FEATURES

UVC-Ultraviolet Air Treatment

The One and Only MS2 UV Dose Response Curve

10 Years of Applied Research to Optimize Pre-Treatment and Post-Treatment of the MP UV/H₂O₂ Process at Water Treatment Plant Andijk

Influence of Effluent Organic Matter on the Hydroxyl Scavenging Capacity of Wastewater Effluents

Sucralose as a Hydroxyl Radical Probe

Introduction of a Mini-Fluidic Photoreaction System
As a global leader in Ultraviolet (UV) disinfection systems, OZONIA offers a wide range of open channel Vertical Lamp Systems (VLS) and closed vessel reactors for wastewater, drinking water, industrial process water and swimming pool applications. OZONIA’s Aquaray® UV systems incorporate the most advanced UV technology in the industry, are 3rd party bioassay validated and have a variety of features developed to simplify installation and minimize operator maintenance requirements.

**PRODUCT HIGHLIGHTS**

New Aquaray® HiCAP™
- Ozonia 1000W Amalgam Lamp Technology
- Integrated UV Bank Lifting System
- Three Module Sizes Increase Flexibility for Design & Expansion
- 3rd Party Bioassay Validated Performance
- Easy Access Vertical Lamp System (VLS)
- Energy Efficient “Row-by-Row” Flow Pacing and lamp dimming
- Automatic Quartz Sleeve Wiping System

For more information please visit our website at:

**WWW.OZONIA.COM**
sales@ozonia.com
INTRODUCING THE
PRODUCT HIGHLIGHTS

> Energy Efficient “Row-by-Row” Flow Pacing and lamp dimming
> New Aquaray® HiCAP™
> 3rd Party Bioassay Validated Performance
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GET THE NEWEST INNOVATION IN UV TECHNOLOGY FROM OZONIA TODAY!
IUVA began 2014 strong, with a series of webinars and meetings focusing on the issues affecting the use and implementation of ultraviolet technology worldwide. Our mission is to provide our members and the communities we serve with information on the contemporary issues influencing the use of ultraviolet technology in the water, air and health arenas.

Meanwhile, the Executive Operating Committee and the Board of Directors are working together to ensure we meet our goals of creating new programs for professional development and educational opportunities with future webinars, conferences and workshops. These programs will embrace our core values and engage our members and the public at large, while promoting the value of ultraviolet technology in the world.

The IUVA Education Committee is leading our efforts to pursue educational opportunities that will include training operators, creating curricula and developing educational programs to better serve the UV community and prepare a future workforce that is able to utilize UV sciences and engineering. Collaboration and partnership with other organizations that share our goals will contribute to our efforts in this area. For instance, IUVA is developing programs and partnerships with the Water Environment Federation (WEF), the American Academy of the Engineers and Scientists (AAEES) and RadTech.

Our IUVA Vice Presidents are also providing leadership in this effort. Among the webinars, programs and workshops to come are: The IUVA Americas Regional Conference in White Plains, N.Y., October 26-28, 2014, and a Symposium on UV Disinfection in Developing Countries on November 6 in Delft, the Netherlands. Stay tuned for more information to come on regional events hosted in South Korea and Singapore in 2015.

While our plate is full, we need your continued support by spreading the word about all of the good work of IUVA. I encourage you to reach out to your extended networks, forwarding announcements to colleagues and friends.

Your continued financial support of IUVA through membership, sponsorship, participation in meetings and events, and making donations enhance our ability to provide ground-breaking programs, which, of course, are inspired by and dedicated to you.

Thank you for your support,

– Karl G. Linden, Ph.D.
Sometimes in the blur of everyday hustle and bustle, one doesn’t realize how much is going on in the world of ultraviolet technology. The opportunities for UV abound worldwide in the water, air and health facilities arenas, as the world becomes more and more aware of the advantages of the technology. Our job at IUVA is to advance the association as the leading organization whose members have the expertise to make this technology work for a better, more safe and secure world. That is a tremendous responsibility and, indeed, it produces a huge reward when one realizes all the good that UV technology does in the world.

A key element of our advancement and marketing efforts for the IUVA brand is the robust schedule of professional development and educational programs, which also provide terrific networking opportunities. In April we had a webinar on UV-C LEDs, a program on disinfection for wastewater and a workshop on Healthcare Associated Infections. All were successful with attendance and reviews afterwards affirming the quality of the content.

We are looking forward to the Americas Regional Conference October 26-28 at the Crowne Plaza Hotel in White Plains, N.Y., where Marvin R. DeVries, president of Trojan Technologies will be the keynote speaker. And we are presenting a Symposium on UV Disinfection in Developing Countries on November 6 in Delft, Netherlands. We are also in the planning stages for our next World Congress in 2015 in Vancouver, British Columbia. I would encourage you to consider participation in all of these. For more information, go to www.iuva.org or contact me if you have any questions.

Educational outreach to students and members of the workforce in all stages of the STEM educational pipeline is a growing area of interest. Indeed, we are finding several attractive grant opportunities, which support these activities that target youth in grades K-12, undergraduate and graduate students, and workforce training. Not only do these activities contribute to the workforce development of the nation and the world, they also introduce and promote UV technology to a whole new population who will remember and hopefully value this information throughout the rest of their careers.

Meanwhile, we would ask you to look for opportunities to promote membership in IUVA to your colleagues and friends. Increasing membership continues to be a priority for IUVA, so that we can sustain the important work of our mission.

Thanks to all of you for your assistance and support – and I want to especially thank the leadership of Karl Linden and all of the members of the IUVA Board. I am sure that working together we can achieve even more for IUVA to the benefit of all our members.

Best wishes.

—Deb Martinez

**A Message FROM IUVA EXECUTIVE DIRECTOR**
When asked to write about my experience as an IUVA volunteer, I was a little bit stumped. I hadn’t really thought about my activities with IUVA as “volunteering.” My involvement with IUVA actually stemmed from fulfilling a more selfish objective of needing to quickly get up to speed on UV technology when I was asked to take charge of the wastewater disinfection technical resources group at CDM Smith. Having a long academic career, I am resourceful enough to know that the easiest way to learn something quickly is to seek out and join the network of other UV-savvy engineers and scientists to learn from them.

At first, I assisted with organizing a few workshops and sat on a few committees to do things like participating in scoring for best paper awards. As I became more involved in the IUVA’s work, including working with teams to develop technical communications documents, I discovered this incredible atmosphere of camaraderie and a highly experienced group of experts in this field who were willing to teach me the things that I didn’t know or understand. With the informal mentoring that I’ve found in this organization, I found myself wanting to be increasingly involved. Eventually I became one of the many contributing members of the IUVA and through continued involvement, served in the role of Secretary and then Treasurer and now, President-Elect — much to my own disbelief.

As a beneficiary of this organization, I’ve had the opportunity to interface with some of the industry’s most accomplished scientists and engineers, who have shared their knowledge and have become collaborators on IUVA events, research and engineering projects. I only hope that I can give back to the IUVA as much what the other “volunteers” have so generously given to me. This is why I’m so excited about all of the activities and volunteer opportunities that IUVA has planned for the future.

We have been fortunate to have tremendous leadership, past-president Paul Swaim has recently handed off the next presidential term to Dr. Karl Linden. Dr. Linden will work with our Executive Operating Committee, Board of Directors, and our incredibly talented Executive Director and Regional Vice Presidents to continue to push IUVA to the forefront as the authority on issues related to ultraviolet technology, its application and regulation. Already, the IUVA has a long list of committees and activities that need volunteers for 2014 and beyond. Our current president has called for our members to lend expertise, passion and support for new initiatives that engage industry, educators, policymakers and potential new members. Some of the committees and activities where volunteers are needed include:

• Education Committee - join subject-matter experts to develop industry-driven curricula in UV applications, including water disinfection and wastewater reuse.
• Technical Committee – work with other technical experts in the industry to develop responses to emerging issues
• Communications Committee – interface with other
committees to communicate the activities of IUVA

- IUVA News Editorial Board – support the distribution of emerging industry research and new case study applications
- Awards and Nominating Committees – work with other committee members to award excellent contributions to our industry; the nominations committee works to make sure that the membership is well-represented by the Board
- Conference and Event Organizers – join other IUVA members in organizing the technical sessions, workshops, tours and other aspects of conferences, workshops and upcoming webinars. Some of our upcoming events are highlighted here:
  - November 6, 2014 - Symposium on UV Disinfection in Developing Countries, Netherlands
  - September 2015 – IUVA World Congress, Vancouver, BC

If you are interested in participating in any of these volunteer opportunities, please feel free to reach out to any of our leadership, including myself (bellky@cdmsmith.com) or our Executive Director, Deb Martinez (deb.martinez@iuva.org), and we can provide more details on the roles and points of contact for participation. Additional information is available on the website at www.iuva.org.

Volunteering for the IUVA has been one of the most rewarding experiences of my recent career. It has been a huge opportunity for me to help promote good science and application of a technology that has a huge positive impact on human health and the environment. Join me and the other volunteers at IUVA to engage in one of the many opportunities for participation.

