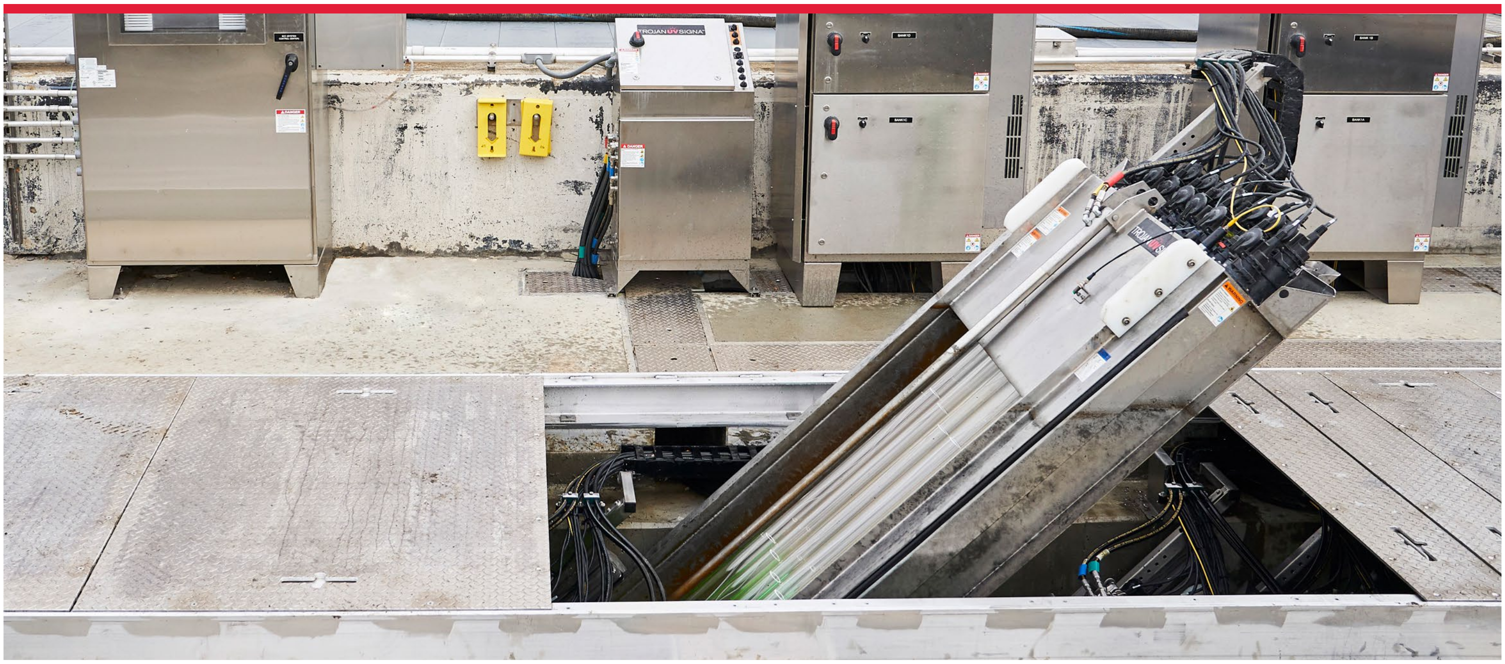
EBOOK

An Introduction to UV Treatment for Municipal Wastewater eBook

TROJAN technologies® | TROJANUV®



An Introduction to UV Treatment for Municipal Wastewater

We developed this eBook to give you the information you need to know about UV treatment for municipal wastewater. It's chock-full of insight and answers many frequently asked questions, such as:

- **Why does wastewater need to be treated?**
- **What is ultraviolet (UV) light?**
- **What happens to microorganisms when they are exposed to certain wavelengths of UV light?**
- **How does UV light treat wastewater?**
- **How long has UV been used as a treatment method?**
- **What are the distinct types of UV lamps?**
- **What are the operating advantages of UV?**
- **What are the cost advantages of UV?**
- **How does UV treatment fit within an existing water treatment regulatory framework?**

Are you currently using a different method to treat wastewater and are wondering why you'd ever convert to UV? **Well, then this eBook is for you.**

Are you already treating wastewater with UV and want to learn more about how it works? **This eBook is perfect for you too!**

Even if you're just looking for some general information about UV and wastewater treatment, you're in the right place.

Ready? Okay, let's go!

