Subject: **A New Paradigm Unfolds for Drinking Water Treatment?**
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Your Worship & Members of Council,

The attached article is very readable, yet has a good balance of science in it, so that it gives an excellent view of the state of UV in potentially treating our water supply. Perhaps a staff report (by District and/or GVWD) is in order?

Yours truly,

Corrie Kost

http://www.trojanuvmax.com/business/disinfection_article1.html

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UV Disinfection:
A New Paradigm Unfolds for Drinking Water Treatment?

By Harold Wright, Senior Research Analyst Trojan Technologies Inc.

Summary: With recent gains in knowledge as to its efficacy on inactivating *Cryptosporidium*, ultraviolet (UV) light irradiation is positioned to become another option as "best available technology" (BAT) for surface water treatment once performance is confirmed. The following article discusses those developments.

The U.S. drinking water industry has become cautiously optimistic over recent reports that ultraviolet (UV) light inactivates *Cryptosporidium* and *Giardia* by several orders of magnitude (99.9% and greater inactivation) using UV doses well below traditional levels used in water and wastewater applications. These findings have convinced the U.S. Environmental Protection Agency (USEPA) to look at UV as a treatment option for surface water disinfection. Assembled this past spring, a UV Technical Working Group, composed of consultants and experts from government, academia and industry, is presently compiling information on UV disinfection in support of USEPA-sponsored rule development to deal with microbial risk, disinfection by-products (DBPs) and *Cryptosporidium*. Simultaneously, the International UV Association (IUVA) was formed to promote discussions on UV science and technology, encourage research, voice manufacturer interests, organize conferences and encourage regulatory development. This article offers background on these exciting events and asks the question-where shall the future unfold for UV?

Setting the Stage

The removal or inactivation of pathogenic organisms in water and wastewater is an important step towards protecting the public against waterborne outbreaks associated with potable and recreational waters. The treatment steps used to accomplish sufficient pathogen removal have evolved over the years driven in part by regulatory changes.

SDWA

In the United States, regulations for potable water treatment are covered by the Safe Drinking Water Act (SDWA). In 1989, the Total Coliform Rule set a maximum contaminant level (MCL) for all public water systems (PWS) and the Surface Water Treatment Rule (SWTR) specified for those PWS using surface water or ground water under the influence (GWUI) of surface water, treatment techniques with the objective of achieving maximum contaminant level goals (MCLG) of zero for *Giardia* and viruses. The 1996 Amendments to the SDWA mandated the USEPA develop new rules that would achieve an appropriate balance between DBPs formed during chemical disinfection and microbial risk.

Stage 1 D/DBP and IESWT rules

Under the Federal Advisory Committee Act, the USEPA set up a committee consisting of industry, government and public and environmental health groups to negotiate new rules governing DBPs and microbial risk. The first stage of this process led to promulgation of the Stage 1 Disinfectant/Disinfection By-Product (D/DBP) Rule and the Interim Enhanced SWTR. The former sets limits on disinfectant residuals and DBPs for community and non-transient non-community water systems. The latter extends the requirements of the SWTR for systems serving greater than 10,000 people to include, among other provisions, an MCLG of zero for *Cryptosporidium*, enhanced turbidity removal and monitoring requirements, a 99 percent, or 2-log, removal requirement of *Cryptosporidium* for those systems that use filtration, and the inclusion of *Cryptosporidium* in watershed control requirements for those systems that do not use filtration. If governed by watershed requirements, things must be done such as monitoring and restricting activities like farming, recreation and sewage discharges (with some exemptions). For systems serving less than 10,000 people, the Long Term 1 Enhanced SWTR-to be promulgated November 2000-will govern microbial risk as those systems implement the Stage 1 D/DBP Rule.

Stage 2 D/DBP and LT2ESWT rules

The Federal Advisory Committee is currently negotiating the Stage 2 D/DBP Rule and the Long Term 2 Enhanced SWTR. The negotiators are challenged to use current sound science to establish requirements that provide additional public health protection. The main issues are still *Cryptosporidium* and DBPs. *Cryptosporidium* is responsible for waterborne outbreaks causing diarrheal infections. In some cases, infection leads to death for the old, young or immunocompromised. *Cryptosporidium* is almost completely resistant against chlorine and an order of magnitude (10x) more resistant to ozone than *Giardia*.[1&5] Water treatment plants that do not use ozone or chlorine dioxide must reduce *Cryptosporidium* risk using filtration and watershed control. DBPs, on the other hand, have been linked to cancer and birth defects. Reducing DBPs may only be achieved by controlling DBP precursors, lowering chemical disinfectant concentrations, moving the disinfectant point more towards the end of the treatment process or changing the disinfectant. However, lowering DBPs by modifying chemical disinfection poses a dilemma-public health benefits achieved through reducing DBPs must not be at the expense of increased microbial risk. While the present debate assumes a trade off-reducing the risk from one agent results in an increased risk from another-a more appropriate strategy would be to ask what combination of technologies allows one to meet acceptable risk levels for both agents.

UV Meets the Challenge

UV is a cost-effective, established and increasingly popular alternative to chemicals for the disinfection of drinking water, wastewater and industrial waters. The science of UV disinfection is well established with fundamental research extending over six decades. With over 2,000 wastewater and reclaimed wastewater installations worldwide, over 2,000 groundwater and surface drinking water installations in Europe and over 1,000 groundwater installations in the United States-the practice of UV is well established. Potable water applications range from home installations to municipal UV treating over 9.5 million gallons per day (mgd). Wastewater applications currently range up to 155 mgd.

