FEATURES

Application of UV Disinfection to achieve Enterococci Removal at a Trickling Filter Plant

UV: Not Just for Cryptosporidium Anymore

Uniform Protocol for Wastewater UV Validation Applications

2011 IOA/IUVA WORLD CONGRESS & EXHIBITION
PARIS, FRANCE

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ON THE COVER
Event Photos from the 2011 IUVA World Congress & Exhibition

JULY 2011 | 3
As I write this, I have just returned from the IOA/IUVA Joint World Congress in Paris, and I am happy to report that the event was a fantastic success. Our UV technical sessions had standing room only, and the world's experts in UV were present, giving presentations, asking questions, interacting, and advancing the state of the science. All of that in one of the world's most beautiful cities, with great weather, great food and drink, and a volcanic ash cloud that very nicely veered around us.

At the World Congress, the "torch" was passed to me, and I took over as International President of the IUVA. I am thrilled and honored to serve you, the IUVA members, in this role.

First, I would like to thank Dr. Bertrand Dussert, who served the IUVA with great distinction in the role of International President, from 2009 to 2011. Bertrand managed the IUVA to a continued position of sound finances and he orchestrated our successful Paris World Congress. Bertrand also led the team that launched a platform of strategic initiatives designed to lead to additional growth, both geographically and in the markets that participate in the IUVA, and to increase the value the IUVA offers back to our membership. I worked side-by-side with Bertrand the past two years, and I know the tremendous sacrifice he made, his personal dedication to our organization, and the many ways in which he contributed to the success of the IUVA. I know I speak for all of us when I say, thank you Bertrand.

I feel greatly honored to try to follow in the footsteps of Bertrand, as well as the many capable leaders who served in this role for the IUVA before me: Jim Malley, who served two terms, and got the IUVA off to such a great start, Jennifer Clancy, Bob Hulsey, Andreas Kolch, Linda Gowman, and Bertrand. I promise you, the members of the IUVA, that I will do my best to continue the success of the IUVA throughout my two year term. We will continue to be in very capable hands after me, with the election of Karl Linden as our next President for the 2013-2015 term.

This is an exciting time for the IUVA, and many positive changes are in store in the next few months. Andreas Kolch has been selected to serve as our "Regional Hub Director" for Europe/Middle East/Africa, and Andreas was working for us even before his agreement was signed. Look for several new activities in Europe in 2011, including a drinking water seminar in the United Kingdom. We also expect to be able to announce the hiring of a new Executive Director, as well as a Regional Hub Director for the Americas in the next several weeks. I could not be more excited about the structure we will have in place shortly to serve the needs of the IUVA and to expand what we are able to accomplish.

There will be a lot of activity within the IUVA in the next few months. Our focus areas will be to continue our platform of strategic initiatives, revamp our webpage, grow our membership, and increase the value of IUVA membership. We also have a world-class IOA/IUVA Joint Regional Conference planned for Toronto in September 2011. I hope to see each of you there, and to get the chance to talk about the bright future of our organization.

As they said when we hit a little turbulence over the Atlantic on the way home from Paris – please buckle your seatbelts. It promises to be a fun ride, and I'm thrilled to embark on it with you.

- Paul

IUVA & IOA

North American Conference
The Fairmont Royal York
Toronto, Ontario, Canada
September 19-21, 2011
As I write this message, I see that this Issue has a lot of interesting items, including exciting news about IUVA and excellent articles. So I will not say a lot.

I am always interested in good UV articles, so if you want to write one, or know of someone who should, let me know.

Have a great Summer, and I hope to see you at the Toronto Conference in September.

Jim

Deb Martinez
IUVA Executive Director

Dear IUVA Board members, past leadership and IUVA members,

I am honored to be selected the new Executive Director of IUVA, and I look forward to working with the Board and members of IUVA to advance the value of ultraviolet technologies worldwide. You can be assured that I am committed to creating a smooth and successful operation of IUVA, and I look forward to working with you.

Currently, we are implementing a transition strategy with the collaboration of Paul Overbeck, the previous Executive Director. I think we owe him a hearty thank you for all he has done for IUVA.

Ensuring IUVA is the recognized leading authority on ultraviolet technologies is my number one goal. We must be a thought leader and have an impact on education, research and public policy.

If you are already a member, great, you know the value of IUVA, and I hope that you will fully engage in our offerings. If you know someone who is a prospective member but who has not yet signed on, please encourage them to join.

With your help and participation, I know that IUVA can take advantage of the many opportunities available to us. And we will all benefit.

Thank you.

Deb
Announcement: IUVA's President, Paul Swaim is pleased to introduce IUVA's new Executive Director, Deborah Martinez.

I am excited to announce that the IUVA has hired a new Executive Director, Deborah Martinez. Deborah is already hard at work, working on several identified top priorities including the North American Regional Conference in Toronto in September.

Following our November 2010 Board Meeting, a task force of Board members developed a position description for the Executive Director position. The position description, which focused on communication, education, and marketing skills was approved by the Board, and we then advertised the position broadly. We heard from a number of qualified candidates, short-listed the top four, conducted phone interviews, and identified Deborah as our top candidate. After Deborah’s in person interview with Karl Linden and me in Denver, the selection committee was unanimous in selecting Deborah for the position.

Deborah brings a high level of energy to the position, as well as a fresh perspective. We sought a candidate with the ability to think outside the box, with strengths in communication and marketing, and with experience running a similar organization. Deborah has all of those qualification, and more.

Previously, she was Director of Programs for the Society of Hispanic Professional Engineers (SHPE) Foundation, and she served as the Director of Education and Conferences for the Society of Military Engineers. She also formerly served as Executive Director of the Society of Geriatric Cardiology. She has extensive experience in higher education and association management, which includes working with the American Dental Education Association for over eight years as Director of Professional Development and Education. Deborah lives in the Washington, DC area with her husband. She has two children and is active in her local community.

We strongly believe that Deborah possesses the leadership experience and judgment to guide our organization in the years to come.

While we welcome Deborah, I would like to personally thank Paul Overbeck for his service and dedication over the past few years.
IUVA Board Actions

The IUVA Board met at the Paris UV Congress. The following were the key action items:

1. The Board moved to accept the IUVA Manufacturers Council position on a Uniform Protocol for Wastewater UV Validation Applications. This Protocol is been published later in this Issue.