IUVA WELCOMES NEW MEMBERS

1. John Putnam, Environmental Dynamics Inc., jmp@eddipure.com, EI – 1 year, Virginia, USA
2. David Richardson, City of Moscow, drichardson@ci.moscow.id.us, EI – 1 year, Idaho, USA
3. John Walsh, Clean Air For The People, Inc., jpwharrier@msn.com, EI – 2 years, Florida, USA
4. Galina Matafonova, g.matafonova@gmail.com, ED – 1 year, Burya Republic, Russian Federation
5. Doug Olson, Associated Engineering, olson@ae.ca, EI – 1 year, Alberta, Canada
6. Jeff Bade, jeff.bade@baldwintech.com, EI – 1 year, Pennsylvania, USA
7. Jose Pelayo, lsl114@att.net, EI – 1 year, Texas, USA

Clean water is a matter of trust.

UV radiation is a reliable way to disinfect water and eliminate harmful substances. That applies to treating drinking water – the essence of life – and waste water alike.

UV lamps from Heraeus Noblelight are particularly efficient and thus stand out due to their very low energy consumption. Our lamps offer this recognized standard of quality throughout their long service life. Heraeus UV lamps combine exceptional reliability with cost-effectiveness.

Each of our UV lamps is tailored to the specific requirements of our customers.

Your partner for reliable UV solutions

Interested in UV solutions for water treatment?
Contact us at: hng-uv@heraeus.com
www.heraeus-noblelight.com
FIBERPLEX FIBER-OPTIC VAN ROLLS FROM AV TO INTERACTIVE EMERGENCY RESPONSE

A fiber optic-ready mobile production van began crisscrossing the eastern United States on a 25-city tour in March, rolling from live production in Georgia and heading straight into the March 24 – 26 North Carolina Emergency Management Association conference.

The FiberPlex-equipped van went from audiovisual lighting and staging or FOH use in Atlanta and continued on into the emergency conference in Raleigh-Durham, where the same fiber-optic communication link will be used to demonstrate a 9-1-1 emergency simulation for more than 300 state emergency managers there.

“Anymore, it doesn’t matter what the application is or where it’s at. Everyone wants the same thing, more bandwidth. I can open up the back doors to the van, and in five minutes, I’ve connected a full audiovisual or emergency system – or both – over a small fiber cable with bandwidth to spare,” said Kyle Rosenbloom, who, when he’s not talking with AV integrators and emergency managers, is behind the wheel of the production van as the Eastern Regional Representative for FiberPlex Technologies, a leading fiber optics equipment manufacturer.

Inside the van is a FiberPlex Live Production Toolbox with everything needed to easily connect remote cameras, microphones, closed-circuit TV cameras and other equipment over fiber optic communications regardless of media type or format. Included in the toolbox is FiberPlex’s LightViper fiber optic audio snake and WDM-16 active wave division multiplexer combining 16 optical channels, each at 3 Gb/s for transporting video, audio, lighting and control feeds onto one fiber pair.

As a result of multiplexing technology, optical fiber communications is not only easier to implement, but also more affordable than in previous years. “Optical fiber was cost-prohibitive just a few short years ago, but new technology from companies like FiberPlex is giving fiber an edge that other communication links can’t even come close to in terms of bandwidth and security properties,” commented Tim Hunnicutt with HWPco, which represents FiberPlex as a strategic partner. Optical fiber cable has ten times the transference rate of copper cable at the high end and can transmit data error-free over greater distances by a 400:1 ratio. And unlike copper, optical fiber does not put out electromagnetic radiation and is therefore not susceptible to emitting data that can lead to security breaches.

“We are seeing a huge demand for more security and bandwidth, especially in the emergency field because of new interactive smart technology that is pushing out more data,” agreed Phyllis Kinard with Strategic Connections, a systems integrator headquartered in Raleigh specializing in low-voltage smart systems. Kinard said bi-directional, high-capacity optical fiber communications is critical for creating new interactive opportunities between emergency command centers and responders at the state, regional, or even global level during a catastrophic event.

FiberPlex’s WDM-16 multiplexer uses interchangeable SFP/SFP+ modules for interfacing to a variety of gear and environments, including converting between media formats SD-SDI, HD-SDI, 3G-SDI, and 6G-SDI and for HDMI/DVI, 10/100/1000 Mbps Ethernet and MADI, as well as full duplex and BiDi optical. FiberPlex makes fiber optic products and systems for government agencies as well as for houses of worship, corporate facilities, broadcast applications, and K-12 and higher education.
About FiberPlex Technologies, LLC (www.fiberplex.com)

FiberPlex Technologies, LLC is a leader in digital transport and communications technology. The FiberPlex name has been around for a quarter of a century and is known for its secure fiber solutions to the U.S. government. Recently, FiberPlex extended its secure communications and fiber optic products to the commercial and AV sectors. As a fiber optics expert and equipment manufacturer, FiberPlex educates businesses, houses of worship, hospitals, financial institutions, campuses, broadcasters and live production firms on how to leverage fiber optics technology for large bandwidth delivery as well as to lower security risk and increase profits.

HANOVIA’S PURELINE PQ OFFERS AN ECONOMIC ALTERNATIVE FOR DAIRY PASTEURIZATION

Hanovia’s PureLine PQ range of UV disinfection systems is designed specifically to provide validated and chemical-free treatment of process water used in the dairy, food and beverage industries. PureLine PQ provides a time- and cost-effective alternative to standard pasteurization – it also meets the U.S. Food and Drug Administration’s 2011 Pasteurized Milk Ordinance guidelines.

PureLine PQ uses either low-pressure high output or medium-pressure lamps to safely disinfect water passing through the system, exposing it to UV light and deactivating any microorganisms present. All systems feature an automatic wiper to automate optical path maintenance, further reducing operating expenses.

The Dairy Plus Co. Ltd. in Thailand has recently replaced its chlorine-based disinfection system with five PureLine PQ UV systems – four duty and one stand-by. Two units disinfect clean-in-place (CIP) water and two are used for treating dairy mixing water, with each system treating up to 130m3/hour of water. Dairy Plus decided to reduce high levels of chlorine dosage throughout the process because it was proving ineffective at removing all microorganisms, particularly in the rainy season. It was also producing an after-taste in the product.

“Since our UV systems were installed the customer is very satisfied and reports excellent disinfection results,” commented Ying Xu, Hanovia’s Asia-Pacific Sales Manager. “Dairy Plus is particularly impressed by the low maintenance costs, the high energy output of the systems and the fact that the frequency of CIP procedures has been dramatically reduced, meaning less down-time of the manufacturing process”.

About Hanovia

Based in the United Kingdom, with a worldwide distributor network, Hanovia is a world leader in UV disinfection technology for industrial applications. The company is celebrating its 90th anniversary this year. From its early days manufacturing UV lamps to treat skin conditions to today’s validated, performance qualified UV water treatment systems, Hanovia has always been a technology leader and at the forefront of UV innovation. Hanovia is a subsidiary of Halma plc.

eta plus electronic gmbh
Lauterstrasse 29
D- 72622 Nuertingen/Germany
info@eta-uv.de, www.eta-uv.de

eta plus derives from η+: a continual increase in efficiency; for over 20 years we have committed ourselves to this principle in R&D, manufacturing and customer service.

Our own medium pressure UV lamps and perfectly matched ELC® electronic lamp control units will provide you with reliable customised solutions for systems up to 32 kW.

H2O + UV = η+

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HAZLUX® HAZARDOUS LOCATION LINEAR FLUORESCENT LIGHTING CAN BE INSTALLED AT VARIOUS ANGLES
Thomas & Betts Adds XFM and DFP Series to Product Line

The Hazlux® line of hazardous location lighting from Thomas & Betts now includes the new XFM and DFP Series linear fluorescent fixtures, which both provide installation at various angles. The XFM Series, designed for explosive atmosphere locations, features five different ½-inch NPT hub entries on each end and provides installers with options for various lighting angles. The DFP Industrial Series, designed for hazardous locations in industrial and wet environments (Class I, Div. 2), features optional mounting brackets that enable precise aiming in multiple angles.

“Hazlux® lighting fixtures provide a wide selection of luminaires for hazardous and adverse environments,” said Chad Smith, vice president, product management and engineering, at Thomas & Betts. “The addition of the XFM and DFP Series to the Hazlux® Lighting product line enables T&B to provide linear lighting solutions for industrial and hazardous locations.”

Additional features of the XFM Series include ballasts placed at the center of the luminaire to provide greater balance for ease of installation, better weight distribution and a low-profile and factory-sealed, cast aluminum construction, with a one-piece painted aluminum reflector.

Lamps are included with the XFM Series luminaires in a choice of Types T5, T5HO, T8 and T8HO. The XFM Series is available in two-foot and four-foot lengths for two-, three- and four-lamp combinations.

Among its applications are paint-spray booths, marine locations, chemical plants, wastewater treatment facilities, oil-drilling rigs and refineries, grain elevators, and coal and dust storage.