WHY DOES WASTEWATER NEED TO BE TREATED?

The final step in municipal wastewater treatment is the inactivation process which is required to reduce microorganism populations in the wastewater before discharge into the receiving body of water. These microorganisms are typically microbes that may cause disease in humans, which must be treated before the wastewater is discharged to a lake or river. There are often recreational activities such as swimming or fishing where the public can come into contact with the local bodies of water. By reducing the concentration of microorganisms in the water, treatment is able to benefit the public.

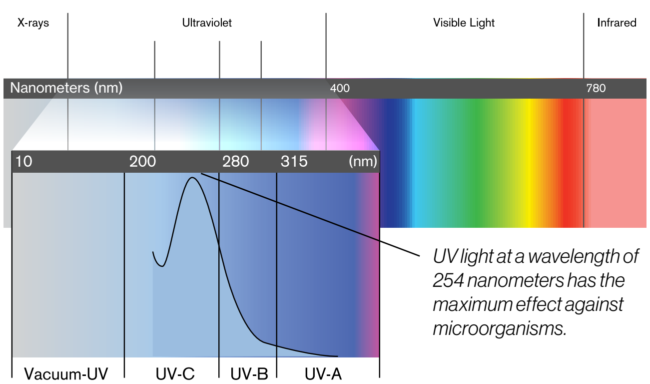
Growing awareness of potential long-term negative impacts of chemical treatment of wastewater along with the generation of toxic byproducts has led to the adoption of treatment alternatives such as ultraviolet light (UV).

There are over 11,000 TrojanUV municipal installations throughout the world – these installations include municipal drinking water and wastewater applications and help municipalities achieve their water quality objectives and serve more than one billion people globally.

WHAT IS ULTRAVIOLET (UV) LIGHT AND HOW DOES IT WORK?

UV light is a form of light that is invisible to the human eye. It occupies the portion of the electromagnetic spectrum between X-rays and visible light. The sun emits ultraviolet light; however, much of it is absorbed by the earth's ozone layer.

A unique characteristic of UV light is that wavelengths between 200 and 280 nanometers (billionths of a meter), are effective for inactivation of microorganisms such as *E.Coli* and Fecal Coliforms. This region between 200 and 280 nm is also known as the UV-C region or the inactivation zone. This capability has led to widespread adoption of UV light as a highly effective way to treat wastewater and drinking water.[1]



UV light at a wavelength of 254 nanometers has the maximum effect against microorganisms.

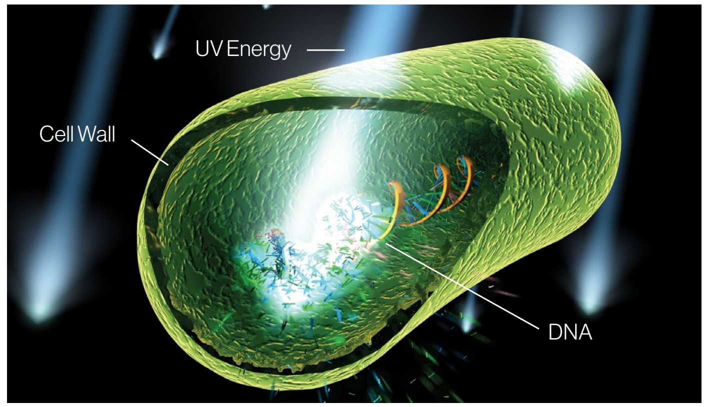
How UV Light Treats Water

A UV lamp is quite different than your standard incandescent light bulb. Yes, electricity is still passed through a filament which heats up, but that energy "excites" a very small amount of mercury vapor contained in the UV lamp. It is the mercury vapor that glows and emits the UV light.

In water treatment applications, UV light provides rapid, effective inactivation of microorganisms through a physical process. When microorganisms are exposed to certain wavelengths of UV light, they are instantaneously rendered incapable of reproducing, and if they cannot reproduce, they are unable to infect.

Microorganisms are inactivated by UV light as a result of damage to nucleic acids. The high energy associated with short wavelength UV energy, primarily at 254 nm, is absorbed by cellular RNA and DNA. This absorption of UV energy forms new bonds between adjacent nucleotides, creating double bonds or dimers. Dimerization of adjacent molecules, particularly thymine, is the most common photochemical damage. Formation of numerous thymine dimers in the DNA of microorganisms prevents replication.[1]

UV light has demonstrated efficacy on microorganisms, including those responsible for cholera[1] polio typhoid,[1] hepatitis,[1] and other diseases.