UV disinfects water by photochemically inactivating or damaging the nucleic acid (DNA and RNA) of pathogens thereby preventing them from undergoing cell division. Pathogen reproduction is part of the host infection process. UV has been demonstrated to be effective against a wide variety of pathogenic viruses, bacteria and protozoans. Using data reported in the scientific literature, Table 1 presents the UV dose required to inactivate disperse cultures of pathogens by various orders of magnitude. UV dose is defined as the product of delivered UV intensity and the exposure time and is analogous to CT values used to define chemical disinfectant dose. Accordingly, the units for UV dose are often expressed using milliwatt seconds per centimeter squared of area (mWs/cm2).

Of particular interest in Table 1 is the inactivation data for Cryptosporidum oocysts and *Giardia* cysts. Until recently, it was believed that UV doses well over 100 mWs/cm2 were required to achieve several logs of cyst and oocyst inactivation. Accordingly, UV disinfection was discounted as a practical technology for meeting the *Giardia* inactivation requirements of the SWTR. The UV inactivation studies upon which these high UV dose requirements were based utilized excystation and vital dye methods to assess the degree of *Cryptosporidium* oocysts and *Giardia* cysts inactivation achieved using UV. Research over the last year, however, has shown that excystation and vital dye methods seriously underestimate the degree of inactivation when compared to animal infectivity methods. In fact, animal infectivity assays have shown that Cryptosporium parvum oocysts, *Giardia* muris cysts, and *Giardia* lamblia cysts are very susceptible to UV light from low-pressure mercury, medium-pressure mercury and pulsed UV sources. Indeed, the low doses required are a fraction of the design dose currently specified in UV disinfection applications.[4]

UV disinfection in water, wastewater and reclaimed wastewater has been found to produce negligible concentrations of DBPs-even at UV doses in excess of those needed for disinfection. UV disinfection produces no measurable change in the DBPs formed when chlorine or chloramine are used as a secondary disinfectant following UV.[2&3]

Other aspects of UV disinfection also offer advantage. While the action of chemical disinfectants varies depending on the temperature and pH of the water, pathogen inactivation by UV light is independent of these factors. While various chemical species in water may absorb UV, the UV absorbance of water is easily measured and its impact on UV dose delivery readily predicted. In contrast, the complexity of chemical mixtures in water makes it difficult to anticipate chemical disinfectant demand and its impact on pathogen disinfection.

UV in the spotlight

UV's ability to inactivate *Cryptosporidium* has thrown UV disinfection into the limelight. On April 28-29, 1999, the USEPA convened a workshop on UV disinfection to define the state of UV science and technology and identify research needs. Presentations were made on *Cryptosporidium* and *Giardia* muris inactivation, the status of current AWWARF (AWWA Research Foundation) and EPRI (Electric Power Research Institute) funded research, aspects of various UV technologies, and examples of current municipal water UV applications. On April 28, a group of participants at that meeting later met to discuss the formation of the IUVA. The organization has since released the first issue of IUVA News, a forum for keeping members informed of new developments in the application of UV technologies.

On May 18-19, 1999, the Technical Work Group (TWG) for the Federal Advisory Committee negotiating upcoming drinking water regulations formed several subgroups, one being the UV disinfection subgroup. The UV subgroup has been given the mandate of providing the TWG information on the efficacy, reliability, safety, costs and benefits of UV disinfection to allow the Advisory Committee to make informed decisions on the role of UV in upcoming regulations.

Several issues have been identified. Confirming studies and dose tables for UV inactivation of *Giardia* and *Cryptosporidium* are needed. A better understanding of the impact of turbidity on disinfection efficacy is required for UV to be applied within unfiltered systems. Standards also are needed for the validation of UV reactor performance and dose delivery. And performance of UV process monitoring and process control needs to be demonstrated as reliable and effective. Many of these issues are the topics of current research. Others will be resolved by industry as competition leads to the demonstration of more reliable and more efficient UV reactors.

Conclusion

Does UV offer a new paradigm? UV disinfection has the potential of changing the way drinking water is treated and saving the public billions of dollars. The possibilities vary from having UV as an add-on technology to inactivate *Cryptosporidium* and *Giardia* to using UV as a primary disinfectant followed by residual disinfection using a chemical disinfectant. UV may also allow unfiltered public water systems to achieve compliance with protozoan cyst removal. The possibilities hold great promise for enhancing public health protection and the future for UV is definitely worth keeping an eye on.

References

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About the Author

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Table 1. UV inactivation of pathogens associated with outbreaks in drinking and recreational waters

Pathogen	UV dose[1] required to inactivate pathogens by a given percent			
	90%	99%	99.9%	99.99%
Cryptosporidium oocysts	N.A.	<10	<19	N.A.
Giardia muris cysts	N.A.	<5	N.A.	N.A.
Vibrio cholerae	0.8	1.4	2.2	2.9
Shigella dysenteriae	0.5	1.2	2.0	3.0
Escherichia coli O157:H7	1.5	2.8	4.1	5.6
Salmonella typhi	1.8-2.7	4.1-4.8	5.5-6.4	7.1-8.2
Shigella sonnei	3.2	4.9	6.5	8.2
Salmonella enteritidis	5	7	9	10
Hepatitis A virus	4.1-5.5	8.2-14	12-22	16-30
Poliovirus Type 1	4-6	8.7-14	14-23	21-30
Coxsackie B5 virus	6.9	14	22	30
Rotavirus SA11 & WA	7.1-16	15-36	23-26	36-50

1. In mWs/cm2

Data summarized from the USEPA Workshop on UV Disinfection of Drinking Water, April 28-29, 1999, Arlington, Va.

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