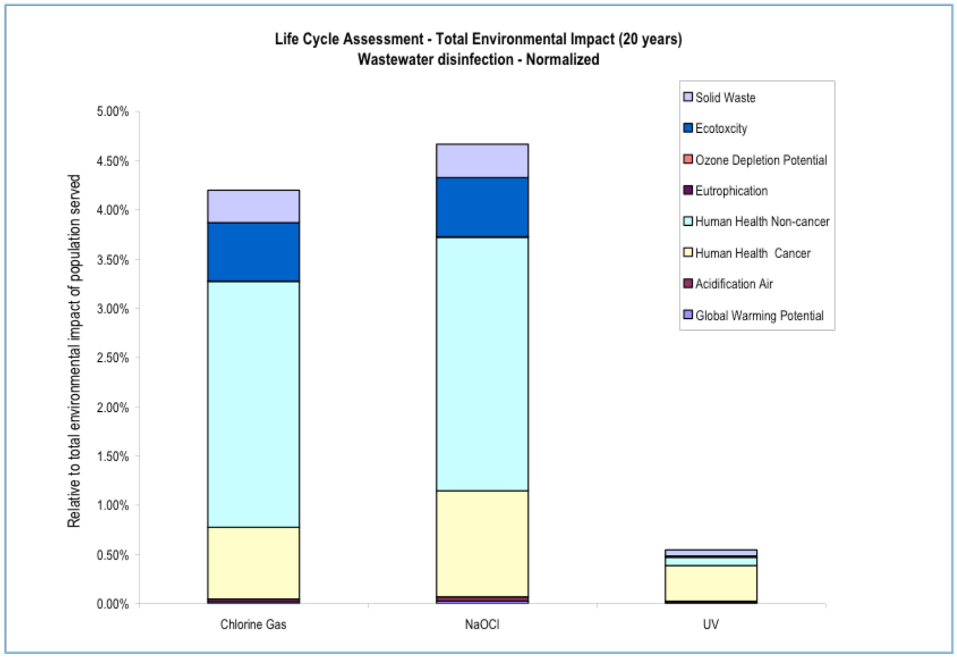
In comparison, facilities with chlorine systems may need to institute a full Risk Management Program as specified by the U.S. Environmental Protection Agency, as well as a process safety management program required by the Occupational Safety and Health Administration. Training and operational controls for these programs are extremely time consuming and expensive.

Is data available to show the environmental impact of UV versus chlorination for disinfection?

The evaluation of chlorination and UV disinfection processes in a lifecycle assessment (LCA) can be performed to determine the environmental impact of each technology. In a LCA, various environmental impacts are taken into account, such as ozone depletion, global warming potential (carbon footprint), acidification, eutrophication, eco-toxicity, human health effects, resource depletion, and land use. When the data is normalized based on the population of a given city, the results can be compared between various disinfection processes. UV has the least environmental impact since the biggest contributor to environmental impact is the transportation of chemicals due to the burning of fossil fuels.

Graph below: Based on a city of 50,000 residents in Washington, USA, the environmental impact of installing UV is significantly less than chlorination. Over time, as the energy source becomes renewable, the environmental impact of UV will be further reduced.

Also, as noted previously, UV adds no toxic chemicals to the water and creates no harmful by-products.



What costs should be considered in the 20-year lifecycle cost evaluation for a new facility requiring disinfection?

The total lifecycle cost of any disinfection system includes both the initial equipment capital cost and the recurring annual operating cost over the life span of the disinfection equipment. Lifecycle cost evaluation offers a good economic model to evaluate alternatives for equipment and projects. Good engineering proposals without thorough economic justification are generally uneconomical. Good engineering paired with good economic analysis provides business successes. The lifecycle cost evaluation of a project provides better assessment of long-term cost effectiveness of a disinfection project than can be obtained with only capital cost decisions. The objective of lifecycle cost evaluation, or net present value (NPV) analysis, is to identify and select the most cost-effective approach to achieve the lowest long-term cost of ownership after comparing a series of alternatives.

The cost of chlorination equipment is typically a small part of the overall capital cost. Because chlorination requires a lengthy retention time, a large chlorine contact tank or channel is required unless one already exists. This adds additional concrete, civil works, excavation, and construction to the overall capital cost. Due to the hazardous nature of chlorine gas, an emergency scrubber system and an enclosed building may need to be installed to protect operators and the surrounding community from a dangerous chlorine gas leak. Sodium hypochlorite (liquid chlorine) has similar equipment and chlorine contact tank costs as chlorine gas. However, if the hypochlorite is delivered to the plant, there will be additional costs associated with building storage facilities to store this corrosive chemical. The large volumes of hypochlorite required means large storage tanks are needed, thereby increasing the total capital cost. If UV equipment is to be retrofitted into an existing chlorine contact tank, the majority of the cost will come from the equipment, and additional space can be reclaimed because of UV's small footprint. If a concrete channel is to be constructed, the cost to accomplish this is significantly smaller compared to chlorine since the footprint of a UV system is much smaller. UV disinfection occurs in seconds, whereas chlorination requires several minutes of retention time.