Rendering of UV energy damaging a microorganism's DNA.

CAN MICROORGANISMS BE REPAIRED?

Photochemical damage caused by UV may be repaired by some microorganisms if the UV dose is too low – this is called photo reactivation or dark repair. However, studies have shown that there is little to no potential for photo reactivation at higher doses (EPA UVDGM). In fact, it has been shown that some microorganisms, like *Cryptosporidium*, do not exhibit any evidence of repair under light and dark conditions following low-pressure or medium-pressure lamp irradiation at UV doses as low as 3 mJ/cm².

That's why it's critical that UV systems be designed with enough UV dose to ensure cellular damage cannot be repaired. Sizing of a UV system should be based on bioassay validation where a challenge organism is used to assess the performance of an UV system over a range of operating conditions (i.e. flow, water quality and UV lamp power) to quantify the degree of inactivation of a microbe for that UV system.

EFFICACY AGAINST RESISTANT MICROBES

Cryptosporidium (i.e. also known as crypto) and *Giardia* are resistant to chlorine treatment (Handbook of chlorination).

UV is effective for *Cryptosporidium* and *Giardia* inactivation. Protection against chlorine-resistant microorganisms is critical, as these same bodies of water may be relied on by communities as a source of drinking water and for recreational use.

THE HISTORY OF UV TREATMENT

The application of UV as an effective technology for water treatment began in Marseilles, France in 1910.[1] About that same time, chlorination was emerging in the United States as the primary means of eliminating microbes in drinking water.

In the early 20th century, the focus on wastewater treatment was essentially non-existent – being governed by the simple belief that the "solution to pollution is dilution." Over time, chlorination was adopted for the treatment of municipal wastewater. However, it was not until the Federal Water Pollution Control Act of 1972 that regulations were put into effect to establish standards for wastewater treatment and the quality of effluent discharged into the environment.

Chlorination addressed a fundamental requirement of wastewater treatment – the reduction of microbes that had the potential to cause illness in humans from water-borne diseases.

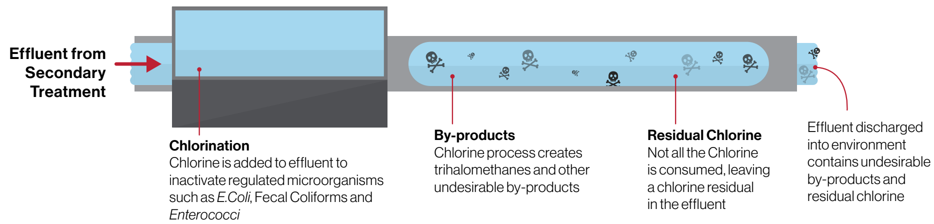
However, in 1976, limits on the levels of chlorine discharged in treated wastewater were introduced. Residual chlorine, being a strong oxidizer, in effluents are toxic to plant life and animal life, and hence to the environment. In response, some facilities installed dechlorination equipment to reduce residual chlorine levels.

Regulations accelerated the development and adoption of UV for municipal wastewater treatment.

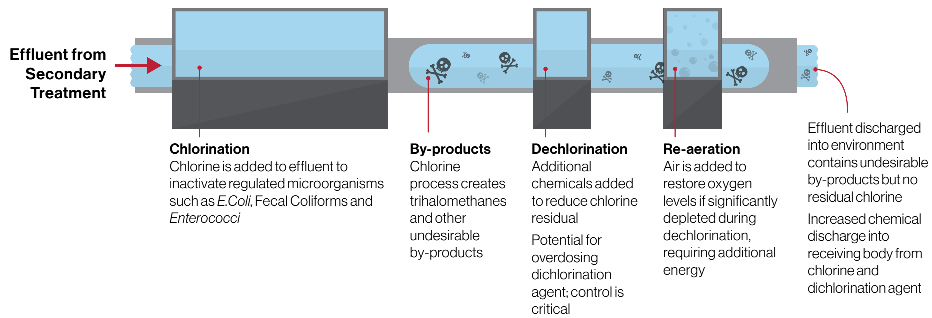
In 1986, the USEPA Design Manual: *Municipal Wastewater Disinfection* was published. It included comprehensive pilot data on UV systems and design guidelines for the application of this rapidly growing technology.