2. The Board further moved to have the Manufacturer's Council keep this Protocol on their agenda of future meetings to accept feedback input to make improvements as needed”.

3. The Board moved to approve that the Executive Operating Committee negotiate a contract with their recommended candidate with the intent of retaining him/her to serve as IUVA Executive Director (see announcement above).

IUVA Board Changes

At the IUVA General Assembly Meeting in Paris, the following changes were made to the IUVA Board (the full Board membership can be viewed at http://www.iuva.org/iuva/board

New Board Members:

Mr. Peer Krueger of ITT Corp.
Professor Ernest R. Blatchley III (Chip) of Purdue University
Professor Joel DuCoste of North Carolina State University
IUVA Secretary - Erik Rosenfeldt
IUVA Treasurer - Kati Bell

The members and the Board of Directors of the International Ultraviolet Association (IUVA) have installed Paul D. Swaim, P.E., as International President of its Board. Swaim will serve, and will continue in his current role at CH2M HILL—a global full-service consulting design, construction, operations firm—as vice president, senior principal technologist, and CH2M HILL’s Global Technology Leader for Water Treatment, responsible for leadership across the spectrum of drinking water treatment processes and services.

Swaim is a recognized international expert in UV disinfection for drinking water, water reuse, and wastewater applications including regulatory issues, pilot testing, design, construction, startup, and operations. He has served as senior reviewer/technical advisor for more than 30 disinfection projects across North America, including key roles on water treatment UV disinfection projects totaling more than 1 billion gallons per day. He received his B.S. and M.S. degrees from the University of California at Berkeley, and has more than 20 years of experience in the successful completion of water projects.

Additionally, the IUVA has selected the President-Elect and two regional hub directors: The President-Elect, Karl G. Linden, Ph.D., is the Helen and Huber Croft Professor of Environmental Engineering and Associate Director of the Mortenson Center in Engineering for Developing Communities at the University of Colorado - Boulder. He teaches classes in UV Processes in Environmental Systems, Sustainable Water Reuse, Water Sanitation and Hygiene, Ecological Environmental Engineering, and Fundamentals of Environmental Engineering. Dr. Linden’s research focuses on novel water and wastewater treatment systems, including advanced and innovative UV and oxidation systems for disinfection and contaminant degradation. He has authored over 95 peer-reviewed publications, given over 100 invited lectures, and guided over $8M in research. Dr. Linden is a Trustee of the Water Science and Research Division of the American Water Works Association, an associate editor of ASCE Journal of Environmental Engineering, and a founding board member of the IUVA. He has a BS from Cornell University and an MS and PhD from University of California at Davis.

Dr. Andreas Kolch for EMEA (Europe, Middle East and Africa) and Dr. Bertrand Dussert for the Americas were elected as the regional hub directors and they are responsible for contributing to the successful leadership and business development of the IUVA in their regions. Specifically, they promote and implement programs with the goal of long-term growth for IUVA and the UV industry.

Dr. Dussert is the founder and president of Dussert Consulting, LLC, a company offering consulting services in the water treatment arena. Dr. Dussert is a water and wastewater treatment expert with over 20 years of management experience working for suppliers and manufacturers of innovative water treatment technologies. He has extensive expertise in water treatment technologies including ultraviolet (UV) disinfection, and advanced oxidation processes (AOPs). He is first-named inventor or co-inventor of five patents and is the author of over 50 technical papers. He is the immediate past international president of the International Ultraviolet Association (IUVA), and has served on the Board of Directors since 2001.

Dr. Dussert is also an Adjunct Professor of wastewater treatment & engineering for the graduate program in the Department of Earth & Environmental Science at the University of Pennsylvania (Philadelphia, PA). Dr. Bertrand
UV Industry News

The following are interesting items of note from IUVA Member Announcements

Blue Ocean Grants and Challenges – Application Period Open for Ocean Optics Blue Ocean Grants and Challenges Program
Dunedin, Florida - April 4, 2011
http://blueoceangrants.com/

Designed to provide funding for new technologies in optical sensing, Ocean Optics’ Blue Grants and Challenges program seeks innovative and novel optical sensing technologies that solve problems and improve quality of life. Applicants from all disciplines are encouraged to apply before the deadline June, 30, 2011...

Philips distributes solution for reduction of environmental pathogens in healthcare facilities.  

Royal Philips Electronics announces an agreement with Lumalier Corporation to address the growing problem of microbial contamination in hospitals. At this year’s annual scientific meeting of the Association for Professionals in Infection Control and Hospital Epidemiology (APIC), Lumalier will showcase Tru-D, a total-room ultraviolet (UV) disinfector...

Calgon Carbon Awarded Two Contracts For Sentinel Systems.  
http://www.wateronline.com/article.mvc/Calgon-Carbon-Awarded-Two-Contracts-For-Senti-0001

Calgon Carbon Corporation announced today that it has been selected by the cities of Indianapolis, Indiana, and Fort Wayne, Indiana, to supply Sentinel® Ultraviolet (UV) Disinfection Systems at drinking water production plants serving their communities. Terms of the contracts were not disclosed...

UV Pure introduces the Cactus™...UV Pure’s Crossfire Technology, Engineered And Priced For Residential Applications.  
http://www.uvpure.com/homepage-nofl.php

UV Pure’s patented Crossfire Technology® has built a reputation, world wide, as the most advanced and effective UV water purification technology for commercial, industrial and municipal water treatment of up to one million gallons per day...

Also UV Pure is pleased to announce that it was selected by the Artemis Project as a 2011 top 50 water company...

RealTech announces their new Real Spectrum Analyzer product series.  
http://realtech.ca/Analyzer_Spec%20_Sheet.pdf LightTech acquires High Pressure UV Suntanning and Collagen Lamp Division of Radium

The LightTech Lamp Technology, Kft./Light Sources, Inc. strategic partnership, a global leader in high tech suntanning lamp technology, is acquiring the production assets of the high pressure UV tanning lamp and collagen high pressure lamp divisions of Radium Lampenwerk GmbH in Wipperfürth/Germany in May 2011...