The DFP Series is available in two-, three-, four-, five- and six-lamp options, all using a 3/16-inch tempered glass lens with acrylic and polycarbonate optional lenses. Lamps are not included with the DFP Series luminaires. Applications include chemical plants; paper mills; tunnels; water treatment facilities; seacoast locations; preparation, inspection and sanding locations; machining locations; and coal and dust storage.

For more information about the new Hazlux® Hazardous Location Linear Fluorescent Lighting XFM and DFP Series from Thomas & Betts, please visit www.tnb.com and look for Hazlux® on the “Brands” tab, or call (800) 238-5000.

About Thomas & Betts Corporation
Thomas & Betts Corporation, a member of the ABB Group, is a global leader in the design, manufacture and marketing of essential components used to manage the connection, distribution, transmission and reliability of electrical power in utility, industrial, commercial, and residential applications. With a portfolio of more than 200,000 products marketed under more than 45 premium brand names, Thomas & Betts products are found wherever electricity is used. Thomas & Betts’ headquarters are in Memphis, Tenn. For more information, please visit www.tnb.com.

WORLD WATER DAY 2014: DISINFECT DRINKING WATER AND SAVE ENERGY AT THE SAME TIME

With long-life UV lamps, Heraeus helps to disinfect drinking water in an energy-saving and environmentally friendly way - whether in Hanau or New York.

“Water and Energy” was the topic at the World Water Day 2014 that was held by the United Nations on March 22. This year’s World Water Day emphasized the connections and interactions between water and energy and focused on energy production and transmission, in particular for water power, nuclear power and thermal energy sources, and the use of water resources. The energy-efficient use of UV lamps for drinking water treatment was also a topic. Smart product solutions and UV technologies by Heraeus enable environmen-
tally compatible, energy-saving and sustainable disinfection of drinking water. All over the world, municipal water works profit from this - from Hanau, Germany, to New York City.

The treatment of drinking water and used water with high-energy ultraviolet radiation for disinfection is an environmentally friendly method established for more than 100 years. It works without chemicals such as chlorine or ozone. Special UV lamps supplied by the specialty light sources division destroy microorganisms such as bacteria, viruses and parasites and help decompose chemicals that are detrimental to health. Neither the taste nor smell of the water are affected. The Hanau municipal utilities have been making use of this drinking water treatment method for more than one year. To treat the water of a Hanau suburb, they have replaced chlorine disinfection in a water tower with a UV disinfection system supplied by Trojan. The system uses modern and long-life Heraeus amalgam lamps.

**Long-life UV lamps enable compact disinfection plants**

Due to a special production process, the Heraeus long-life UV lamps enable almost constant disinfection over the entire life of a lamp. Up to 90 percent of the original output is achieved even after a good 16,000 hours of operation, which is almost twice as long as usual commercial UV lamps. Thanks to the higher UV output and long service life, plant manufacturers such as Trojan need fewer lamps to design UV systems for disinfection. Moreover, the systems are low-maintenance and cost-efficient because lamps only need to be replaced after two or three years of operation. This provides a considerable potential for saving as regards number of lamps, system components, energy requirement, service intervals and cost of operation and maintenance. Compact disinfection systems are made possible, which further reduces the amount of space required.

**12,000 UV lamps for the Big Apple**

The water treatment plant put into service in New York at the end of 2013 is much larger. It is the world’s largest UV disinfection system. Some 12,000 UV lamps in 56 so-called reactors, each the size of a truck and likewise supplied by Trojan, treat more than 8 million cubic metres of water for the City of New York every day. Heraeus has supplied the initial UV lamp equipment. The water passes the special low-pressure gas discharge lamps and their UV light renders microorganisms innocuous within seconds. With this ‘green’ disinfection method, the city minimises its expenditure on maintenance and energy consumption for drinking water treatment to guarantee perfect drinking water for the metropolis.

Learn more about specialty light sources for water treatment at www.heraeus-noblelight.com.

**SENSOR ELECTRONIC TECHNOLOGY INC. UNVEILS SMD-BASED 10MW UVC LEDS AT PITTCON 2014**

Sensor Electronic Technology, Inc., announced the launching of its latest product in the line of surface mount UVC LEDs at the Pitcon Conference and Expo in Chicago in March. The new SMD consists of a large area single chip device packaged in a 4.2mm x 4.2mm ceramic package that can deliver 10mW of optical power at 275nm.
The current line of surface mount UVTOP® LEDs were released at the beginning of 2013 to drive standard 1mW UV LED technology into ultra-high volume applications and SETi stated that the market response has been overwhelming. The new 10mW product is designed to further drive down the cost per milliwatt of UVC power for high volume, power intensive applications such as water, air and rapid surface disinfection.

“The new 10mW SMD based UVC LED strengthens SETi’s leadership in the UV LED market and demonstrates our commitment to new high volume market opportunities” said Dr. Remis Gaska, president and CEO.

These LEDs are now available for purchase at sales@seti.com.

For more information, please contact SETi at info@seti.com or visit www.seti.com

CRYSTAL IS PRIMES FOR TRANSITION TO COMMERCIAL MANUFACTURING AND ANNOUNCES NEW VICE PRESIDENT OF OPERATIONS

Crystal IS, a leading developer of the most effective UVC LEDs, recently announced the appointment of John Gartner as its first vice president of operations. Gartner brings more than 30 years of experience in manufacturing and engineering, including establishing and growing manufacturing operations for clean and reliable energy solutions.
His expertise and experience will help transition Crystal IS from R&D to a manufacturing company poised to become the market leader in UVC LEDs for life sciences, environmental monitoring and disinfection.

“It is clear that Crystal IS has committed to moving from R&D to commercial product development,” said John Gartner, vice president of operations, Crystal IS. “I’m thrilled to be part of the team leading the company in this exciting time.”

In conjunction with the addition of Gartner, Crystal IS continues to expand the Green Island facility preparing it for full-scale production and shipping of soon-to-be-announced Optan product with the addition of:

• a raw material furnace as well as three additional furnaces and a chiller to double manufacturing capacity
• a new lab and production equipment for fine wafer polishing
• moving fabrication in-house to the AK Fuji facility
• 23 percent employee growth across the organization in areas including application engineering, quality, customer support and product marketing

“Appointing John Gartner as our first vice president of operations and expanding our manufacturing capacity demonstrates our commitment to commercializing our superior technology and getting our breakthrough products to customers,” said Larry Felton, chief executive officer.

Crystal IS, an Asahi Kasei company, is an innovative U.S.-based manufacturer of proprietary, high-performance UVC LEDs. Crystal IS products are suitable for monitoring, disinfection and sterilization in a variety of applications, including industrial and point-of-use (POU) water purification as well as infection control in air and surfaces in health-care industries. The company’s powerful and reliable UVC LEDs provide customers with the flexibility to develop new products that enhance and sustain life. For more information, visit www.cisuvc.com.
IUVA Americas Regional Conference

**Date:** October 26, 2014 - October 28, 2014

**Location:** Crowne Plaza Hotel, White Plains, 66 Hale Avenue White Plains, New York 10601

**Hotel Information**
Crowne Plaza Hotel, White Plains
66 Hale Avenue White Plains, New York 10601
Phone: 914-682-0050

To make a reservation call 1-800-227-6963 and ask for the International Ultraviolet Association or code W7A.

The Crowne Plaza White Plains provides complimentary transportation to and from the Westchester Airport every hour from 6am - 11pm. If you land at Laguardia and JFK Airports, the hotel recommends Red Dot Airport Shuttle (800-673-3368) and reservations are required. The Crowne Plaza is within walking distance of 60 restaurants and bars. Westchester Mall which hosts 150 stores including Neiman Marcus and Nordstrom is across the street. The hotel will contact local cab companies for guests who wish to take the Metro North Train into New York City. The approximate cost of a one way cab ride to the train is $10.00.

**Technical Tour**
There will be a Technical Tour of the Cat/Del UV facility, the world largest UV Disinfection facility.

Sponsorships and Exhibit Space are available. For more information please email info@iuva.org

For more information about the Regional Conference, including hotel information and the Technical Tour, visit: https://www.iuva.org/event/americas-regional-conference
NEW! ILT1000 Light Meter, Monitor & Datalogger -
Designed with OEM and custom configurations in mind - can easily accommodate most solid state detectors, 1/2” and 1” optical filters and a vast selection of standard and submersible/watertight fibers and input optics.
Measure over 6 decades of light intensity. Provides direct readout in W, W/cm², Lux, Fc, Lumens, cd/m², cd, W/sr, W/sr/cm² and more.
On board data storage for continuous monitoring at customer specified sampling rates using the “set it and forget it” datalogging.

UV Monitoring Applications include bottled beverage and food industry, drinking and pool water disinfection, HVAC, pharmaceutical/cosmetics, semiconductor, municipal water/wastewater disinfection.