Today, there are approximately 16,000 municipal wastewater treatment plants in the United States and roughly 50% of these plants use UV. This includes new plants as well as existing ones that have converted from chlorine.

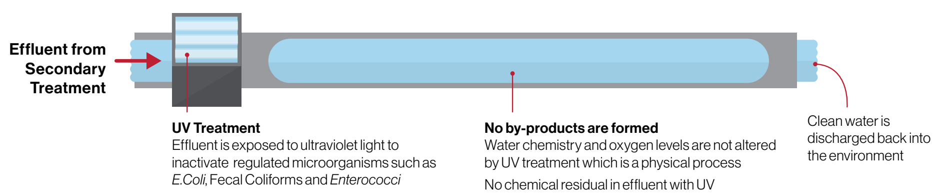
Chemical Treatment



Chemical Treatment with Dechlorination



UV Treatment



WHAT IS DECHLORINATION?

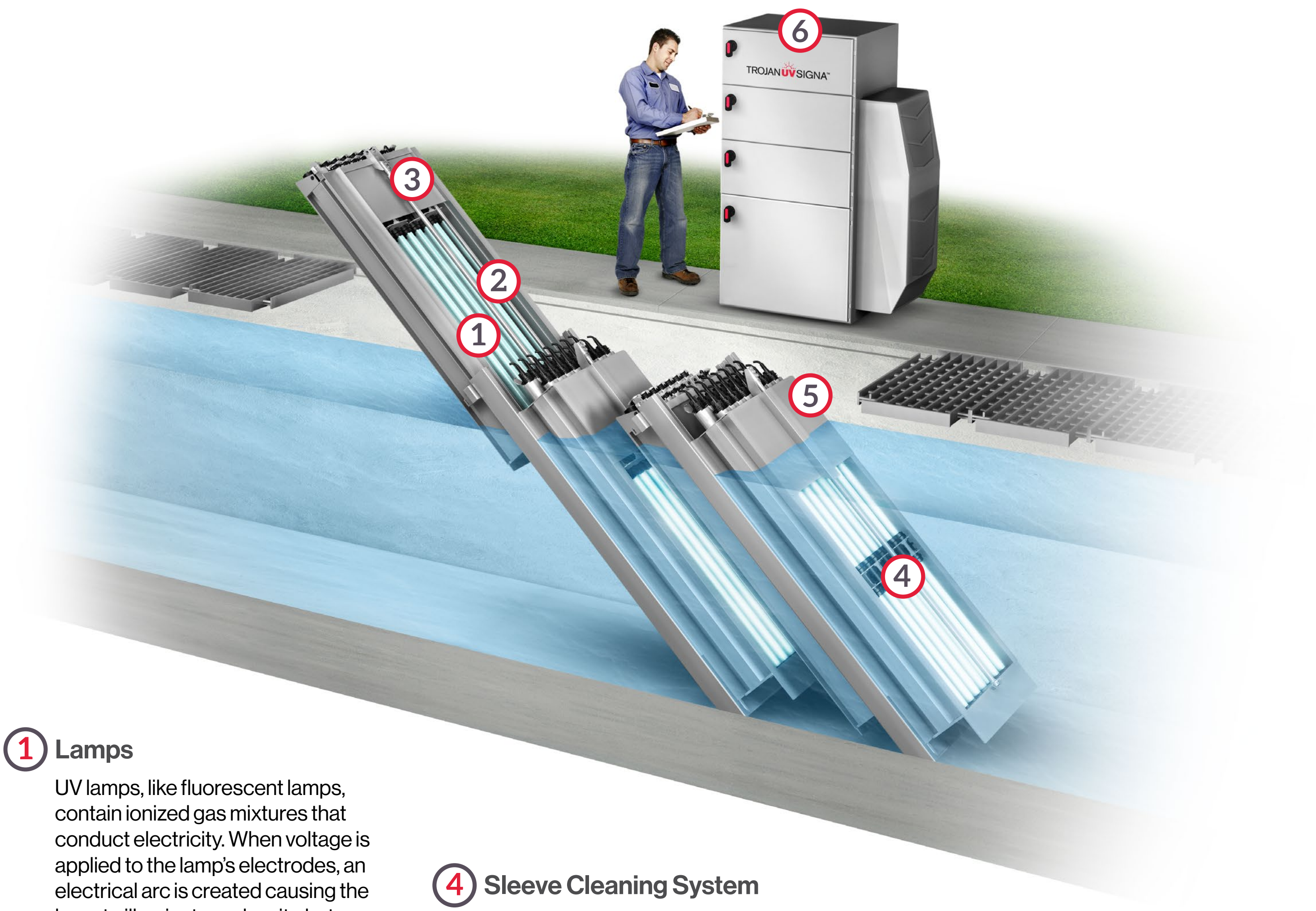
The dechlorination process typically involves the use of a reducing chemical such as sodium bi-sulfite or sulfur dioxide (SO^2). It requires special provisions for handling, storage, and emergency response training. Increasingly, sodium bi-sulfite ($NaHSO^3$) is being used as an alternative to sulfur dioxide.