Aquafine Corporation Launches Beverage Industry Disinfection System with Groundbreaking Validation
Valencia, California - April 26, 2011  
http://www.aquafineuv.com/

Aquafine® Corporation introduces their newest line of ultraviolet (UV) disinfection systems to the beverage industry, which are validated to fully comply with USEPA federal regulations for delivering inactivation of viruses, including the highly resistant adenovirus...

WEDECO adds medium pressure UV disinfection to its portfolio of potable water solutions
Herford, Germany – 2 May 2011  
http://www.wedeco.com/us/

Featuring compact size and an innovative flow diverter that enhances hydraulic conditions to improve system performance, the new WEDECO Quadron™ ultraviolet (UV) system from ITT’s Water & Wastewater business offers better assurance for safe water...

NEWS FROM IUVA Continued from pg 7

Dussert has an M.S. in Chemistry from Université Claude Bernard, Lyon 1 (France), and completed his Ph.D. in Environmental Engineering from the Institute National des Sciences Appliquées de Toulouse (France).

Dr. Kolch worked in various senior positions in the water treatment sector for many years before he founded Hytecon – a water and cleantech consulting company, where he is a partner and managing director. Dr. Kolch is a founding member of the IUVA serving as its President from 2005 to 2007. He has an M.S. and Ph.D. in Microbiology from the University of Bonn.
NEW IUVA MEMBERS

Welcome to the Following NEW IUVA Members:

Americas

Jeff Beaty – CH2M Hill, Ottawa, Canada
Claudio de Oliveira – Air Quality Engelhari, a, Brazil
Jose Duran Herrera – University of Costa Rica, San Jose, Costa Rica
David Gaithum – Greenfield, New Hampshire, USA
Albert Ilges – Golden, Colorado, USA
Omar Miranda – San Gabriel, California, USA
Chad Talbot – Portland Water Bureau, Portland, Oregon, USA

Europe/Middle East

Didier Chavanon – BMES, Saint Priest, France
Jean-Michel Faurie – BMES, Saint Priest, France
Cedric Fellers – Veolia Eau, Nanterre, France
Carmelo Llorente – teqma S.L., Sant Pere de Ribes, Spain
Hadas Mamane-Gravetz – Tel-Aviv University, Tel-Aviv, Israel
Ian Mayor-Smith – Imperial College, London, UK
Frank Seitz – IBL, Heidelberg, Germany
Danae Venieri – Technical University of Crete, Chania, Greece

Asia/Australasia

Yiru Zhu – Haining Yaguang Lighting Co., Ltd.
Haining, China
Yibing Zhu – Haining Yaguang Lighting Co., Ltd.
Haining, China
Chen Zia – Haining Yaguang Lighting Co., Ltd.
Haining, China
Fangli Pu – Haining Yaguang Lighting Co., Ltd.
Haining, China
Rongxiang Zhu – Haining Yaguang Lighting Co., Ltd.
Haining, China
Linda Yu – Haining Yaguang Lighting Co., Ltd.
Haining, China

IN ADDITION, WE ARE PLEASED TO WELCOME TWO NEW CORPORATE MEMBERS:

Haining Yaguang Lighting Co., Ltd. Haining, China

This company was established in 1996 and specializes in the manufacture of quartz ultraviolet bacterial lamps. It has had many years of experience in manufacturing OEM products for domestic and overseas customers, while at the same time, it gets support from internationally well known companies and optoelectronic technology research institutes. Under such support, it has steadily improved its technical capacity and has always been in a leading position in the UV lamp field in China. To better improve its management, after 2004, the company started introducing the ISO9001:2000 quality management system.

BMES, Saint Priest, France

BMES is an engineering and consulting firm and also a manufacturer that specializes in the design and the manufacture of units for treatment of water and air. From research, through prototyping and onto the end product, the designed units use technologies such filtration, UV rays and photocatalysis.

With many years of experience, BMES can bring its own solution of treatment, disinfection, reducing ethylene and VOC, eliminating smells for domestic use and in industrial air applications.

For water treatment we have a well-established solution for the disinfection and treatment of water, medical waste and for domestic and collective waste and are able to reduce or eliminate their components. Our knowledge coupled with CAD and the latest tools enable us provide quick and effective designs of your products.

We have excellent production and testing facilities, which enable us to offer reliable and full satisfaction for your customers.

UPCOMING CONFERENCES

27 – 29 July 2011
Fourth IWA Specialty Conference on Natural Organic Matter: From Source to Tap and Beyond
Costa Mesa, CA

19 – 20 September 2011
Annual North American Conference on UV, Ozone and AOP Technologies, co-organized by the International Ozone Association (IOA PAG) and International Ultraviolet Association (IUVA)
Toronto, ON, Canada

15 – 19 October 2011
WEFTEC-2011 - Los Angeles, CA

13 – 17 November 2011
Water Quality Technology Conference and Exposition
Phoenix, AZ

10 – 14 June 2012
ACE-12 - Dallas, TX

16 – 21 September 2012
IWA World Congress and Exhibition, Busan, South Korea

29 September - 3 October 2012
WEFTEC-2012 – New Orleans, LA

9 – 13 June 2013
ACE-13 - Denver, CO

24 – 27 September 2013
IOA/IUVA Joint Congress
Las Vegas Mirage Resort, Las Vegas, NV

Look Here for Future Announcements
IUVA AWARDS
IUVA Announced its 2011 Awards at the 6th Biannual IUVA World Congress in Paris, France

Best UV Engineering Project: 2010
Winner: Tianjin, China TEDA Municipal Drinking Water Plant UV Disinfection Project

This award recognizes an exemplary engineering project involving UV applications in operation and is reviewed for innovation and excellence and its impact on society. The winning entry is the Tianjin, China TEDA Municipal Drinking Water Plant UV Disinfection Project. This project was a collaboration by Universities (Tsinghua: Professor Wenjun Liu), Engineering design institutes (BEMEDI: Ms. Yanqie Qie) and water utilities (Teda: Mr. Ziyi Fang).

This system in Tianjin, China is the first large-scale municipal drinking water UV disinfection project in China and the first UV water disinfection system designed and implemented by local Chinese engineers. It is a novel treatment process using UV as primary disinfectant to meet stringent new Chinese water quality standards, including DBPs, Giardia and Cryptosporidium and represents effective collaboration among university researchers, design engineers, and end users.

