UV DISINFECTION FOR WATER REUSE GAINING IN ARID REGIONS

By Wayne Lem and Jennifer Muller

In many water-stressed countries around the world, limited water resources can pose severe constraints on economic and social development and threaten the livelihood of people. Available groundwater sources are declining as the result of over-pumping of aquifers beyond natural recharge rates resulting in lower water tables, increased groundwater salinity in some cases, and depleted groundwater sources.

India has the second largest population in the world. The population is three times that of the United States, but the Country is only one-third the physical size. While India’s aquifers are currently associated with natural replenishing sources, the country is also a major grain producer with a great need for water to support the commodity. As with all countries with large agricultural output, excess water consumption for food production depletes the overall water table. This poses a concern that India may lack overall long-term availability to replenish groundwater sources. At the same time, the overall population is expected to increase, and there are an increasing number of wells being drilled to access existing groundwater sources for food and human sustenance — this leads to overall depletion of water.

Fast Facts
- Project: Doha North STW
- Product Used: TrojanUV3000Plus
- Project of: Public Work Authority of Qatar

Global water scarcity is expected to become a leading cause of regional and national political conflict in the future, and the prognosis for India is no different. With increasing water scarcity and deterioration of water quality, this looming crisis has prompted many governments to seek more efficient uses of water resources and develop interventions to narrow the gap between supply and demand.

Reuse of municipal wastewater is a proven and promising option for developing non-conventional water resources. In India, and most Arab countries, agriculture is by far the main water consumer. For example, about 80% of the total water supply in Tunisia and up to 90% in Syria is used for agricultural irrigation. The reuse of reclaimed (treated) wastewater for irrigation and
other purposes would alleviate the water stress and scarcity arid regions face. In fact, it has been argued that the greatest potential for wastewater reuse is through using properly treated wastewater for irrigation purposes, as a substitute for conventional ground and surface water sources. The scarcity of water has motivated the Qatar government to introduce wastewater treatment and reuse as an additional water resource in their national water resource management plan. Representing a major investment by the Qatar Government, construction is in progress for the largest greenfield wastewater treatment, water reuse and sludge treatment plant in the Middle East: The Doha North Sewerage Treatment Works (Doha North STW). This modern facility will feature advanced biological treatment processes, membranes for tertiary treatment and ultraviolet (UV) technology for disinfection to produce high quality reclaimed water for reuse.

For the past three decades UV technology has been successfully used around the world for municipal applications including wastewater and drinking water disinfection. UV is a cost–effective and reliable technology that protects the public against pathogenic microorganisms, including protozoa, bacteria and viruses. As a growing alternative and in many cases, a direct replacement technology to chemical (chlorine) disinfection, UV does not produce harmful by–products and is non–toxic.

The presence of pathogenic bacteria, viruses and protozoan in wastewater and drinking water represents a potential risk to the public. To prevent the transmission of waterborne diseases, regulations specify water treatment processes, nutrient removal, final effluent quality and disinfection criteria based upon the specific requirements of the reuse application.

UV disinfection systems have been successfully designed, tested and installed in thousands of municipal treatment plants around the world. While individual applications (e.g., wastewater, stormwater, drinking water) and treatment objectives differ, they have one important goal in common – to provide cost–effective and safe water for the public while minimizing the environmental impact of the treatment process.

UV disinfection of wastewater is a physical process whereby ultraviolet lamps, producing energy in the UVC range (200–400 nm), are housed within a specifically designed treatment reactor. The UV lamps produce photons that attack the microorganisms in wastewater as it flows through the reactor. Within a few seconds of exposure, the DNA of the microorganisms is permanently altered and the bacteria can no longer reproduce or infect those coming in contact with the water.

**Project Background: Doha North STW**

Qatar occupies a peninsula, projecting northwards from the Arabian mainland, on the west coast of the Persian Gulf. The peninsula is roughly 180 km long and between 55 and 85 km wide.

With a peak design capacity to treat wastewater of up to 439,000 m3/day, Doha North STW will serve a projected population of over 900,000 people. With the facility becoming a source of water supply for non-potable use, it will free up precious drinking water supply for the community.