In the last step of the wastewater treatment plant using chlorine, sodium bi-sulfite is often dosed into the wastewater in a dechlorination basin. To adequately manage residual chlorine, it must be thoroughly mixed and requires the appropriate contact time with the effluent to be effective.

Precise dosing and control of the reducing agent (i.e. sodium bi-sulfite or sulfur dioxide) is essential to achieve the desired result. Overdosing can result in the formation of sulfite and lower the dissolved oxygen (DO) content and pH level of the effluent. If too much oxygen is depleted, the water must be re-aerated prior to discharge which requires additional energy and cost. There are often regulatory permit limits for dissolved oxygen concentration in an effluent stream as low DO levels to a receiving water body will harm aquatic and plant life in the environment.

WHAT A UV TREATMENT SYSTEM LOOKS LIKE

UV treatment uses a fundamentally different process than chemical-based systems. Clarified wastewater, typically secondary effluent, is directed through open channels where it flows past a series of ultraviolet lights that are submerged in the effluent. As microorganisms in the water flow past the array of UV lamps, they are exposed to ultraviolet light at a wavelength of typically 254 nm (inactivation zone). These powerful photons in the UV-C range alter the genomic structure of microbes rendering the microbe unable to reproduce and therefore becomes non-infectious.



1 Lamps

UV lamps, like fluorescent lamps, contain ionized gas mixtures that conduct electricity. When voltage is applied to the lamp's electrodes, an electrical arc is created causing the lamp to illuminate and emit photons that pass through quartz and reach microorganisms in water.

2 Lamp Sleeves

The UV lamps are housed in protective quartz sleeves that protect the lamps from moisture while allowing UV energy (photons) to be emitted into the water.

3 UV Intensity Sensor

The UV intensity sensor detects UV light and provides the ability for real-time monitoring of UV lamp output to ensure that specified UV levels are maintained throughout the operating life of the UV lamp.

4 Sleeve Cleaning System

Over time, exposure to the wastewater can result in the quartz lamp sleeves becoming fouled, thereby limiting the amount of UV energy reaching target microorganisms in the water. To prevent this build-up from occurring, and maximize system efficiency, many UV treatment systems are equipped with automatic sleeve wiping/cleaning.

5 UV Banks or Modules

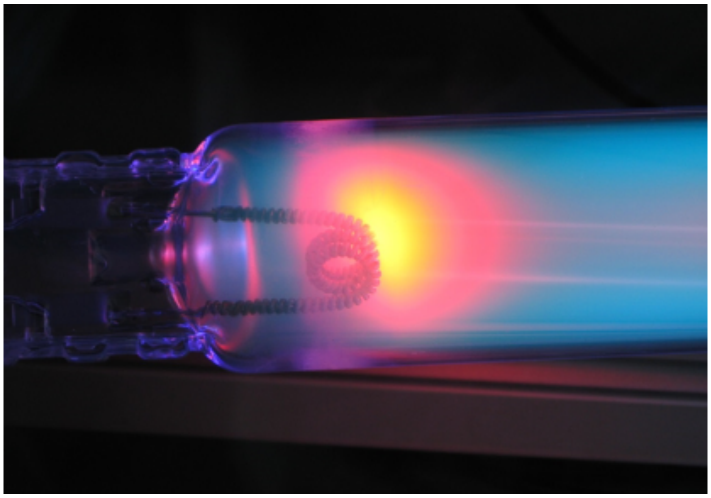
Modern UV systems use stainless steel banks or modules containing the UV lamps, lamp sleeves, wiring and, in some instances, the lamp drivers that regulate power to the lamps. The lower portion of the modules containing the lamps is submerged into the clarified or filtered wastewater to allow the wastewater to be treated with UV light.

