

Trends and Developments in the UV Water Treatment Industry

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Although ultraviolet (UV) irradiation technology has been available for more than a century, its use by the water treatment sector only became pronounced during the last two decades. Today, UV represents a hot growth area in the water treatment market, with total global estimates at \$500MM across all water segments: municipal wastewater (\$120MM), municipal drinking water (\$120MM), industrial (\$100MM), commercial (\$80MM) and consumer/residential (\$80MM). The market is forecast to grow to more than \$880MM by 2010, with a combined predicted growth rate of 10% for the industrial, commercial and consumer/residential markets and 15% to 20% for the municipal water and wastewater markets.

By 2010, North America, with a large established wastewater market and burgeoning drinking water and water reuse markets, is expected to represent the largest UV market, with approximately 45% of the total market size. Other growth markets include Europe (wastewater), the Middle East (wastewater and water reuse), and Asia/Pacific – primarily China and Australia (wastewater and water reuse, respectively).

In the past five years, the number of key water companies specializing in UV technology has dwindled. ITT acquired Wedeco; Danaher, Trojan Technologies and Aquafine; Siemens Water Technologies, Sunlight Systems; and Severn Trent Services, Quay Technologies. This consolidation trend is expected to continue in the near future, as small, successful niche players represent excellent growth opportunities for large corporations wishing to get in on the UV action.

Advantages and Limitations of UV Technologies

UV's key advantages make it an alluring treatment technology for the various water markets. Foremost, UV is effective for a wide variety of microorganisms, including bacteria, viruses, and fungi as well as protozoa such as *Cryptosporidium* and *Giardia*. The technology is also chemical free, meaning there are no requirements for chemical transport, storage, handling, removal, or hazardous material management planning. Its chemical-free state also means it is not corrosive nor poses a hazard because of accidental overdosing.

UV also has low overall capital and operating costs and is easy to maintain and operate. The environmentally friendly technology is safe and, contrary to chemical disinfectants, does not form disinfection by-products (DBPs). Further, UV does not impact the aesthetic quality of the water (taste, odor, or color). Its compact design makes it easy to retrofit while its efficacy is independent of pH.

UV technology does have a few limitations. It is difficult to monitor efficacy during operation. Some in the municipal drinking water market perceive mercury lamps as an environmental detriment and also express concern about the lack of residual protection for the distribution system. UV is not effective as a pre-oxidant or taste and odor control.

Certain viruses, like adenovirus, necessitate high doses of UV. The technology is also ineffective with high solids waters in the municipal wastewater market.

Treatment Objectives

For most applications, UV is used for disinfection purposes, i.e., to inactivate waterborne pathogens such as bacteria, viruses, protozoa and fungi.

In recent years, another application for UV has emerged: to remove chemicals from water. When used alone (a process called “photolysis”), UV removes total organic carbon in high-purity applications (pharmaceutical and semiconductor industries) and chemical disinfectants such as chlorine, chloramines, and ozone in certain commercial and industrial applications.

For Advanced Oxidation Processes (AOPs), UV can be used in conjunction with oxidants such as ozone and hydrogen peroxide, or semiconductors such as titanium dioxide to oxidize refractory chemicals such as chlorinated solvents, taste-and-odor compounds, nitrosodimethylamine (NDMA), methyl-tert-butyl-ether (MTBE), endocrine disrupting chemicals, and pharmaceuticals.

Regulatory Drivers

In Europe and the United States, regulatory drivers are already greatly impacting UV market growth. The European Bathing Water Directive, the Water Framework Directive, and Integrated Pollution Prevention Control are just some of the many statutes driving the UV market in Europe.