Doha North STW selected the TrojanUV3000Plus™ system (instead of chlorine) to disinfect their municipal wastewater plant effluent to reuse standards. The selection criteria included:

The looming water scarcity crisis is prompting many governments worldwide to develop non–conventional water resources through municipal reclamation. Ultraviolet disinfection ensures that the high–quality reclaimed water for non–potable use is reliably safe.
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Sodium hypochlorite is a diluted liquid form of chlorine. It is a clear, yellow liquid that is corrosive. Because it is diluted, it is not as volatile or toxic as chlorine gas – nor does its unintended release have the same disastrous potential. It is typically purchased and delivered to the treatment plant in large volumes. As with chlorine gas, sodium hypochlorite can create disinfection by-products and often requires a dechlorination step to remove residual chlorine before the water is released or reused.

With the objective to ensure public safety and environmental protection and provide effective disinfection, almost 30% of municipal wastewater treatment plants in North America have converted to UV from chlorine. UV disinfection is a physical process that instantaneously disinfects microorganisms as they pass by ultraviolet lamps submerged in the wastewater effluent. As well, UV is effective against chlorine--resistant Cryptosporidium and Giardia (pathogens in surface water sources that can easily find their way into drinking water supplies).

The annual cost of operating and maintaining a disinfection system can have a significant impact on the economic evaluation of the technology. The O&M costs for disinfection 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 build--up in piping and pumps require regular acid cleanings to remove. The O&M costs associated with UV, however, 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, but are not limited to operator and community safety, ease of operation, process reliability, constructability and space requirements and sustainability / environmental impact.

Evaluating Disinfection Alternatives
Traditionally, disinfection using chlorine gas has been 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. It is a strong oxidizing agent that can be extremely dangerous to humans if exposed.

Chlorination with either chlorine gas or sodium hypochlorite gradually destroys microorganisms, but also imparts a residual that even at low concentrations can be toxic for aquatic and plant life. Although adding dechlorination post disinfection would essentially eliminate toxic residuals, the long--term effect of discharging dechlorinated compounds into the environment are still unknown. Also, dechlorination does not eliminate disinfection by--products (i.e. THMs) which are caused by chlorine oxidizing with certain types of organic matter. The dechlorination process, which consists of adding chemicals such as sulphur dioxide, tends to deplete oxygen from the effluent which also affects downstream aquatic environments. A re--aeration process – an additional expense – is often included to increase dissolved oxygen levels in the final effluent before discharge.

Considering community and employee safety, UV has tremendous safety advantages over chlorine gas. Although a chlorine dosing system is relatively easy to operate, it does require a high degree of safety training and maintenance checks. Sodium hypochlorite is less volatile, but is still very corrosive and also requires a high level of safety training and maintenance checks. The UV system consists of seven duty UV channels for the current design capacity plus provision for
The TrojanUV3000Plus, an open channel system, contains a total of 420 UV modules. With seven duty channels, the system at banks per channel for a total of 480 lamps per bank with 30 UV modules contains 8 UV lamps per channel. There are two PDCs per channel and each a Power Distribution Cabinet (PDC) for one UV bank. Each channel. There are two PDCs per channel and each a Power Distribution Cabinet (PDC) for one UV channel. PDC powers 30 UV modules in a “bank”. Each bank with 30 UV modules contains 8 UV lamps per module for a total of 240 lamps per bank (with 2 banks per channel for a total of 480 lamps per channel). With seven duty channels, the system at Doha contains a total of 420 UV modules.

The TrojanUV3000Plus system was validated by a third-party in accordance with protocols outlined in National Water Research Institute (NWRI) UV Guidelines (2003) for wastewater reuse. The disinfection performance of the installed UV system at Doha is shown in Figure 5A and consists of seven duty channels located beneath the grating to transport the design flow to the plant. Figure 5B shows the close-up of installed UV system at Doha is shown in Figure 5A and consists of seven duty channels located beneath the grating to transport the design flow to the plant. Figure 5B shows the close-up of the disinfected wastewater. These systems are used to safeguard public health through pathogen removal, but they also minimize the operating costs and environmental impact of the treatment process. Drawing from global experience and track records with proven installations, India, the Middle East and Asia is seeing an increasing number of wastewater plants disinfect utilizing ultraviolet disinfection.