6 System Controller

Modern UV systems include microprocessor or PLC based control systems that vary the output of the UV lamps based on the volume and conditions of the wastewater they are treating. These are linked into the main control systems of the treatment plant and permit remote monitoring of the UV system's performance.

THESE AREN'T YOUR ORDINARY LAMPS

A UV lamp is quite different than your standard incandescent light bulb. Yes, electricity is still passed through a tungsten filament which heats up, but that energy "excites" a very small amount of mercury vapor contained in the lamp. It is the mercury vapor that glows and emits the UV light.



TrojanUV Solo Lamp starting up.

Low-pressure lamps are extremely efficient and have a longer life. Medium-pressure lamps have higher UV output and power consumption but are more compact and can have less head loss.

In recent years, new lamp technology that combines the best features of both low- and medium-pressure lamps has been introduced. Thanks to this advanced technology, UV systems have become much more compact, efficient, and easier to install and maintain.

Lamp Spacing

UV banks and modules should be designed to optimize the number of UV lamps required to provide a specific dose with the necessary hydraulic capacity. The hydraulic characteristics require turbulent flow with mixing and minimal head loss. Lamp spacing is designed to optimize the water layer around the quartz sleeve and to provide the maximum average intensity, while minimizing the potential of short-circuiting.

UV Transmittance (UVT)

UVT is the ratio of light entering the water to that exiting the water. Simply put, water with high UVT (e.g., 90%) is relatively clear, allowing more UV light to reach the organisms you are trying to treat. As water quality decreases, the UVT is reduced (e.g., 50%) which in turn reduces the amount of UV light that can penetrate and provide treatment.

Lamp Aging

As lamps age, the amount of UV output decreases. The number of on/off cycles of the lamp also contributes to the decay in output of the lamp. UV systems should be designed to deliver the required UV dose at the end of lamp life (EOLL) to ensure proper inactivation before lamp replacement. EOLL should also be independently validated to guarantee the system meets treatment requirements.

Quartz Sleeve Cleanliness

As mentioned earlier, each UV lamp is typically enclosed in a quartz sleeve to insulate them from the water. Quartz is used because it is transparent to UV light. An accumulation of inorganic and organic solids on the quartz sleeve, also known as fouling, decreases the intensity of UV light that can enter the surrounding water.

UV lamps in TrojanUV systems are enclosed in a quartz sleeve to insulate them from the water. ActiClean™ is our patented dual-action sleeve cleaning system that uses mechanical wiping in conjunction with ActiClean Gel contained within wiper canisters surrounding the quartz sleeves.

The fouling rate is site-specific, varies with treatment process, and may be more rapid in the presence of high concentrations of iron, calcium and magnesium ions. Other variables like water quality, temperature, velocity, and chemicals can affect sleeve fouling. In general, the fouling rate on the quartz sleeve is unpredictable, but can be prevented through a sleeve cleaning system or manually cleaning the sleeves with chemicals.

SUMMARY OF UV BENEFITS

UV is an effective and reliable technology that treats microorganisms such as *E.Coli*, Fecal Coliform and *Enterococci*, as well as chlorine-resistant microbes including *Cryptosporidium* & *Giardia*.

UV provides effective inactivation of microorganisms through a physical process. The retention time required to achieve inactivation is usually in the range of a few seconds which reduces the physical footprint and capital costs of installation for UV systems.

UV system design includes measures to contain UV light and minimize the risk of exposure to operation and maintenance staff at treatment plants. UV system design incorporates channel grating and light locks to contain UV light to prevent operator exposure. In addition, operational and safety features protect against electrical hazards. These include lock-outs in the power cabinets to ensure power is off prior to servicing the UV system. The Operations and Maintenance manual includes further details on the lock-out/tag-out procedures for operation and servicing TrojanUV systems.

Transportation, handling and storage for UV systems are focused on preventing damage to the equipment and component parts until installation and commissioning.