NEW! ILT950-UV Portable Spectroradiometer
Most Cost-Effective, Fully Integrated, CCD-based Spectroradiometer Available with ISO17025 Accredited Calibration
Two Versions:
ILT950UV: 200-450 nm
ILT950: 250-1050 nm
Includes ILT’s powerful SpectriLight III software, including PAR, μmol/m²/s, Metamerism, and baseline overlay comparisons.
ILT offers pre-configured complete measurement systems that include everything you will need to take accurate, calibrated light measurements. Or build your own system with our vast array of standard or submersible/watertight fibers, input optics, accessories, calibrations, and software.

Go-To Standards! ILT1400 & ILT1700 Radiometers
For over 45 years, ILT has been providing unmatched UV measurement results to researchers, engineers and QC personnel with our ILT1400 Portable and ILT1700 Research Radiometers. Hundreds of sensor configurations available including UV measurements from 185 to 400 nm with interchangeable, submersible, ISO 17025 /NIST traceable, calibrated sensors.

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USA
By now, IUV A readers are well aware of the application of UVC in water disinfection; the same ultraviolet technology has been found to be useful in air and surface disinfection as well. The use of ultraviolet technology to minimize airborne contaminants, reducing infection and providing ultraclean air, has been studied and used since the 1930s. UVC technology used in HVAC applications can be beneficial in various environments ranging from residential to commercial to industrial HVAC systems. There are two major kinds of HVAC applications of UVC: pass-by disinfection, and coil and drain pan treatment. This same technology has also been documented to be beneficial to healthcare settings.

PASS-BY AIR DISINFECTION
Pass-by air disinfection improves the overall air quality by decontaminating air as it is pushed through the HVAC system. For residential HVAC applications, we would typically see a single ultraviolet lamp located in the return duct while a bank of lamps would be used to treat air in commercial or industrial applications. For example, American Ultraviolet’s ICR Rack (Figures 1,1A) works by increasing the density of UVC light in a critical run of duct in a commercial or industrial application or in a large commonplace scenario. Following an easy installation process, reduction rates of bacteria, viruses, fungi and other such contaminants can be over 99 percent, depending on the microbe, with most documenting well over 90 percent.

COIL AND DRAIN PAN TREATMENT
The second option involves the coil and drain pan of the HVAC system. The coil is the heat exchange (heating) or (cooling) coil of the HVAC system, the heating and cooling of the coil creates condensation, which collects in the drain or drip pan. Coil and drain pan treatment works by directly irradiating the surfaces of the coil and drain pan with UVC light. In this type of HVAC application, the origin of the problem is treated as opposed to treating the symptom of infected airborne contaminants, which is targeted by pass by disinfection. Coil and drain pan treatment can either be used in a new installation to preserve the performance of the system or prevent the start of contaminants or used as a retrofit to an existing installation to fix current problems and return the system to the designed performance characteristics. Due to blow off that can occur from dirty coils, it is incredibly important to use a moisture proof fixture in the retrofit application to keep the electrical connections from shorting out. This is less of a concern with new systems, but moisture can still be present for a variety of reasons.

SO WHICH SOLUTION IS BETTER?
Ideally, it would be the most beneficial to combine both methods, by treating the coil directly as well as one or two critical places of ductwork for pass by air disinfection. This approach would not also provide intensive ultraviolet treatment with an additional buffer, but would also maintain the designed performance of the coil and drain pan system for longer periods of time. Ultimately, this approach would preserve the HVAC system thus allowing it to last longer before replacement and effectively saving money down the road. In theory, who doesn’t want the air they are breathing, like anything else important to us, not checked once, but twice! However, there are reasons why someone may choose one system or the other; we typically see more coil and drain pan treatment applications for its system benefits. There are situations where the pass by air disinfection route is an appropriate alternative especially when, planning and space are of concern, the pass by disinfection can be mounted to ductwork pretty quickly and easily. For
example, we have a specific series (Figures 2,2A) with various size offerings that can be mounted essentially anywhere, as opposed to the coil and drain pan treatment which may need additional planning and retrofits that at times may not work reasonably in certain space confinements. Both solutions have similar overall results of reduction in airborne contaminants of over 99 percent, depending on microbe, thus whatever the solution is called for, the end result would be similar.

HEALTHCARE AIR TREATMENT APPLICATIONS

There is a large demand to keep hospital-acquired infections (HAI’s) and contaminants low in rooms frequented by sick individuals, such as waiting rooms and patient examination rooms. In these scenarios, we would recommend in-room upper air treatment systems. These devices disinfect air in the room using upward facing ultraviolet lighting mounted to the wall, thus avoiding exposure by patients directly to the light.

Why would this be necessary? Imagine a scenario of a patient visiting a doctor’s office or clinic. The patient would more than likely spend at least some period of time in a waiting room with other patients, many of who could have an infectious illness. It is unreasonable to believe that an airborne microorganism transmitted from one individual in the waiting room would travel through the entire HVAC system prior to being inhaled by the second individual. The in-room application can acutely treat high traffic rooms to provide disinfection at a quicker rate. To provide an additional level of protection in surgery rooms, upper air treatment can be combined with direct surface treatment using UVC light before, during, and after surgeries. This method, combined with the existing HVAC UVC units, has been documented in various studies to create a reduction in HAI rates. The Journal of Bones & Joint Surgery ran an article discussing such matters in 2008. The authors analyzed the results of a study conducted over a 19-year period. In this specific study, one surgeon conducted 5,980 joint replacement surgeries from 1986 to 2005, at The Center for Hip and Knee Surgery, St. Francis Hospital in Mooresville, Ind. In September 1991, ultraviolet lighting was installed in the operating room while the technology in place, laminar airflow that filters and creates a reduction in microbes in the air, was discontinued. The infection rate prior to the installation of UVC lighting was 1.77 percent, while the infection rate with UVC lighting was 0.57 percent, a three times reduction in the infection rate. The infection rate of total hip replacement went from 1.03 percent with laminar airflow to 0.72 percent with ultraviolet lighting, while the rate for infection during total knee replacement lowered from 2.20 percent to 0.50 percent with the use of ultraviolet technology. According to the article, “when appropriate safety precautions are taken, ultraviolet lighting appears to be an effective way to lower the risk of infection in the operating room during total joint replacement surgery” (Journal of Bone & Joint Surgery, 2008). Why is this important? It demonstrates the benefit of ultraviolet technology by actually killing bacteria/contaminants as opposed to simply reducing the amount of these DNA based airborne contaminants in the operative environment.

In closing, UVC technology has many applications shown to be beneficial. Regardless of using ultraviolet lighting to disinfect water, air, or surfaces, the results are both impressive and needed. There is something to be said about any technology that documents benefits of three to four time reductions in infection, thus proving that UVC light is a technology that more industries should consider implementing!
The One and Only MS2 UV Dose Response Curve

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The UV inactivation kinetics of microbial species are predictable, within a range of variability, in waters free of interfering particles, and when the UV absorbance is accounted for in the measured irradiance through the UV light path. While some organisms, particularly bacterial spores, show a lag period of relatively low sensitivity at low UV doses followed by steeper kinetics at higher UV doses, others, such as vegetative bacteria and viruses exhibit first order kinetics from low to higher levels of inactivation. At levels above 4- to 5-log10, most microorganisms exhibit a tailing of the UV dose response. Given the growing body of data generated by UV reactor bioassays, the UV dose response of many studied microorganisms is quite predictable within species or strains. However, measured UV dose responses will vary arising from experimental variability, water quality influences, and microbiological variability. For applications to UV reactor bioassays, acceptable UV dose response bounds for coliphage MS2 have been prescribed by several sets of guidelines, including the USEPA’s UV Disinfection Guidance Manual (UVDGM, 2006), and the NWRI UV Guidelines (2000, 2003 and 2012). This paper reviews the history of the NWRI MS2 UV dose response bounds through the three editions from 2000 to 2012, and assesses the newest edition’s standardized UV dose response relationship as well as the data with which it was developed.

Editions 1, 2 and 3 of the NWRI Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (National Water Research Institute, 2000, 2003, 2012) provide guidance for the design, installation, operation and maintenance of UV systems, and include a protocol for performance validation by bioassay. This protocol specifies the bioassay surrogate microorganism as coliphage MS2 (ATCC 15597 B1), and that the UV dose response of the stock microbial suspension must fall within defined upper and lower bounds. A significant change made in the third edition is the assignment of a fixed, or standardized, UV dose response of the MS2 used in all bioassays, as opposed to the conventional use of the specific UV dose response, developed by collimated beam (CB), of MS2 in feed water samples collected each day of bioassay testing. The purpose for this change was to “minimize the impact of experimental variability” (NWRI, 2012), and the drive for this was to avoid the possibility that reactors that had been validated prior to installation might be de-rated in a post-installation spot check if the variability in the measurement of the MS2 UV dose response returned a lower reduction equivalent dose (RED) than was predicted by pre-installation test results.