Innovations in UV - Green Award
Winner: TrojanUV Solo Lamp

This award recognizes an exemplary product or process improving the Green image of UV applications. Each nominated UV-based product, process, or application is reviewed for its Green design and engineering attributes. The winning entry is the TrojanUV Solo Lamp™System.

The TrojanUV Solo system—offers the advantages of both existing medium pressure and low pressure high output lamp technologies, leading to lower life cycle costs, easy maintenance and reduced environmental impact. The Solo lamp combines the low power consumption of a low pressure UV lamp with high output that is characteristic of a medium pressure UV lamp, leading to low lamp count. This combination allows the Solo Lamp™ to have a significantly lower environmental impact compared to other UV lamp technologies as measured by carbon footprint and lifecycle assessment. Scientists and engineers at Trojan UV have worked over the past 5 years to develop this green UV technology addition to UV disinfection systems.

Lifetime Achievement Award in UV Science and Engineering
Winner: Dr. William L. Cairns, Chief Scientist at Trojan Technologies

This Award recognizes professional dedication and lifetime achievement in promoting UV and the mission of the IUVA. The Award is given every two years. The winner is Dr. William L. Cairns, Chief Scientist at Trojan Technologies in London, ON, Canada

Dr. Cairns has a doctoral degree in biochemistry and
biophysics, has been a professor and has served the Water Environment Federation’s Research Foundation and Disinfection Committee. He has worked closely with academic and professional organizations, such as the Canadian Water Network, the American Water Works Association, and the IUVA.

Dr. Cairns has dedicated himself to research for over 30 years and has globally contributed to the advancement and efficiency of ultraviolet water treatment at Trojan Technologies since 1989. He has been described as “One of the most collaborative and knowledgeable scientists in the water treatment field.” He is known to have quietly planted the seeds for many great research ideas that have come to fruition. Cairns is known to be a real gentleman, very polite, and is well-regarded for his expertise and knowledge.

Classic UV Paper Awarded in 2011

**Winner: Zia Bukhari, Tom M. Hargy, Jim Bolton, Bertrand Dussert, and Jennifer L. Clancy**

This award is given every 2 years and recognizes a peer-reviewed journal article from any year, reviewed and evaluated for the impact of the paper on the development of UV research and technology. This year’s classic paper is: Z. Bukhari, T.M. Hargy, J.R. Bolton, B. Dussert, J.L. Clancy (1999) “Medium-Pressure UV Light for Oocyst Inactivation” *Journal of the AWWA*, Vol. 91, No. 3, 86-94.

The winning paper is definitely a classic. It comes from a collaboration of researchers (Zia Bukhari and Tom Hargy) from the lab of Jennifer Clancy and scientists (Jim Bolton and Bertrand Dussert) from Calgon Carbon. The research described in this paper definitively demonstrated the effectiveness of low levels of UV light for inactivating Cryptosporidium in water. Impacts of this discovery have been tremendous for the UV industry and for application of this technology in the drinking water industry. This work, along with subsequent studies it inspired, set the groundwork for the use of UV in disinfection of drinking water and allowed more robust regulations to be developed for the protection of public health, using UV light.

Best UV paper of the year 2009-2010

**Winner: A.C. Eischeid, J. Meyer, and K.G. Linden**

This award is given every 2 years and recognizes a peer-reviewed journal article from 2009-2010, reviewed and evaluated for the impact of the paper on the development of UV research and technology. The best UV paper of this year is A.C. Eischeid, A.C., J. Meyer, K.G. Linden (2009) “UV Disinfection of Adenoviruses: Molecular Indications of DNA Damage Efficiency” *Applied and Environmental Microbiology* Vol. 75, No. 1, 23-28.

This paper coupled with a subsequent one published in 2011, sets the foundation for understanding of fundamental processes occurring at the molecular level in the inactivation of adenovirus at 253.7 nm (LP) and at shorter wavelengths as emitted by polychromatic light sources. Moreover, the paper provides a scientific, robust and sound approach to a complex study, use different methods and tools, suitable to
the hypothesis. This type of work advances the science in UV disinfection and solves the mystery around the difficulty to inactivate the adenovirus. As a bonus, the paper is published in a high impact factor, highly reputable journal in Microbiology.

UV Light Award for Volunteer Recognition

Winner: Dr. Rongjing Xie, Singapore Public Utilities Board

This Award recognizes the most dedicated volunteer (individual or organization) to support the mission of the IUVA. The Award is given every two years. The recipient is Dr. Rongjing Xie, Singapore Public Utilities Board.

Dr. Xie volunteers his time, energy and resources to furthering UV education and the goals of the association as a whole. In the past few years he has personally spearheaded growing IUVA involvement in Asian markets, identified event opportunities, secured funding for invited keynote (IUVA member) international speakers to come to Asian events, as well as securing sponsorship and event partnership funding to support new events in emerging markets, and has successfully coordinated 2009 & 2010 UV conferences at the Singapore International Water Week.

Best Student UV Paper and Poster Awards at IUVA World Congress

Two cash awards were given out at the 2011 IUVA World Congress for the student paper and poster that was best presented. The winners were: Miguel Pelaez, University of Cincinnati and Nalan Bilgin Öncü, Bogazici University-Institute of Environmental Sciences in Turkey

Best Paper:

“TiO2-based enhanced photocatalytic degradation and disinfection in water under solar light irradiation”

Lead student author: Miguel Pelaez

Advisor: Professor Dionysios D. Dionysiou

Miguel Pelaez is a Ph.D. candidate in the Environmental Engineering and Science Program at the University of Cincinnati. His research interests are in the fields of environmental chemistry and environmental catalysis, with specific focus on water treatment using advanced oxidation processes and advanced oxidation nanotechnologies. His recent work includes studies to develop and evaluate emerging solar-driven technologies for the degradation of deleterious organic pollutants in water.