	Chlorine Treatment	UV Treatment
No Treatment By-products (DBP's)	✖	✔
No Chemical Residue	✖	✔
No Chemical Spill Risk	✖	✔
Effective Against *Cryptosporidium* and *Giardia*	✖	✔
Well-Suited for Changing Regulations	✖	✔

AT-A-GLANCE CHART

	Chlorine	Sodium Hypochlorite	UV Treatment
Transportation	Chlorine gas is delivered to the treatment plant by truck or train.	Has a limited shelf life, requiring frequent transportation and deliveries.	Lamps are typically delivered once or twice a year.
Operators	Chlorine must be handled with caution. Training programs and certifications must be in place and routinely practiced and updated.	Corrosive and agitating if ingested or inhaled. It must be handled and stored with caution. Containment and leak protection equipment must be in place.	Employees handle the UV lamps.
Public	By-products from treatment with chlorine remain in the water when it is discharged into the environment.	By-products from treatment with Sodium Hypochlorite remain in the water when it is discharged into the environment.	UV does not produce by-products from treatment.
Performance	*Cryptosporidium* & *Giardia* are chlorine-resistant microorganisms.	*Cryptosporidium* & *Giardia* are chlorine-resistant microorganisms.	UV inactivates chlorine-resistant microorganisms like *Cryptosporidium* & *Giardia*.
Environment	Chlorine is toxic to aquatic life. Dechlorinating (removing residual chlorine) requires the addition of a second chemical, which subsequently depletes dissolved oxygen that is essential for the survival of aquatic life.	Dechlorination is required when using sodium hypochlorite for treatment. Dechlorinating (removing residual chlorine) requires the addition of a second chemical, which subsequently depletes dissolved oxygen that is essential for the survival of aquatic life.	UV treatment is a physical process and does not chemically alter the water conditions for aquatic life and wetlands.

TROJAN UV

TROJAN technologies

COSTS

The initial capital expense and the operating expenses over a finite length of time (typically 20 years) can be added together to determine the total cost of implementation. This analysis is called a Life Cycle Cost analysis or an Investment Return Analysis. When combined with an evaluation of qualitative factors, the decision maker can then select the most appropriate treatment process for their application.