In all three editions, the NWRI protocol requires that the UV dose response of stock MS2 suspensions used in bioassays be determined by the CB method, using exposures to produce UV doses of 20 to 150 mJ/cm2. The linear regression of the resulting data points is determined and compared to upper and lower bound equations (Eq 1 and 2). To be acceptable, 80% of all data points from 20 to 150 mJ/cm2 must fall within these bounds.

\[ \text{1) } -\log_{10} \left( \frac{N}{N_0} \right) = (0.040) (\text{UV dose, mJ/cm}^2) + 0.64 \]

\[ \text{2) } -\log_{10} \left( \frac{N}{N_0} \right) = (0.033) (\text{UV dose, mJ/cm}^2) + 0.20 \]

These NWRI UV dose response bounds were derived from an undefined body of MS2 UV dose response data that had been generated prior to the first (2000) edition, prior to the publication of standardized CB methodology (Bolton and Linden, 2003). Neither this body of data nor the methodology(ies) used to generate it has been available for review. The linear equations were developed with data from 20 to 150 mJ/cm2, and do not incorporate any data for 0 log inactivation at 0 mJ/cm2 data point (zero UV dose).

In editions 1 and 2, the bounds were applied in two ways. First, stock MS2 UV dose response was measured after being produced in a laboratory, and if it was within these
bounds, it could be used in a bioassay. Second, the UV dose response of the MS2 in the seeded reactor feed water in a bioassay was also measured by CB and used as the basis for determining the RED. This UV dose response must also lie within the NWRI bounds, or the bioassay must be repeated. Edition 3 retains the same bounds, and stock MS2 UV dose response must again fall within them to qualify for use in a bioassay. Likewise, the UV dose response of MS2 seeded to the reactor feed must meet the bounds, or the bioassay is repeated. The third edition differs, however, from its predecessors and from conventional bioassay protocol, in that the UV dose response curve of the seeded MS2 is not used in the determination of RED. Rather, a UV dose response relationship calculated from a large body of more recent collimated beam test results, generated by three independent laboratories involved in NWRI and UVDGM validations, is used as the default curve to which all reactor inactivations are compared to determine the RED achieved during any bioassay. The data used to produce this relationship, given in Equation 3, are shown in Figure 1, along with the upper and lower NWRI UV dose response bounds.

\[
\log_{10} \left( \frac{N}{N_0} \right) = (0.0368) \text{ (UV dose, mJ/cm}^2\text{)} +0.5464
\]

Figure 1. MS2 data used in NWRI 3rd Edition linear standardized UV dose response (dataset courtesy A. Salveson, K. Bourgeois, Carollo Engineers)

Representing the full NWRI dataset with a polynomial equation does indeed give a better fit, as shown in Figure 2. It can be seen here that the slope of the data from 20 to 60 mJ/cm² is steeper than that from 90 to 140 mJ/cm². The NWRI approach of excluding data below 20 mJ/cm² because they are not linear should preclude the use of any MS2 data, as no significant segment of the UV dose response relationship is linear.

Figure 2. MS2 data used in 3rd Edition standardized UV dose response, and including data points below 20 mJ/cm²

The consequences of using a linear relationship and ignoring the <20 mJ/cm² data manifest in several ways. One
is that the NWRI bounds, while drawn from a different dataset than the standardized curve, also exhibit artificially low slopes and positive y-intercepts. As a result, valid data points, including many of those used to develop the standardized curve, lie outside the bounds. Particularly troublesome are the many above the bounds in the 40 to 100 mJ/cm² range, visible in Figure 2. An MS2 stock with two of these “high” data points could not be used, even though it exhibits a conventional UV dose response. Any bioassay run with a corresponding CB curve that returned two such points would be disqualified. Aside from the cost and inconvenience of re-testing a UV reactor, the disqualification of these higher inactivation data means that conservative results are not used, while less conservative data are readily accommodated by the wide gap between the data and the lower bound line.

As noted above, neither the methods used to generate the raw data for the original (and still current) NWRI bounds, nor the data themselves, are available for review. Until standardized collimated beam procedures became routine in the wake of Bolton and Linden’s 2003 treatise on the subject, laboratories tended to use well practiced methods, but not necessarily incorporating certain factors which affected the total irradiance, such as UV absorbance, reflectance, divergence, and radiant distribution, or Petri factor. These factors are now included in exposure calculations by laboratories for bioassay CBs supporting UVDGM and NWRI bioassays, although NWRI does not require the divergence correction, which varies with distance from the lamp and reduces the measured irradiance (and extends exposure times) by 2% at 25-cm distances. All of these factors adjust the measured center irradiance in the same direction, correcting it downward because of photons lost due to absorbance, reflection, divergence, or poor distribution as quantified by the Petri factor (which typically manifests with less irradiation away from the center). In drinking water and wastewater bioassays, adjustments made for reflection, divergence and distribution typically reduce the measured center irradiance by a total of 5 percent to 10 percent, and UV absorbance would result in an additional reduction. Thus, it might be hypothesized that MS2 data generated in the pre-Bolton and Linden era could have overstated irradiance, and under-calculated exposure times, resulting in a low UV dose response slope. The new, post-UVDGM generated data used in the 2012 Edition standardized curve suggests this is the case, as Figure 2 shows that the recently generated data from three UV validation laboratories consistently bump against and exceed the upper NWRI bound. Evaluating another multi-lab dataset generated since Bolton and Linden, Malley et al, 2004, reported MS2 inactivation frequently fell above the upper NWRI bound, and they suggested a revision of the NWRI bounds should be made. Data from that study were in fact evaluated by NWRI for adjustment of the MS2 bounds (R. Sakaji, pers comm, 2003). A draft revision (not publicly distributed), issued in March 2003 for review preceding the May 2003 second edition presented the bounds given in Equations 4 and 5.

\[4 \quad \log_{10} \left( \frac{N}{N_0} \right) = (0.044) \text{ (UV dose, mJ/cm}^2) + 0.7 \]

\[5 \quad \log_{10} \left( \frac{N}{N_0} \right) = (0.036) \text{ (UV dose, mJ/cm}^2) + 0.13 \]

Comparing the 3rd Edition standardized curve data against these draft bounds (Figure 3) gives a much different picture than seen in Figures 1 and 2, as the draft bounds better accommodate the entire dataset, and do not disqualify bioassays that produced the higher, conservative inactivation points. However, because of a lack of time to allow full review of these data prior to publication of the second edition, the bounds defaulted to the 2000 equations, and were not revisited for the 3rd edition in 2012.

Finally, aside from the question of whether the NWRI standardized curve adequately represents the dataset used to develop it, one must ask whether the use of a fixed MS2 UV dose response equation is appropriate at all for reactor RED assignment. The underlying assumption justifying its use is that all variability of the MS2 UV dose response is because of experimental artifacts during the collimated beam process and that in all cases, and in all water matrices, MS2 has an exact and constant inactivation kinetics profile. If this is not a valid assumption, reactors may be credited with inaccurate performance ratings, resulting either in validation failure or inadequate public health protection. That a constant UV dose response may not exist across site-drinking water and wastewater qualities is a distinct possibility, as MS2 has been reported to exhibit
increased inactivation kinetics in the presence of certain chemicals or dissolved ions. (Protasowicki and Malley, 2002, Butkus et al 2004, Hargy et al 2007). In wastewater, to which the NWRI guidelines apply, an unlimited array of chemicals could be present which may enhance MS2 inactivation. While a collimated beam exposure with the same water would capture that effect and accurately reflect the site-specific UV dose response at reactor scale, the fixed, standardized curve cannot respond. As a result, the inactivation achieved because of water quality influences would be attributed solely to the efficacy of the UV reactor, and an artificially high RED would be assigned. If the influencing water quality components are intermittent, the enhancement would also be intermittent, but the treatment credit would remain a constant. Finally, as any synergy between UV and water quality components that enhances MS2 disinfection may not be realized in treatment of target pathogens, using a standardized curve and ignoring the true site-specific UV dose response would result in an over-prediction of pathogen disinfection efficacy.

The use of a standardized MS2 UV dose response does provide a hedge against variability in the collimated beam process, but at the cost of having the reactor RED assigned by a UV dose response curve that may not represent the actual inactivation kinetics. A fixed, standard curve does not use the true UV dose response determined in a well-controlled CB process, and it does not account for changes in MS2 UV dose response caused by water quality influences, or any real laboratory-specific inactivation kinetics variation arising from the host/phage interaction. The disconnect between actual and standardized UV dose responses is exaggerated in the NWRI third edition protocol by the fact that the ‘curve’ is expressed as a linear relationship, which it decidedly is not.

A better means of characterizing a bioassay microbes UV dose response is to ensure that thorough quality control measures are used by the microbiology laboratories undertaking validation bioassays. The use of a second radiometer, as required in the UVDGM, would verify the incident irradiance measurement. Because the radiometer measurements made for the bioassay CB set the irradiance for all exposure calculations, they directly affect the resulting UV dose response curve and ultimately the RED assignment for that reactor for all present and future operation based on that bioassay. Radiometer readings tend not to be randomly variable, with one measurement being high and the next low, but rather, if not perfectly accurate, will be consistently high or low off the true value, or will drift in a given direction over time. Neither sudden divergence from true calibration nor slow drift of the laboratory radiometer will be readily apparent unless a reference radiom-eter or chemical actinometer is used to confirm readings.