Similarly, in the United States, the Stage 2 Microbials/Disinfection By-products cluster of rules is expected to significantly increase the use of UV technologies. The primary objective of these rules is to address the risky trade-off between microbial disinfection and the by-products formed by commonly used chemical disinfectants. They include the Long-Term Two Enhanced Surface Water Treatment Rule (LT2ESWTR) and the Stage 2 Disinfection By-products Rule (Stage 2 DBPR). The LT2ESWTR, enacted by the U.S. Environmental Protection Agency (USEPA) in 2006, is an incredible industry driver for UV in the U.S. The Rule primarily targets *Cryptosporidium*, which is prevalent in most surface water supplies, including groundwaters under the influence of surface water. The Stage 2 DBPR is also expected to be a significant driver for UV as UV does not form harmful DBPs.

It is unclear at this stage how the recently promulgated Groundwater Rule will impact the adoption of UV technologies for groundwater. Under this Rule, which establishes multiple barriers to protect against bacteria and viruses, systems required to disinfect will need to ensure that they reliably achieve 4-log inactivation or removal of viruses. Adenovirus, the most UV-resistant waterborne pathogen posing public health concern, has hindered the increased usage of UV for disinfecting groundwater supplies. While a dose of 40 mJ/cm² is considered largely sufficient for 4-log inactivation of most

waterborne pathogens (bacteria, protozoa, and most viruses), a much higher dose (greater than 100 mJ/cm^2) is required for adenovirus. However, recent work conducted at Duke University (North Carolina) shows that a much lower dose (less than 60 mJ/cm^2) is required when using medium-pressure lamp technology.

Finally, stricter regulations over the transport, storage, toxicity and handling of chemicals such as chlorine (primarily chlorine gas) will further benefit chemical-free UV technology. These more stringent regulations over chlorine have sped up the adoption of UV. To illustrate, approximately 50% of all new wastewater plants built in the U.S. incorporate UV technology.

Certifications/Validations

As previously discussed, a key limitation of UV technologies is the difficulty of monitoring efficacy during operation. Accordingly, to ensure that the UV dose required for a given application is delivered at all times, UV systems must be validated and subsequently certified for numerous applications. Using bioassay (biodosimetry) testing, validation testing certifies reactors for performance, i.e. dose delivery.

For instance, for the U.S. drinking water market, the USEPA's LT2ESWTR requires the use of validated UV reactors for receiving Cryptosporidium, Giardia or virus inactivation credit. Accordingly, UV systems must meet stringent protocols such as DVGW W294 (Germany), ÖNORM (Austria) and/or comply with guidelines specified in the USEPA's UV Disinfection Guidance Manual or by the National Water Research Institute.

For water reuse applications, UV systems must comply with the Title 22 guidelines specified by the National Water Research Institute.

Lastly, for wastewater (discharge) applications, more and more engineers today specify UV systems that have undergone bioassay testing, due to the uncertainty associated with existing mathematical models.

Cryptosporidium, Waterborne Pathogens and the Multiple Barrier Concept

While chemical disinfectants such as chlorine can effectively treat bacteria and viruses, they are not very effective against such protozoa as Giardia and are almost useless against Cryptosporidium. The 1993 Cryptosporidiosis outbreak in Milwaukee, Wis., that resulted in over 100 deaths moved the water sector to develop more reliable treatment technologies for Cryptosporidium inactivation or removal.

The late-1990s discovery that UV readily inactivates Cryptosporidium created a huge opportunity for UV technologies in the drinking water market, primarily for the disinfection of surface water supplies (e.g. rivers, reservoirs) where Cryptosporidium oocysts are prevalent worldwide. Compared to ozonation and membrane separation processes, which are also effective at removing Cryptosporidium, UV is significantly less capital- and operations-intensive.

Prior to the Milwaukee outbreak, UV was a minor player in the North American drinking water market. Today, large municipalities such as New York City, Vancouver, Seattle, and Cincinnati have either installed, or are in the process of installing, UV. In most installations, UV will be part of a multiple barrier approach, meaning it will be one of multiple combined technologies that complement each other and add a degree of safety and efficiency to drinking water treatment.

The concern over *Cryptosporidium* is not limited to the drinking water market, however. Numerous recent *Cryptosporidium* outbreaks have also been documented in swimming pools, creating yet another market opportunity for UV technologies.