Best Poster:

“Antimicrobial Pollution Removal from Environmentally Relevant Matrices by Advanced Oxidation Processes”

Lead student author: Nalan Bilgin Öncü

Advisor: Professor Isil Balcıoğlu

Nalan Bilgin Öncü received her B.S. in Chemistry from Koc University and her M.S. in Materials Science and Engineering from Sabancı University. She is currently continuing her Ph.D. at Bogazici University-Institute of Environmental Sciences with a focus on Advanced Oxidation Processes (AOPs). Her research under the supervision of Prof. Isil Balcıoğlu involves ozonation of sludge, targeting destruction of persistent antibiotics and investigation of the effect of AOPs on antibiotic resistance carriers during drinking water disinfection.
Reliable disinfection from every angle

Introducing the new WEDECO Quadron™ medium pressure UV system

The new WEDECO Quadron™ UV system is the ideal solution for drinking water disinfection when space is at a premium. The unique shape in conjunction with the OptiCone™ flow diverter guarantees optimum flow conditions up to 4,100 m³/h (26 MGD), even with a close coupled 90 degree inlet bend.

With its advanced US EPA UVDGM validation, the WEDECO Quadron™ considers safely influencing factors specific for disinfection by medium pressure UV technology. That makes the Quadron the safe choice when applying medium pressure UV.

www.wedeco.com

ITT is a global provider of water handling and treatment solutions for municipal and industrial customers in more than 140 countries. The company designs and delivers energy-efficient solutions and related services for water and wastewater transport, biological treatment, filtration, and disinfection. ITT maintains one of the industry’s most extensive sales and service organizations to ensure it meets more than one customer’s needs locally.

Flygt | Leopold | Sanitaire | WEDECO
Pulsed UV light cuts peanut allergens by up to 90 percent.

http://www.foodproductiondaily.com/Processing/Pulsed-UV-light-cuts-peanut-allergens-by-up-to-90-per-cent-study

Exposing peanuts to bursts of pulsed ultraviolet light (PUV) can reduce their allergenic potential by up to 90 per cent, according to new research from the US...

WSSC Unveils New UV Water Disinfection System

http://chevychase.patch.com/articles/wssc-unveils-new-uv-water-disinfection-system-7

Drinking water in Montgomery and Prince George’s counties may not taste any different, but a new ultraviolet disinfection system at Washington Suburban Sanitary Commission is helping make water safer and cleaner...

Could Milk get Ultraviolet Treatment?


At A 3000-cow dairy farm near Ithaca, New York, Rodrigo Bicalho wrestles a 3-week-old calf onto a scale. The calf totters about; the scale reads 52 kilograms, a healthy weight. Bicalho makes a note. He is trying to find out what happens if he gives his calves milk that, instead of being pasteurized, is treated with ultraviolet light...

Fight Germs with Gadgets ...

http://www.startribune.com/lifestyle/wellness/124105229.html

Consider the VIOLight UV Cell Phone Sanitizer, a $40 device that promises to eliminate 99.9 percent of the bacteria and other nasties sitting on your phone. It purports to do so by using a beam of ultraviolet light, which is a specific wavelength of light that, when focused precisely, penetrates and damages the DNA of microorganisms...

German firm aims to widen use of UV LEDs with AlN


German firm CrystAl-N is producing aluminium nitride (AIN) substrates for fabricating specialist ultraviolet lasers and LEDs...

Global Water and Wastewater Treatment Equipment Market Worth $500 Billion


The global water and wastewater treatment equipment market is reportedly valued at $400 billion to $500 billion, according to a report on companiesandmarkets.com. Between $65 billion and $75 billion is related specifically to equipment...

UV disinfection pioneers receive 2011 European Inventor Award

Budapest, Hungary


Ashok Gadgil of the University of California/Lawrence Berkeley National Laboratory and Vikas Garud of WaterHealth International have been named the recipients of the 2011 European Inventor Award for their work in the field of ultraviolet (UV) water disinfection...
APPLICATION OF UV DISINFECTION TO ACHIEVE ENTEROCOCCI REMOVAL AT A TRICKLING FILTER PLANT

Gary Hunter,¹ Amy Kliewer,¹ Ed Kobylinski,¹ Charlie Klinger,² and Manuel Carrera²
¹ Black & Veatch Corporation, 8400 Ward Parkway, Kansas City, MO, 64114
² City of Leavenworth, 1800 S. 2nd St, Leavenworth, KS 66048

ABSTRACT

The City of Leavenworth, KS operates a wastewater treatment plant with an average daily capacity of 16.54 MLD (4.38 MGD) with a peak flow rate of 104.98 MLD (27.50 MGD). The plant currently uses trickling filters to remove organics (BOD) and suspended solids. In 2010 the State of Kansas (KDHE) issued a discharge permit that required disinfection be incorporated into the plant and that a plan be developed to provide nutrient removal. Collimated beam testing was conducted during the month of October 2010. Results of the testing indicated that a fluence (UV dose) of 600 J/m² would be needed to achieve compliance with either the E. coli permit compliance or future enterococci limits. To confirm the transmittance data, measurements were collected using an on-line HACH UVAS transmittance sensor. This data indicated values more in line with typical values observed from trickling filter plants. Design transmittance values were developed that resulted in a UVT of 38 percent. Chemical testing was examined as a potential for increasing the transmittance resulting in a reduction in the cost and size of the UV system. The results of these preliminary tests indicated, with chemical addition, that a higher UVT could be used for design.

Keywords: UV-C; UV Disinfection, Collimated Beam, Trickling Filter

INTRODUCTION

The use of UV disinfection for trickling filter effluent is traditionally difficult and often results in periods of non-compliance. The City of Leavenworth, KS operates a wastewater treatment plant (WWTP) with an average daily capacity of 16.54 MLD (4.38 MGD) with a peak flow rate of 104.98 MLD (27.50 MGD). The Leavenworth WWTP consists of the following facilities: influent screening and pumping, aerated grit removal, primary clarification, intermediate pumping (settled sewage), trickling filters, final clarification, and sludge dewatering (belt filter press) as shown in Figure 1.

BACKGROUND

In 2010 the State of Kansas Department of Health and Environment (KDHE) issued a discharge permit requiring that disinfection be incorporated into the plant and that a plan be developed to provide varying levels of nutrient removal. The KDHE has established two sets of disinfection requirements at the WWTP, a monthly geometric mean limit of 160 cfu/100 mL E. coli from April through October and a 2,358 cfu/100 mL E. coli limit from November through March. The permit requires the final limits for E. coli for the current WWTP be achieved by December 31, 2012.