The requirement that MS2 UV dose responses meet linear statistical bounds that were developed from a population of data not representative of well-measured MS2 inactivation kinetics can cause good phage stock and well-run bioassays to be disqualified. Re-defining the NWRI bounds equations as polynomial expressions based on the more recent dataset and including data below 20 mJ/cm2 (and preferably excluding data well above the UV dose range relevant to the bioassay) could be undertaken simply by editing the Excel trendline format.

Statistically sound UV dose response curves developed in a well-controlled manner, using seeded feed water, and analyzed in the same manner as the reactor inlet and outlet samples, will capture the impact of any site- or lab-specific inactivation kinetic nuances, and offer a more accurate RED assignment than one based on a pre-established MS2 UV dose relationship.

REFERENCES


10 Years of Applied Research to Optimize Pre-Treatment and Post-Treatment of the MP UV/H$_2$O$_2$ Process at Water Treatment Plant Andijk

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ABSTRACT
Requirements of a treatment process for drinking water production from challenged surface water sources shifted over the past decades. The role UV can play in an integrated treatment approach is illustrated by a case study discussing the various research results leading to treatment upgrades at Andijk. The paper describes the feasibility of advanced oxidation based on MP UV/H$_2$O$_2$ treatment for organic contaminant control and a robust primary disinfection. The impact of conventional surface water treatment based on coagulation, sedimentation, filtration and advanced surface water pre-treatment, based on ion exchange and ceramic microfiltration, on the efficiency and by-product formation is presented. Finally, the role of post-treatment by biologically activated carbon filtration on by-product and toxicity control is evaluated.

INTRODUCTION
Water treatment plant (wtp) Andijk (The Netherlands) was constructed in 1968 as a conventional surface water treatment plant based on breakpoint chlorination and coagulation sedimentation and filtration (CSF), servicing water from the IJssel Lake as raw water source. Before 1978, the treatment process was upgraded by implementation of granular activated carbon (GAC) filtration (Figure 1). Customer complaints regarding taste and odor were the main cause for this modification. In addition, to further improve the taste and odor of the produced water, post-chlorination was replaced with chlorine dioxide dosage.

The next retrofit of wtp Andijk was necessary in view of upcoming regulations regarding THMs (Kamp et al., 1997). Furthermore, additional disinfection capacity for protozoa was required. Finally, PWN pursued implementation of a non-selective barrier against organic contaminants because of a shift from non-polar to more polar compounds and from just pesticides to a wide variety of micro-pollutants.

Concentrations of organic micro-pollutants such as pesticides, endocrine disruptors and pharmaceuticals as high as 1.0 mg/L have been observed in the raw water source. Storage in reservoirs lowered the maximum concentrations to 0.5 mg/L. Treatment should be capable of lowering this concentration by 80 percent to satisfy the EC standard for pesticides of 0.1 mg/L.

As a non-selective barrier, advanced oxidation was pursued. Initially O$_3$/H$_2$O$_2$ treatment was considered (Kruithof et al., 1995). O$_3$/H$_2$O$_2$ treatment (O$_3$/DOC 1.1 g/g, H$_2$O$_2$/O$_3$ 2 g/g) proved to be a very robust barrier against organic micro-pollutants. With bromide levels of 300 - 500 mg/L, IJssel Lake water can be regarded as bromide rich. This high bromide content may cause bromate formation by ozone-based processes (Gunten, von, Hoigné, 1994). In CSF pre-treated IJssel Lake water the bromate formation proved to be very high, especially at low water.
temperatures. By increasing the H\textsubscript{2}O\textsubscript{2}/O\textsubscript{3} ratio from 2 to 4 g/g and increasing the pH from 8.0 to 8.3, bromate formation was restricted but could not be lowered to values less than 3 μg/L. Therefore PWN decided to reject O\textsubscript{3}/H\textsubscript{2}O\textsubscript{2} treatment for full-scale application.

Because O\textsubscript{3}/H\textsubscript{2}O\textsubscript{2} treatment achieved the required degradation of organic micro-pollutants, an obvious option was to pursue another advanced oxidation process without the formation of any bromate. For this purpose UV/H\textsubscript{2}O\textsubscript{2} treatment was selected. In the UV/H\textsubscript{2}O\textsubscript{2} application, OH radicals are generated by UV photolysis of H\textsubscript{2}O\textsubscript{2}. UV/H\textsubscript{2}O\textsubscript{2} treatment is based on hydroxyl-radical oxidation combined with UV photolysis (Bolton and Cater, 1994). Depending on the chemical characteristic of the pollutant, one of these two processes plays a predominant role. Extensive pilot and bench scale work at PWN showed that UV/H\textsubscript{2}O\textsubscript{2} treatment met all criteria for disinfection, organic contaminant control without the formation of THMs and bromate. Besides, no formation of harmful metabolites from the priority compounds was observed.

In 2004 at wtp Andijk breakpoint chlorination was stopped and the MP UV/H\textsubscript{2}O\textsubscript{2} installation was located after the existing CSF pretreatment (Figure 2). The MP UV/H\textsubscript{2}O\textsubscript{2} is followed by GAC filtration and by chlorine dioxide post disinfection. The MP UV/H\textsubscript{2}O\textsubscript{2} installation consists of three independent process lines with four UV reactors each. Per UV-reactor 16 MP UV-lamps of 12 kW are installed.

**PRACTICAL EXPERIENCES WITH MP UV/H\textsubscript{2}O\textsubscript{2} TREATMENT USING NATURAL QUARTZ SLEEVES OF CSF PRE-TREATED WATER**

**Disinfection**

Primary disinfection with breakpoint chlorination proved to be an insufficient barrier against protozoa. Bench and pilot scale research into the inactivation of pathogenic organisms by UV, resulted in dose response relationships for MS-2 phages, Bacillus subtilis spore, Giardia muris and Cryptosporidium parvum (Kruithof and Kamp, 2005). It was observed that no reactivation of encysted protozoans was observed at UV-doses > 60 mJ/cm\textsuperscript{2} (Belosevic et al, 2001). Collimated beam experiments showed that the required 3 log inactivation of Cryptosporidium parvum was obtained at doses lower than 120 mJ/cm\textsuperscript{2} (Figure 3).

Reference compounds atrazine and bromacil, were reduced by 80 percent and 70 percent respectively at process conditions 0.54 kWh/m\textsuperscript{3} and 6 mg/L H\textsubscript{2}O\textsubscript{2}. Figure 4 shows the electrical energy per order (EE/O) for atrazine and bromacil degradation in CSF pre-treated IJssel Lake water with a relative low UVT\textsubscript{254} and an average nitrate concentration. For compounds such as carbamazepine, diclofenac, bisphenol A, microcystine, 80-100% degradation was observed under the same process conditions.
conditions. A somewhat lower degradation was found for diglyme and ibuprofen while TCA was degraded poorly and PFOA and PFOS were not degraded at all by the UV/H$_2$O$_2$ process. Post treatment by GAC filtration removed the non-oxidizable compounds such as PFOA and PFOS, showing the robustness of a multi-barrier approach based on UV/H$_2$O$_2$ treatment and GAC filtration.

**POST TREATMENT BY GAC FILTRATION**

**Excess H$_2$O$_2$ removal**

For the formation of OH-radicals by the UV/H$_2$O$_2$ process, a large excess of H$_2$O$_2$ is necessary. PWN standard process conditions require a H$_2$O$_2$ dose of 6 mg/L (Kruithof and Kamp, 2005). The residual H$_2$O$_2$ is catalytically decomposed completely by GAC filtration, in the first eight minutes EBCT (total EBCT 25 minutes) (Figure 6).

**Biostability**

Advanced oxidation converts trace organic contaminants into biodegradable reaction products when appropriate process conditions are applied. Extensive research efforts in this field did not show any harmful metabolite formation from the converted trace chemical contaminants under those conditions.

The full-scale UV/H$_2$O$_2$ system for wtp Andijk was designed with an electric energy of 0.54 kWh/m$^3$ for treatment of 3000 m$^3$/h. In a site acceptance test, degradation of atrazine was measured at several UV-doses at a fixed H$_2$O$_2$ dose of 6 mg/L. The installation performed as predicted by the collimated beam experiments and the design models, so design criteria were met. Three streets of four Trojan Swift 16L30 reactors are in operation since October 2004 providing primary disinfection and a barrier for organic contaminants (Figure 5).
Advanced oxidation processes such as UV/H$_2$O$_2$ generate biodegradable organic acids from the organic micropollutants and especially from natural organic matter (NOM). Assimilable organic carbon (AOC) is a major parameter indicating the biological stability of water (Kooij, van der, et al, 1982). Post filtration by BAC filters lowered the formed AOC content to levels guaranteeing biological stability (Figure 7).

**Nitrite formation and removal**
Nitrite formation by MP UV photolysis of nitrate can be significant. Figure 8 presents the nitrite levels in the full-scale process at wtp Andijk. As expected the nitrite content increased significantly by medium-pressure UV. After MP UV/H$_2$O$_2$ treatment, with natural quartz sleeves, of CSF pretreated water, the nitrite concentration was about 200 mg NO$_2$/L. The formed nitrite is completely re-oxidized to nitrate by post BAC filtration.