Market Awareness and Growth

UV is effective at reducing chloramines levels in swimming pools. Chloramines, a chlorine DBP, create the chlorine smell in indoor pools. Recent studies indicate chloramines contribute to dry skin, eye burn and potential respiratory ailments, which especially affect children, professional swimmers or people who regularly work in or around swimming pools (e.g. lifeguards).

In the years ahead, UV will become more prevalently used in various industrial applications such as food & beverages, biopharmaceuticals and semiconductors (high-purity water), cooling towers, maritime/ballast water, and fish hatcheries/aquaculture.

Demand for UV technologies is also expected to increase in both the residential and commercial drinking water markets worldwide. The former can be attributed to renewed public awareness about tap water quality issues as well as increasing concerns over the quality, cost and environmental impact of bottled water. UV will be used as either a point-of-use or a point-of-entry device for such applications. Potential commercial users include hospitals (for control of *Legionella*, for instance), office buildings, schools, restaurants, and campgrounds.

Meanwhile, UV is projected to steadily grow in the municipal markets. Municipal drinking water applications include the use of UV for either surface or groundwater sources. Municipal wastewater applications are comprised of conventional discharge applications (where treated water is discharged to a water body such as a river) as well as water reuse/recycle/reclaim applications.

Developing Markets

The United Nations and other international bodies are encouraging UV system manufacturers to develop inexpensive and simple UV systems that can be made available to the more than 1 billion people who currently do not have access to clean drinking water.

Along with membrane separation processes, UV will also be used more frequently to treat wastewater to high water quality standards as concerns over water scarcity and droughts increase. As a result, water reuse will become a more acceptable practice in arid regions such as the Middle East, Southeast Asia, Europe, and certain parts of the U.S.

Finally, new applications for AOPs involving UV will also develop as concerns arise over chemicals in the environment (e.g. endocrine disrupting chemicals, pharmaceuticals, algal toxins, etc.). AOPs using UV will also become more prevalent for both drinking water and water reuse applications.

Technological Trends

UV systems have evolved over the years. Equipped with low-pressure, low-output mercury gas discharge lamps, the systems used to be expensive and difficult to install (large footprint, large headloss), operate (output negatively affected by water temperature) and maintain (manual cleaning of lamps, numerous lamps to replace).

In the last few decades, several technological developments increased the mercury-based lamps' power and lifetime and decreased the impact of water temperature. Today, commercially available UV systems use either low-pressure (low-output, high-output or amalgam) or medium-pressure lamps. There are key differences between both types of lamp technologies, which are ultimately selected based on specific application needs.

Future product improvements include reducing the overall cost of operations and extending lamp life. Low-pressure amalgam lamps can last as long as 15,000 hours. Manufacturers hope to develop electrode-less lamps that can last 30,000 hours or more, using technologies such as microwave UV. Newly developed coatings will also extend lamp life.

Mercury-free UV lamps may also eventually be brought to market if regulatory bodies decide to address the perceived environmental concern associated with mercury in UV lamps. Broadband xenon pulsed lamps, narrow-band dielectric barrier discharge excimer lamps, and light emitting diodes (LEDs) are some possible options. However, to be successful, these innovative lamp technologies will need to overcome major hurdles such as high cost, low power, short life and/or poor UVC efficiency (conversion of electrical power into germicidal UV light).

The cost-effectiveness of UV systems will also improve through continuous hydraulics enhancements that will lead to better dose distribution within both closed-vessel and open-channel UV systems. The latter are used primarily for wastewater applications.

About the Author

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years ago and has more than 15 years of industry experience. A member of the Board of Directors of the International Ultraviolet Association (IUVA), Dr. Dussert has published more than 40 papers and holds five patents for such water treatment technologies as UV, ozone, activated carbon, chlorine dioxide and membrane separation processes. He has a Ph.D. in Environmental Engineering from the National Institute of Applied Sciences in Toulouse, France.

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