The Leavenworth WWTP has an existing chlorine contact basin and a building for storage of chlorine gas cylinders. The basin has not been used since its construction, and the building is now being used for storage. A review of future regional and federal regulations pertaining to disinfection was made to ensure flexibility of the disinfection system to be installed at the plant. Currently, the permit lists a monthly geometric mean for the final E. coli limits, based on the schedule of compliance for both winter and summer seasons. Regionally, the USEPA is requiring that States establish either weekly maximum or maximum not to exceed limits. In addition, the EPA is requesting that States examine (i.e., lower) the risk values that have been used to establish bacterial permit limits.

Nationally, the EPA will be proposing new guidance for the establishment of bacterial limits in the wastewater discharge permits in 2012. Early indications are that limits will be established for enterococci (instead of E. coli), partly due to
the fact that the EPA proposed enterococci in 1986, and the States did not adopt this guidance.

TRANSMITTANCE TESTING
Early testing of the percent transmittance at 254 nm indicated values around 65%. This is extremely high for trickling filter effluent, which typically ranges from 35% to 45%. To confirm the transmittance, measurements were collected using an on-line HACH UVAS transmittance sensor. One of the key items in using the sensor was that, to ensure that correct measurements were collected, it needed to be cleaned on a weekly basis because of biological fouling. A number of items may have resulted in higher values however, it was observed that transmittance values collected by the sensor would match the transmittance values collected as part of the bench-scale testing. Therefore a practice of weekly cleaning was implemented. Design transmittance values were developed using all the data collected, which resulted in a UVT of 38%. Figure 2 provides a historical plot of the transmittance data collected by the online sensor and Figure 3 provides a summary of the T10 analysis.

BENCH SCALE TESTING
A series of bench-scale chlorine and UV disinfection tests were carried out at the B&V research facility between September 29 and October 21, 2010 to determine the optimum disinfectant dose required. Bench scale testing prior to design is important, since the design dose is highly dependent on effluent water quality, which varies from plant to plant. Two sets of bench-scale tests were performed to collect data for the design of the UV disinfection system. Collimated beam testing was conducted during the month of October 2010. Results of the testing (Figures 4 and 5) indicated that a UV dose of 60 ml/cm² would be needed to achieve compliance with either the E. coli permit limit or the future enterococci limit. In 1986, the USEPA recommended the establishment of water quality standards using enterococci. The USEPA is anticipating reposing the use of enterococci in 2012. State regulatory agencies, who have not already adopted these new water quality standards, will need to develop an implementation schedule.

RESULTS AND DISCUSSION
In order to reduce the project costs, additional tests were conducted. These tests examined both filtration and chemical addition to determine if either of these alternatives could result in a reduction in the cost and size of the UV system.
The results of collimated beam tests demonstrated that a UV system could be installed to comply with current regulatory limits. In the future, after nutrient limits are written into the discharge permit resulting in an improved effluent water quality, the UV system should be able to disinfect effectively the future design flows. Therefore, by adding the polymer, the design value for the UVT could be increased to 50% allowing for the installation of a UV system at this facility.

### CONCLUSIONS

The use of polymer at the Leavenworth WWTP was found to be a cost effective alternative to increase solids capture. Colloidal solids in the effluent could be flocculated into larger solids, which would then settle. With increased solids capture, the UVT increased to levels that allowed for UV to be implemented in a cost-effective manner at the treatment plant. Other utilities may find polymer addition as a means to allow UV to be implemented with poor-water quality effluents.

**Table 1. Polymer Testing For Transmittance Improvement**

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Dose, mg/L</th>
<th>Molecular Weight</th>
<th>Charge</th>
<th>Increase in UV Transmittance, %</th>
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<tbody>
<tr>
<td>1 (dry)</td>
<td>2</td>
<td>High</td>
<td>High</td>
<td>15</td>
</tr>
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<td>2</td>
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<tr>
<td>5</td>
<td>4</td>
<td>High</td>
<td>High</td>
<td>4</td>
</tr>
</tbody>
</table>

**Figure 6. Results of Bench Scale Testing with Chemical Addition E. coli.**

**Figure 7. Results of Bench Scale Testing with Chemical Addition Enterococci.**

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UV: NOT JUST FOR CRYPTOSPORIDIUM ANYMORE

Paul D. Swaim, P.E.¹, Anthony Myers, P.E.², Todd Elliott, P.E.³, Lisa Voytko, P.E.⁴ Bruce Jacobs, P.E. ⁵, and James Malley, Jr. Ph.D.⁶

ABSTRACT

In North America, most UV disinfection installations at drinking water treatment plants have been designed to address the threat of Cryptosporidium, which has been the focus of new surface water treatment requirements. There have been several UV projects implemented to address other treatment objectives as well. Several of these applications are summarized in this paper.

Key words: UV disinfection; multiple disinfection barriers; Cryptosporidium inactivation; virus inactivation; DBP reduction

INTRODUCTION

Since 2000, the implementation of ultraviolet (UV) disinfection has grown rapidly in North America, with most North American installations focused on Cryptosporidium inactivation in response to the United States Environmental Protection Agency’s (USEPA’s) Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Many drinking water utilities have implemented UV disinfection, although not explicitly required to by the LT2ESWTR. These utilities have focused on UV systems as part of a multiple barrier treatment train, in which the UV system serves as a barrier for Cryptosporidium, while also addressing other system-specific treatment objectives. In selecting UV to address site-specific treatment objectives, several unique UV applications have been implemented.

RESULTS AND DISCUSSION

In North America, UV disinfection has been installed at water treatment plants (WTPs) by utilities with the objective of achieving regulatory compliance. The USEPA’s LT2ESWTR addresses the need for Cryptosporidium removal and/or inactivation for unfiltered systems that meet the USEPA filtration avoidance criteria, uncovered reservoirs, and filtration plants in higher bins (meaning higher risk of Cryptosporidium in the source water). UV disinfection is acknowledged as typically representing the most cost-effective approach for Cryptosporidium, and the USEPA estimated that 503 to 979 WTPs will be required to implement UV disinfection in response to the LT2ESWTR (USEPA, 2006).