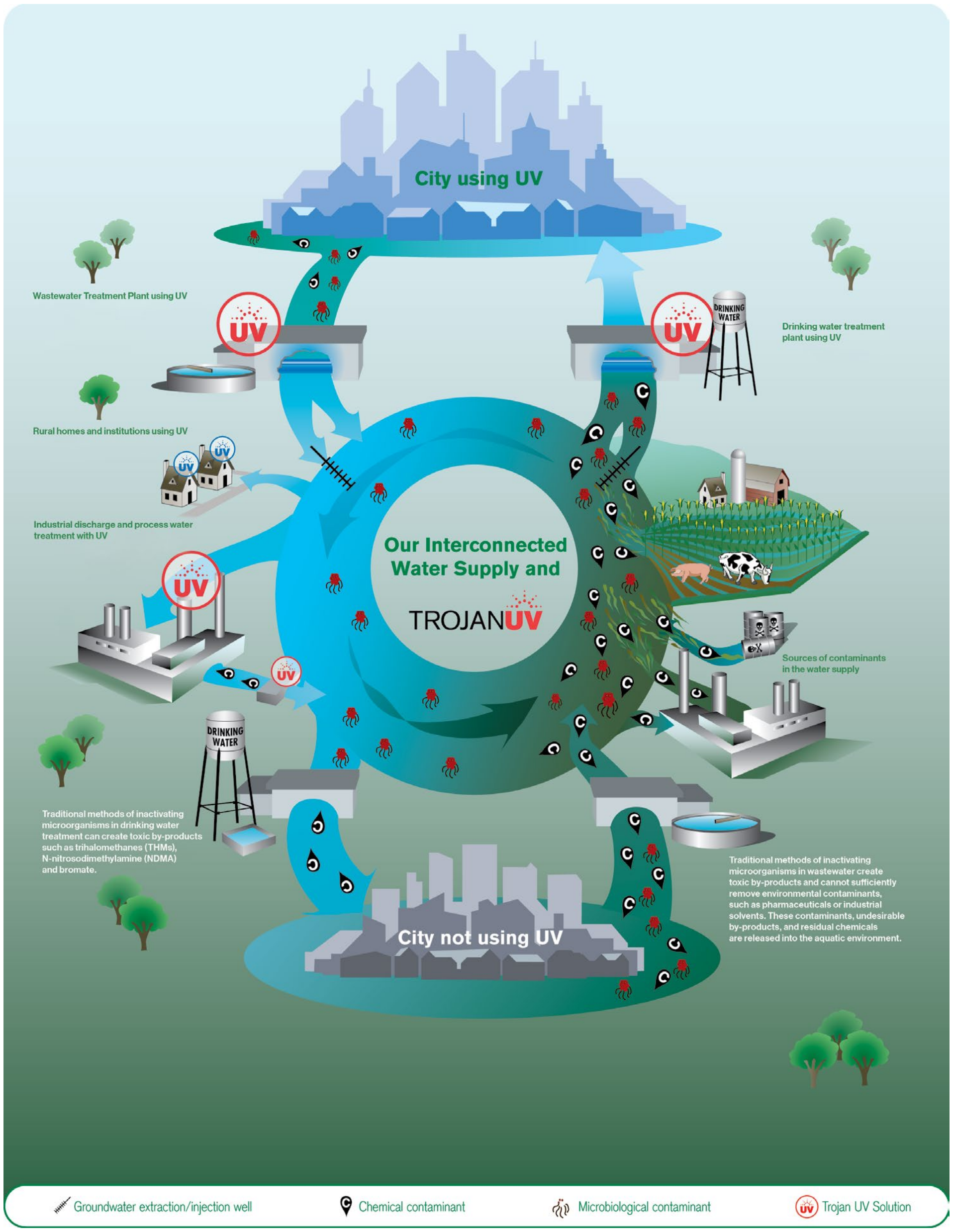
AT-A-GLANCE CHART: COSTS

	Chlorine	Sodium Hypochlorite	UV Treatment
Chemical Supplies	**$$$** Purchase and delivery of chlorine gas cylinders	**$$$$$$** Purchase and delivery or on-site generation of hypochlorite	**N/A**
Electricity	**$** Low electricity requirements	**$** Running chemical feed pumps and aeration equipment if applicable	**$$$$** Electricity is required to power the UV lamps
Replacement Parts	**$** Minimal replacement parts required	**$** Minimal replacement parts required	**$$$** Replacement parts for UV systems are primarily comprised of replacement lamps
Operators	**$$$$$$** Labor required for changing chlorine cylinders, maintaining lead detection and emergency equipment, maintaining on-site chemical distribution and storage equipment.	**$$$** Labor required to maintain pumps, generators, storage tanks, water conditioning equipment, de-scaling equipment, on-site chemical distribution piping.	**$** Labor includes replacing UV lamps periodically and ensuring that quartz sleeves that house the UV lamps are kept clean.
Leak Response	**$$$$$$** Costs of responding to and repairing leaks are high	**$$$** Costs of responding to and repairing leaks are moderate	**N/A** UV lamps contain a small amount of mercury. Leak response and emergency preparedness plans are not required; however, local guidelines must be adhered to.
Ensuring Compliance	**$$$$$$** Time-intensive administration for compliance with regulated risk management plans, emergency response plans and community right-to-know programs.	**$$$** Sodium Hypochlorite is corrosive. Procedures must be in place to ensure proper transportation, handling, storage and spill protection	**$** No special preparedness programs or risk mitigation are required.
Training	**$$$$$$** Employees must be trained on process management, risk management plans, and evacuation procedures in addition to routine operation of the system.	**$$$** Training programs must be in place to ensure chemicals are properly transported, stored and handled.	**$** UV equipment is straightforward to operate. It requires no certifications for operators.

WHY COMMUNITIES DOWNSTREAM (AND WE AT TROJAN TECHNOLOGIES) LOVE UV

UV is a effective physical treatment alternative that will not create by-products or discharge a chemical residual which will impact the environment. In addition, UV is an effective treatment for chlorine-resistant microorganisms like *Cryptosporidium* and *Giardia*.

Wastewater treated with UV is ready to be released into receiving waters. As a result, UV is well suited to meet current local regulations as well as more stringent regulations expected in the future. And as regulations continue to evolve, we believe that UV will remain a cost-effective and preferred choice for water treatment in our communities.



THANKS FOR READING

We trust that you found it to be insightful and informative. To further your knowledge, we encourage you to visit www.trojantechnologies.com and https://www.resources.trojanuv.com/.

References: 1. Whitby, GE and Scheible, KO. 2004. The History of UV and Wastewater. IUVA News. Volume 6, Number 3. 2. USEPA. 2006. Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule. 3. Black and Veatch Corporation. 2010. White's Handbook of Chlorination and Alternative Disinfectants. John Wiley & Sons, Inc., Hoboken, New Jersey

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