![Figure 8: Nitrite formation in CSF and IX-MF pre-treated IJssel Lake water by MP UV/H$_2$O$_2$ treatment utilizing synthetic and natural quartz sleeves](image)

**Formation and removal of genotoxic compounds**
Genotoxicity formation was studied by the standard Amestest. Applying MP UV/H$_2$O$_2$ treatment, utilizing natural quartz sleeves, to the CSF pretreated water, no response was found.

**Summary**
Due to 10 years of applied research the start-up in 2004 and the resulting performance of wtp Andijk has met all treatment objectives: no THMs or other harmful disinfection by-products were formed, robust disinfection was achieved and a non-selective barrier for organic micro-pollutants in an integrated treatment approach of MP UV/H$_2$O$_2$ treatment with post-BAC filtration was achieved. The excess H$_2$O$_2$ biodegradable compounds and nitrite were removed by BAC filtration. The only concern was the substantial energy demand of this MP UV/H$_2$O$_2$ process.

**PRACTICAL EXPERIENCES OF CSF PRE-TREATED WATER WITH MP UV/H$_2$O$_2$ TREATMENT USING SYNTHETIC QUARTZ SLEEVES**
In the UV reactor, the UV-lamps are housed in so-called quartz sleeves, protecting the lamps from direct contact with water and providing thermal insulation for the lamps. Different types of quartz can be applied, some blocking wavelengths <240 nm emitted from MP UV-lamps, others enabling transmission at these wavelengths.

Application of the more transmissive quartz, often referred to as synthetic quartz, allows the transmission of wavelengths <240 nm, contributing strongly to the formation of OH radicals from H$_2$O$_2$. Therefore application of synthetic quartz sleeves results in a lower energy consumption to meet the same treatment objective.

The UV/H$_2$O$_2$ treatment is based on the formation of OH radicals by H$_2$O$_2$ photolysis. The molar absorption of H$_2$O$_2$ increases with lower wavelengths (see Table 1), indicating an economic benefit in utilizing these wavelengths emitted by MP UV. However, as a consequence of the increased availability of photons at lower wavelengths, nitrate photolysis increases as well, resulting in elevated nitrite formation (see Figure 8). Replacing natural quartz sleeves with synthetic quartz sleeves caused an increase in the nitrite formation from 200 mg NO$_2$/L to 600 mg NO$_2$/L.

![Figure 9: Amestest response before and after full-scale MP UV/H$_2$O$_2$ treatment utilizing synthetic quartz sleeves and after post-BAC filtration](image)
the Amestest (see Figure 9). The practical implications of these findings are that additional treatment is required to control these side effects. Currently at PWN, biologically active GAC filters (BAC) following MP UV/\textsubscript{2}O\textsubscript{2} treatment lowers both the genotoxic response and the nitrite concentration (see Figure 8).

**Summary**

By the use of synthetic quartz sleeves, the energy consumption was reduced by about 20 percent. As a disadvantage a significant formation of genotoxic compounds and nitrite by MP UV/\textsubscript{2}O\textsubscript{2} treatment was observed. However, the genotoxic response and nitrite were removed by the post BAC filtration, making this last step an essential part of the treatment. Although synthetic sleeves reduced the required energy, improved pretreatment may bring further energy savings and other benefits.

**PERSPECTIVE: REPLACEMENT OF CSF PRE-TREATMENT BY IX-MF PRE-TREATMENT FOR A RESTRICTED ENERGY CONSUMPTION AND BY-PRODUCT CONTROL**

The energy consumption is strongly dependent on the UV-transmittance of the water. Therefore the composition of the UV absorbing compounds in raw and pre-treated IJssel Lake water was analyzed. The most important UV absorbing compounds in raw IJssel Lake water were found to be NOM and nitrate (Figure 10). The NOM content is rather stable over the year (6.0 mg/L C) while there is a strong seasonal variation of the nitrate content (1-14 mg/L nitrate) with an average concentration of 6.5 mg \textsubscript{NO}_3/L.

To improve the economics of the UV/\textsubscript{2}O\textsubscript{2} treatment, both NOM measured as DOC and nitrate content should be lowered. In the current situation at wtp Andijk, conventional pre-treatment by coagulation, sedimentation and filtration (CSF) is applied. CSF lowers the DOC from 6.0 mg/L to 4.2 mg/L. Nitrate removal by CSF is insignificant. In the near future, PWN will replace the existing conventional pretreatment by ion exchange in combination with ceramic microfiltration (IX-MF).

Pretreatment impacts the composition of the water matrix. CSF lowers the DOC content, but does not impact the nitrate concentration. Advanced pretreatment with ion exchange and ceramic microfiltration (IX-MF) removes both nitrate and DOC (Galjaard et al, 2005). The higher removal of DOC lowers the UV transmission, favoring the formation of OH radicals by UV photolysis of \textsubscript{2}O\textsubscript{2} and lowers the scavenging of OH radicals. The removal nitrate also lowers the UV transmission, favoring once again OH-radical formation.

**Table 1: absorbed photons at wavelengths of 254 nm and 240 nm by 6 mg/L H\textsubscript{2}O\textsubscript{2} in several water types**

<table>
<thead>
<tr>
<th>water type</th>
<th>254 nm</th>
<th>240 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>raw water</td>
<td>2.6%</td>
<td>4.5%</td>
</tr>
<tr>
<td>CSF pretreated water</td>
<td>5.3%</td>
<td>8.2%</td>
</tr>
<tr>
<td>IX-MF pretreated water</td>
<td>14.7%</td>
<td>19.4%</td>
</tr>
</tbody>
</table>

**Figure 10: Average annual DOC and nitrate concentration in raw water, CSF pretreated water and IX-MF pretreated water**

Compared to CSF, pretreatment by ion exchange improves the DOC removal and even more significantly the nitrate removal. This improved the energy consumption for MP UV/\textsubscript{2}O\textsubscript{2} treatment strongly. Applying IX-MF instead of CSF increased the photon flow absorbed by \textsubscript{2}O\textsubscript{2} by a factor of almost 3 (Table 1). In addition the scavenging of OH radicals was reduced (Martijn et al, 2010).

**Figure 11: EE/O for atrazine and bromacil degradation in CSF pre-treated IJssel Lake water with a UVT\textsubscript{254} 84% and 4.7 mg NO\textsubscript{3}/L and in IX-MF pre-treated IJssel Lake water with a UVT\textsubscript{254} 95% and 2.3 mg NO\textsubscript{3}/L and 5 mg H\textsubscript{2}O\textsubscript{2}/L**
Pilot experiments with MP UV/H$_2$O$_2$ on CSF pretreated water and IX-MF pretreated water were conducted to determine the impact of the pretreatment on the EE/O for reference compounds atrazine and bromacil. The improved removal of DOC and nitrate from the IJssel Lake water by IX-MF pretreatment resulted in a substantially reduced EE/O. Compared to CSF, the EE/O for IX-MF pre-treated water was reduced by about 50 percent (Figure 11).

**By-product control**

Formation of by-products after MP UV/H$_2$O$_2$ treatment of IX-MF pretreated surface water was determined for the parameters; AOC, nitrite and Amestest response. AOC formation was not significantly different from values found after MP UV/H$_2$O$_2$ treatment of conventionally pretreated surface water, despite the lower DOC content. Lower nitrate concentrations after IX-MF pretreatment, resulted in a reduced nitrite formation. Also the Amestest response after MP UV/H$_2$O$_2$ treatment of IX-MF pretreatment was reduced substantially as a result of improved pretreatment by ion exchange and ceramic microfiltration. However, a small but significant effect of MP UV/H$_2$O$_2$ treatment on the Amestest response remained (Figure 12).

![Figure 12: Amestest response before and after MP UV/H$_2$O$_2$ treatment and post-BAC filtration](image)

**Summary**

Pretreatment by IX-MF reduced the energy required for AOP significantly and lowered the formation of the by-products measured as nitrite and Amestest response. The new treatment train of wtp Andijk is shown in Figure 13 and will be operational in 2014.

After the last innovation, MP UV/H$_2$O$_2$ treatment is still an essential process for organic contaminant control and primary disinfection in a multi-barrier approach. The economics have improved significantly while the by-product formation was reduced strongly.

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![Figure 13: Process scheme wtp Andijk after implementation of IX-MF pretreatment in 2014](image)
In wastewater, effluent organic matter (EfOM) is the principal scavenger of hydroxyl radicals (OH•) generated in advanced oxidation processes (AOPs) (Dong et al., 2010). This radical scavenging affects the AOP efficiency because of reduced •OH radical concentrations, and can increase the UV dose required for effectively treating wastewater effluents for contaminants of concern, such as micropollutants. EfOM, as the primary scavenger, is comprised of natural organic matter and soluble microbial products (SMPs). Of these, SMP is the major EfOM constituent and its characteristics may vary from one wastewater to the next. Hence, variability in EfOM components and effluent characteristics may lead to variations in the scavenging capabilities of effluent streams from different treatment processes.