Each UV installation will be successful if the stakeholders proceed through planning and design phases with diligence. The UV manufacturer can contribute valuable experience to the process by educating municipalities about the science of UV disinfection, understanding the impact of effluent quality on UV disinfection and by properly designing and validating their reactors over a range of operating conditions.

Even in the most arid regions, municipal wastewater reuse with UV is proven and has been implemented around the world as a solution to the growing issue of water stress. Countries like India can successfully implement this technology to provide clean, pathogen-free, treated water for agricultural and non-potable uses.

The treatment requirements for the final reuse water are shown in table 1.

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Organism</th>
<th>Disinfection Limit</th>
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<tbody>
<tr>
<td>90th</td>
<td>Fecal coliform</td>
<td>Non-detect</td>
</tr>
<tr>
<td>90th</td>
<td>Giardia cysts</td>
<td>&lt;1/40L</td>
</tr>
<tr>
<td>90th</td>
<td>Enteric virus</td>
<td>&lt;1 pfu</td>
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</tbody>
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The system design parameters for the UV system are:

- **Peak design flow:** 5284 L/s (120 MGD)
- **Future peak flow:** 7011 L/s (160 MGD)
- **TSS:** 10 mg/L (90th percentile)
- **UV Transmittance (1 cm):** 45%

Keppel Seghers (Singapore), the environmental arm of Keppel Integrated Engineering, in partnership with the Public Works Authority of Qatar designed, built and are operating the plant for a period of 10 years. The Doha North STW is the first wastewater treatment facility in Qatar to use advanced membrane and ultraviolet light to treat and reclaim high quality wastewater for non-potable use.

The disinfection performance of the installed TrojanUV3000Plus system was validated by a third-party in accordance with protocols outlined in National Water Research Institute (NWRI) UV Guidelines (2003) for wastewater reuse. The installed UV system at Doha is shown in Figure 5A and consists of seven duty channels located beneath the grating to transport the design flow to the plant. Figure 5B shows the close-up of a Power Distribution Cabinet (PDC) for one UV channel. There are two PDCs per channel and each PDC powers 30 UV modules in a “bank”. Each bank with 30 UV modules contains 8 UV lamps per module for a total of 240 lamps per bank (with 2 banks per channel for a total of 480 lamps per channel). With seven duty channels, the system at Doha contains a total of 420 UV modules.

Because UV is a nearly instantaneous physical process where the effluent requires a contact time of only seconds, the required treatment footprint is a fraction of that of chemical disinfection methods – where contact times can be in excess of 30 minutes (>90 or 120 minutes for reuse) and large concrete holding tanks are required.

Around the world, municipal UV systems have been installed to safely and reliably disinfect wastewater. These systems are used to safeguard public health through pathogen removal, but they also minimize the operating costs and environmental impact of the treatment process. Drawing from global experience and track records with proven installations, India, the Middle East and Asia is seeing an increasing number of wastewater plants disinfect utilizing ultraviolet disinfection.

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**Figure 5B: TrojanUV3000Plus – Two Power Distribution Cabinets (PDC) per Channel**

**Figure 6: Typical TrojanUV3000Plus UV Disinfection Installation**

**About the Authors**

Wayne Lem has nearly 20 years of experience in the water industry, with in-depth involvement in technologies used in several treatment applications, including municipal wastewater, water reuse, drinking water and trace contaminant removal. Wayne has been with Trojan Technologies since 2003. Prior roles included Senior Process Engineer as well as Manager of Validation and Research. He is currently Municipal Market Manager and leads various global market strategies, new product developments and reactor validations.

Jennifer Muller joined Trojan in 1997. Since then she has held roles within Municipal Sales and Global Market Strategies. She was appointed to Director of UV Markets in 2008 and then to Vice President, Global Municipal Sales in 2012. In 2016, she was appointed to Vice President, Marketing.

TrojanUV designs and manufactures pressurized and open-channel UV disinfection systems for municipal wastewater and drinking water, and UV–oxidation systems for environmental contaminant treatment and potable reuse. TrojanUV is part of the Trojan Technologies group of businesses.

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