The annual cost of operating and maintaining a disinfection system can have a significant impact on the economic evaluation of each option. The operations and maintenance (O&M) costs include the cost of chemicals, electricity, replacement parts, and labor required to maintain each system. The hazards of chlorine gas results in a significant amount of investment into training staff, emergency preparedness planning, and maintaining the chlorine system. Chlorine gas prices are relatively low, but this is often outweighed by the intensive maintenance and safety precautions needed for the system. Due to the corrosive nature of chlorine, piping and pumps are prone to leaks and scaling and subsequent replacement. Scaling buildup in piping and pumps

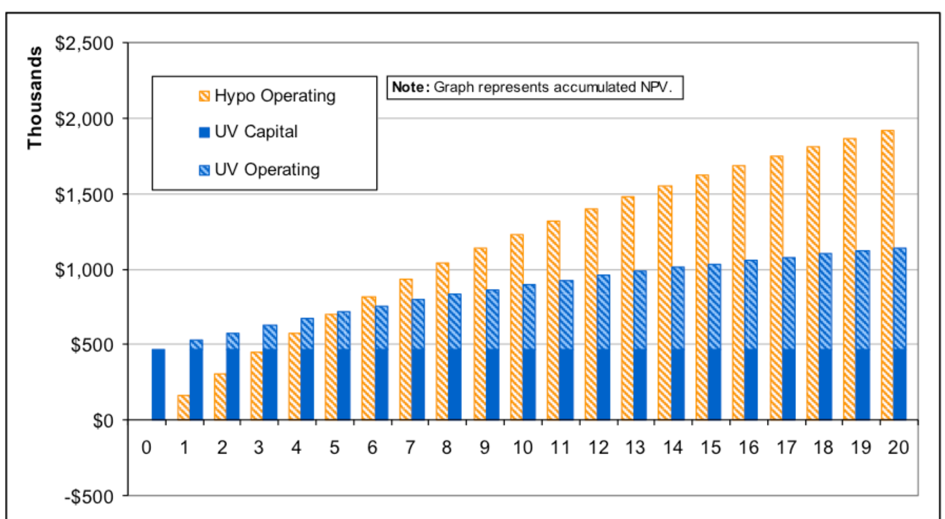


Figure 1.0

requires regular acid cleaning to remove. Therefore, these ongoing maintenance costs associated with chlorination systems must be addressed when comparing disinfection alternatives. The O&M costs associated with UV consists primarily of lamp replacement costs and the electrical cost of operating the UV system.

Any disinfection alternative evaluation should also take into account the non-economic factors that can heavily weigh into the decision-making process. These factors typically include operator and community safety, ease of operation, space requirements, and environmental impact.

Are there economic or other advantages to be had by retrofitting existing chemical disinfection facilities to UV?

The cost of retrofitting an existing chlorination system to UV is a common economic evaluation and often reveals UV having the lowest lifecycle cost. The capital cost of a UV system is higher than a typical sodium hypochlorite system. Fortunately, the operating cost of a typical UV system is significantly lower than a hypochlorite system due to the increasing cost of chemicals. The retrofit of an existing hypochlorite system to UV has a higher initial capital cost, but over a span of a few years, the cost of the UV system would provide a return on investment. This payback is illustrated in Figure 1.0, which shows the cost of electricity and replacement lamps being lower than the cost of purchasing hypochlorite.

This graph represents the accumulated net-present value cost of UV and sodium hypochlorite for an actual wastewater treatment plant in New Jersey, USA. Based on a design flow of 16 MGD and average flow of 10 MGD, the cost of the UV system would almost equal the cost of staying with hypochlorite in 5 years. Over the long-term, UV becomes the more cost-effective solution at this plant.

Table showing summary of operating costs for hypochlorite and UV disinfection:

SODIUM HYPOCHLORITE	UV DISINFECTION
Annual Cost = $166,900	Annual Cost = $58,100
• Sodium Hypochlorite • De-chlorination (SO2 or Bisulfite) • Hazardous Chemical Handling Charge • Fuel Delivery Surcharge • Laboratory Chlorine Testing • Electrical Cost • Chlorine Residual Probe • Hypochlorite Tank • Hypochlorite Containment • Hypochlorite Feed System • De-chlorination Feed Equipment • Personal Protective Equipment • Annual Equipment Maintenance (including de-scaling) • Spill Kit	• Lamp Replacement • Electrical Requirements • Equipment Maintenance • Indicator Organism Testing • Wiper Seals, solution, parts • Ballasts Replacement (if required)

The table above summarizes the factors that were taken into account for the operating cost of the wastewater treatment plant illustrated in the figure above. Plants can also benefit from the non-monetary benefits of a UV system, such as increased operator safety and the use of UV as a public relations tool, to emphasize the plant's use of "green" technology. ■