Considering the effluents from two common wastewater treatment systems – conventional activated sludge (CAS) and membrane bioreactor systems (MBR) – the objective of this study was to compare the background scavenging capacity of these matrices. It was hypothesized that the EfOM from a CAS system may consistently have different •OH scavenging properties compared to the EfOM produced from MBRs, such that the effluent from one form of treatment may generally be more easily and cost-effectively treated using advanced oxidation. This evaluation would determine the extent to which scavenging capacity varies between the two systems and which effluent may be more amenable to treatment using AOPs because of lower UV dose and energy requirements. UV/H2O2 was used as the applied AOP for the study.

The scavenging capacities of the effluents from three CAS and three MBR plants were determined using a Rayox® UV collimated beam apparatus equipped with a 1kW medium-pressure UV lamp and the ROH_UV concept reported by Rosenfeldt et al., (2007) which was modified to account for a polychromatic light source. All effluents were collected from nitrifying plants prior to disinfection. Comprehensive characterization of the bulk EfOM was performed using specific UV absorbance (SUVA), resin fractionation, fluorescence excitation emission matrix (FEEM) analyses, and liquid chromatography-organic carbon detection (LC-OCD) analyses. Effluent samples were also analyzed for EfOM concentration (measured as TOC), UV254nm absorbance and the concentration of anions (chloride, nitrate, nitrite, sulfate, and phosphate).

For the six effluents used in this study, the average scavenging capacity of the CAS effluents exceeded that of the MBR by a factor of 1.6 (a difference that was significant at the 85 percent confidence level). Both effluent types had a similar distribution of EfOM components based on FEEM, LC-OCD and resin fractionation analyses. Both effluents were composed mainly of high molecular weight constituents (humic substances and biopolymers). The study also found a strong correlation between the high molecular weight components and the scavenging capacity of EfOM.

Our findings are consistent with the hypothesis that MBR effluents may be more amenable to AOP treatment and may require lower UV dose and energy requirements, but it is recognized that this is a limited case study. Our results also indicate that the cost of AOP treatment may be lowered by reducing the concentration of high molecular weight components, such as by use of enhanced coagulation that targets this EfOM fraction.


Sucralose as a Hydroxyl Radical Probe

By Olya Keen, Ph.D., currently Assistant Professor in the Department of Civil and Environmental Engineering at the University of North Carolina – Charlotte. At the time of the study referred to in this article Ms. Keen was a student at the University of Colorado - Boulder.

The study by Keen and Linden “Re-engineering the artificial sweetener: sucralose transformation by hydroxyl radicals and its suitability as a probe” discusses the fate of a popular artificial sweetener sucralose in UV/H\textsubscript{2}O\textsubscript{2} AOP. The molecule is not susceptible to photolysis at wavelengths of ≥ 200 nm, but it reacts with hydroxyl radicals. Its reaction rate constant is somewhat lower than the reaction rate constants for most other common trace organic contaminants found in drinking water or wastewater. The study also determined that the reaction with hydroxyl radicals replaces chlorine atoms on the sucralose molecule with hydroxyl groups. The process almost reverts the molecule back to sugar – the starting compound used to produce sucralose. The end product is a molecule consisting of fructose and sugar alcohol moieties and is likely to be as biodegradable and as benign as sugar.

Based on the findings above, the authors proposed sucralose as a hydroxyl radical probe suitable even for full-scale AOP. The compound is already found in environmental samples at levels higher than most other trace organic contaminants. The parent compound is benign enough to be added to the reactor to test its performance. The procedure would not require a photolysis control. And due to the slower reaction rate between hydroxyl radicals and sucralose, compared to many other trace contaminants, sucralose level of attenuation in the process would be a conservative estimate of the efficiency of the process for transforming the majority of other contaminants that may be present in the sample.
UV photoreactions (photochemical and photobiological) have been widely used for chemical synthesis, pollutants degradation, and water/wastewater disinfection. Being different from conventional chemical reactions, the determination of kinetic parameters for photoreactions needs an accurate measurement of UV fluence rate (FR) and a supply of fluences over a broad range. At present, bench-scale photoreactions are commonly performed using a quasi-collimated beam apparatus (CBA). The CBA can produce a relatively uniform FR over the surface of a Petri dish, which can be measured easily with a UV radiometer. Water samples are exposed to various fluences through varying the exposure time to obtain the kinetic parameters of photoreactions. The CBA is usually equipped with a low-pressure (LP) mercury vapor lamp, which produces an FR ranging from 0.01 to 0.50 mW/cm²; however, this range is much different from that in a practical LP UV reactor (i.e., 3−30 mW/cm²). Thus, there are inevitable errors for kinetic parameters determined in a CBA.

This study, inspired by the micro-fluidic device idea [1,2], has developed a mini-fluidic photoreaction system (MFPS) for bench-scale photochemical and photobiological experiments. A 105 W LP high-output UV lamp (with a quartz sleeve of 23 mm o.d.) was housed in the center of an annular quartz reactor (> 90% of the UV transmittance of quartz). A polytetrafluoroethylene (PTFE) tube (about 75% of UV transmittance, 2 mm i.d.) was coiled around the outer surface of the annular quartz reactor. Water sample was continuously pumped through the PTFE tube using a peristaltic pump for UV exposure. Based on the flow rate of water sample and the UV-exposed length of the PTFE tube, the total exposure time could be readily calculated. To obtain various FR values in the tube, the annular quartz reactor was fabricated specially to have several segments with different diameters for the tube to coil around. A micro-fluorescent silica detector (MFSD) [3,4], inserted into a short PTFE tube, was placed close to the reactor surface for accurate FR measurements. This detector has a 360-degree response to FR and a maximum measurement error of 3%. In addition, an adjustable ballast was utilized to tune the lamp output so as to export a desired FR. The preset fluence was equal to the product between the FR (measured by the MFSD) and the exposure time (calculated from the sample flow rate and the exposed tube length).

Photochemical experiments were conducted with the MFPS. KI/KIO₃ actinometer was chosen to validate the preset fluences through measuring the 352 nm absorbance [5]. Three FR values were tested including 24, 4.60, and 0.44 mW/cm². At a fixed FR, the exposure time was varied by adjusting the exposed tube length and the sample flow rate to achieve the preset fluencies (2.0, 3.7, 4.8 and 6.0 mJ/cm²). The results showed that the KI/KIO₃ actinometer had almost the same response for three different FRs applied, which demonstrated that the MFPS could provide accurately measured and practical FRs for photochemical and photobiological experiments.

REFERENCES


Introducing the Duron, Wedeco’s latest offering for open channel waste water UV disinfection. With more than 20 years of vertical UV disinfection engineering & research behind its design, the Duron is shining new light on wastewater treatment. Duron systems take the latest Ecoray high powered energy efficient lamps and incline them at a 45 Degree angle, saving additional space in the channel. Its integral lifting device allows for easy maintenance and accessibility, making it a clear choice in terms of ease of operation.
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The need for clean water
Many people are concerned with the quality of water, because microorganisms present in water can make them ill. In emerging economies the water infrastructure is often to blame, yet even in developed countries incidents of contamination still occur. As one study shows, in North America alone 85% of sicknesses in children and 65% of adult diseases are a result of waterborne viruses and bacteria.

Disinfection of water
UV technology is a natural way to make sure water is safe to drink. UVC deactivates microorganisms, rendering them harmless. It is effective against all types of bacteria, viruses and protozoa and there are no known pathogens resistant to it. Moreover, it does not add chemicals or other additives that may be harmful to human health or the environment. It doesn’t alter the taste, pH value or other properties of the water either.

InstantTrust: a new cutting-edge disinfection technology
Philips has developed a complete disinfection solution for point-of-use equipment based on a patented disinfection technology – InstantTrust. It breaks new ground, overcoming four key limitations of existing UV disinfection systems: size, run-up time, temperature sensitivity and environmental impact. InstantTrust is half the size or less of existing disinfection functions, which means it can be built into almost any POU application, from fixed taps to portable pitchers. Moreover, it provides an instant start with no run-up period so that safe water is delivered from the very first second onwards – eliminating waiting time and the risk that the water is not always disinfected. It can be used for both cold (4°C) and hot water applications – an industry first – thanks to its constant temperature curve. From an environmental perspective it is completely mercury free.

A broad range of applications
With demand for residential purifiers increasing every day, this new technology with its promise of almost complete design freedom comes at a good time. Its benefits make it ideally suited for instantly disinfecting small quantities of cold water (up to 4 liters/minute) taken from dispensing equipment such as bottle refill stations, bottled water dispensers and for example. Other point-of-use applications include hot and cold water systems with taps and under-the-sink water treatment systems.

With the introduction of InstantTrust, Philips has a unique and innovative UV-based water disinfection solution that improves access to safe drinking water around the world.

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1 UV Disinfection (Source: Excel Water Technologies)
2 Global Competitive Environment for Residential Water Treatment Equipment Markets (Source: Frost & Sullivan 2005)