In addition to utilities that implement UV disinfection to meet regulatory requirements, many utilities have implemented UV disinfection generally to increase finished water quality and improve public health protection. In several cases, utilities have identified site-specific treatment objectives for the application of UV systems. Several applications of UV to achieve site-specific treatment objectives are reviewed in the following sections.

These novel UV applications for drinking water treatment include:

- UV disinfection for virus inactivation credit at two operating water treatment plants in Cedar Rapids, IA, as necessitated by the presence of ammonia in the raw water.
- UV disinfection for Giardia inactivation credit to reduce free chlorine contact time and minimize disinfection by-product (DBP) formation in Poughkeepsie, NY, and Ketchikan, AK. The Poughkeepsie facility has been operating since 2005, while Ketchikan’s system began receiving disinfection credit in 2011.
- UV disinfection for pathogen disinfection in backwash recycle flows in Fort Collins, CO. This facility has been operating since 2003.
- High-dose UV advanced oxidation for contaminant destruction in Aurora, CO, with the application point following clarification and before biological filtration. Facility commissioning occurred in late 2010, and the system is now operating.
UV for virus inactivation credit
The City of Cedar Rapids, IA, USA had a unique drinking water problem. They could not get enough disinfection credit to meet regulatory requirements for virus reduction because of the presence of naturally occurring ammonia in their source water. Due to the presence of ammonia, Cedar Rapids uses chloramine as its primary disinfectant, not free chlorine. Consequently, the plants would have inadequate disinfectant contact time during cold water periods of the year under high flow rate conditions. After an extensive evaluation of alternatives, UV disinfection was selected to allow the City to meet its disinfection requirements.

The City of Cedar Rapids owns and operates two conventional water treatment plants, the J Avenue WTP and the Northwest WTP. The plants treat groundwater from alluvial wells along the Cedar River with aeration, lime softening, recarbonation, filtration and chloramine disinfection. Recently, several wells were designated as groundwater under the direct influence of surface water. As a result, both plants were required to comply with the USEPA Surface Water Treatment Rule (SWTR) regulations by July 2010.

Both water plants can currently meet SWTR regulations for Cryptosporidium and Giardia. However, with the available chloramine contact time, disinfection regulations for viruses cannot be met during periods of cold water and higher plant flow rates. To meet disinfection regulations for viruses under all plant operating conditions, UV disinfection was selected as an additional disinfectant barrier for the Cedar Rapids water treatment process.

CH2M HILL completed the study, design, and construction management of the UV disinfection projects for the 40 mgd (151 MLD) J Avenue lime softening plant and the 20 mgd (76 MLD) Northwest lime softening plant, which is expandable to 40 mgd (151 MLD). The project included retrofitting UV disinfection into the two existing water treatment plants. Both medium- and low-pressure high output UV reactors were evaluated at several potential UV sites. Impacts on existing facilities, operational access, hydraulics, and future plant improvements were considered in determining the optimum UV facility location at each facility. Extensive hydraulic and site location issues were also evaluated.

This was one of the first projects designed for virus inactivation with UV light, and design occurred prior to the release of EPA’s Final UV Disinfection Guidance Manual (UV DGM). Therefore, early stages of the project included a UV demonstration project to determine the water quality impacts of UV on chloraminated water containing nitrate. A 6-mgd UV system was designed and constructed to serve a specific service area of the distribution system. Water quality in the distribution system was monitored for one year, indicating no detrimental impact of UV disinfection on the water quality. The study also involved collimated beam testing for adenovirus and MS-2 bacteriophage inactivation on Cedar Rapids water at various locations, with and without the presence of chloramines.

Through workshops with the Iowa Department of Natural Resources (DNR) and the City, additional virus disinfection credit was granted by the Iowa DNR based on the low filter turbidity and high softening pH at the two plants. The UV disinfection system was designed to provide an additional 0.5 log inactivation of viruses with a minimum operating UV dose (i.e., an MS2 reduction equivalent dose, or RED) of about 45 to 50 mJ/cm². This dose incorporates the UV dose of 39 mJ/cm² for 0.5-log virus inactivation from the LT2ESWTR, and the validation factor for the full-scale UV reactor. For virus inactivation, the RED bias is much smaller than it is with MS2 validation for Giardia or Cryptosporidium inactivation. In the future, the recent research results demonstrating the ability of medium-pressure UV disinfection to achieve higher levels of virus inactivation (Linden et al., 2007) may be discussed with the DNR.

The UV system design included the flexibility to expand the system in the future (e.g., additional lamps per UV reactor and/or additional UV reactors in series) for advanced oxidation to control future contaminants (e.g., NDMA). Due to competitive pricing from the UV manufacturer, the City purchased the ‘future’ UV reactors for the Northwest plant with the intent to use redundant UV reactors to achieve higher log virus inactivation. This will help to reduce reliance on chloramines for primary disinfection and can achieve greater than 2-log virus inactivation with UV alone under many plant operating conditions.

At the Northwest plant, the UV facility was located hydraulically between the filter effluent control weir upstream and the chloramine contact tank effluent control weir downstream. At the J Avenue plant, the UV facility was located hydraulically between the filter clearwell upstream and the finished water reservoir downstream. Water flows by gravity through the UV facility and is then pumped to the chloramine contact tank and high service pump station reservoir.

The project also included the design and construction of a chloramine contact tank and high service pump station at the J Avenue treatment plant. Total UV facility construction costs for both treatment plants were about $13 million, including about $1.9 million (USD) for City pre-purchase of eight UV reactors. Construction began in the summer of 2007; start-up began in 2009 at the Northwest treatment plant, and in 2010 at the J Avenue plant.

Cedar Rapids’ project represents one example of using UV disinfection to achieve virus inactivation. UV disinfection may have applicability for virus inactivation for systems with challenging chlorine contact time conditions, due to ammonia present in the source water, no available contact tank, or very rapid formation of disinfection by-products during free chlorine contact.

UV for DBP reduction
Poughkeepsie, NY, USA

Since 1872, when the City of Poughkeepsie, NY, USA, became the first community in the United States to filter its
water, Poughkeepsie has a long tradition of producing a high quality drinking water that meets the needs of its customers. The goals of the UV disinfection project were to upgrade the existing water treatment plant, constructed in 1962, by providing treatment facilities necessary to comply with current and future drinking water regulations and to increase the treatment capacity from 16.0 mgd (61 MLD) to 19.3 mgd (73 MLD). The facility treats surface water from the Hudson River.

The project included upgrades to several facilities that were reaching the end of their useful life, such as the filtration system, solids contact clarifier mechanisms, and high-pressure pumps. Prior to beginning the detailed design of the plant, CH2M HILL worked with plant staff to perform both pilot scale and full scale testing of the existing treatment processes to confirm that the existing solids contact clarifiers could process the higher design flows required for this project. Alternative coagulants were also studied with the goal of improving cold water coagulation performance and reducing sludge production. Based upon this testing, the plant switched their primary coagulant from alum to polyaluminum chloride.

A new multiple barrier disinfection strategy was implemented as part of the project. The project implemented a combination of free chlorine and UV light for primary disinfection, followed by monochloramine for residual disinfection on startup in 2006. The addition of UV disinfection facilities downstream of the existing filters enhanced the existing disinfection system by increasing its effectiveness against a wider variety of microbes of concern, while also reducing the formation of DBPs associated with free chlorine primary disinfection. The lack of a finished water clearwell downstream of the filters and the need to provide adequate disinfection contact time for microbial inactivation had historically limited the plants ability to control DBPs. The addition of UV disinfection downstream of the filters allowed the point of chlorine addition to be shifted from the upstream end of the sedimentation basins to the downstream end.

The addition of UV disinfection also allowed the role of free chlorine disinfection to be changed from primary Giardia disinfection to virus disinfection. Viruses are easily inactivated with free chlorine within a short contact time, such as the detention time within the existing filter boxes. UV disinfection is well suited to inactivate all other microbes of concern, including Cryptosporidium and Giardia, and was installed in the limited space available in the existing WTP filter pipe gallery.

Work associated with the design and construction of the new UV disinfection system included preparation of evaluated bid type procurement documents for UV disinfection equipment, as well as drawings and specifications that defined how to confirm the specified performance of the disinfection system via full-scale, third party validation testing. Throughout the project, CH2M HILL worked closely with the State of New York Department of Health to ensure that the installed UV disinfection system met their design and performance requirements and was eligible for full disinfection credit once installed and tested.

For Poughkeepsie, the implementation of UV disinfection provided enhanced disinfection capabilities, allowed a reduction in free chlorine contact time prior to ammonia addition, and helped to reduce the levels of regulated DBPs that formed during treatment. UV disinfection was implemented with one dedicated medium-pressure UV reactor for each of 6 granular media filters, as shown in Figure 1. Each filter and reactor can treat up to 4.5 mgd (17 MLD). The design UV dose was 40 ml/cm² based on the MS2 RED at the end of lamp life, peak flow, and design UV transmittance of 88 percent. Key design elements included fitting UV disinfection within the plant hydraulic profile and filter pipe gallery constraints.

UV for DBP reduction
Ketchikan Public Utilities, Ketchikan, AK, USA

On completion and startup of the 2011 construction, the Ketchikan Public Utilities (KPU) water treatment system treats unfiltered surface water with free chlorine for virus inactivation, UV disinfection for Giardia and Cryptosporidium inactivation, and monochloramine for distribution system residual
disinfection. The average daily flow is 4.1 mgd (15.5 MLD) and the maximum daily flow is 12 mgd (45 MLD). The design capacity of the UV Disinfection and Chloramination Facility is 15 mgd (57 MLD).

KPU installed UV disinfection, as shown in Figure 2, and chloramination in response to USEPA regulations that address the public health risk posed by pathogens and DBPs in drinking water. The UV disinfection system installed by KPU is credited with 3-log inactivation of Cryptosporidium and Giardia credit according to the EPA.

UV disinfection and chloramination provide the following benefits to KPU customers:

- Reduced pathogen risk from Cryptosporidium, Giardia and many other protozoan, bacterial, and viral pathogens
- Provision of a second treatment barrier to pathogens resistant to chlorine disinfection
- Reduced formation of DBPs
- Improved public health protection

Free chlorine is used for virus inactivation, so it is added to the system upstream of the UV reactors. UV disinfection reduces the chlorine residual, with the rate of chlorine reduction proportional to the chlorine dose and applied UV dose. Therefore, at very low flows, additional chlorine must be added to achieve the desired chlorine residual for the point of ammonia application for chloramine formation.

UV for backwash recycle treatment in Fort Collins, CO

In 2003, Fort Collins Utilities, working with CH2M HILL and Hydro Construction Co., Inc., implemented a UV disinfection system for treatment of filter backwash recycle flows at the existing 87-mgd (329 MLD) conventional water treatment plant. This innovative project was among the first of its kind,

---

*Figure 2. KPU’s UV Disinfection System*
taking advantage of the disinfection effectiveness of UV treatment to conserve water and save money for Fort Collins’ customers.

Because of its simplicity, low costs, and outstanding capability for pathogen disinfection, UV disinfection was implemented for treatment of the filter backwash wastewater. The project consisted of new piping to divert the wastewater decanted from the existing washwater lagoons, a variable speed pump station, pipeline, and medium pressure UV reactor, flow meter, and power supply. The system was sized to recycle and treat flows up to 3 mgd, which allowed capture of at least 90 percent of the flow that was previously discharged to the Pleasant Valley Lake and Canal system.

Prior to this project, as part of Fort Collins Utilities’ potable water treatment process, filter backwash water was discharged to local surface water ponds. The USEPA and State of Colorado allow either recycle or discharge of the spent backwash water. Rather than discharge the backwash water, Fort Collins Utilities elected to begin recycling the backwash water for the following reasons:

- Two of the previous treatment trains were replaced with more efficient and reliable treatment processes that were able to appropriately handle and treat the recycle flow stream.
- On-going drought conditions necessitated that Fort Collins Utilities examine every option to increase its water supply. Backwash water recycling significantly reduced raw water requirements, in a timely fashion, with minimal impact to customers.

During the two years prior to this project, approximately 1,800 acre-feet of washwater were discharged annually. For Fort Collins Utilities to have an equivalent amount of source water to treat, the wastewater lost to discharge could be replaced through purchase of Colorado Big Thompson (CBT) Project units, at costs in the tens of millions of dollars. The total project cost for treatment of the backwash recycle flow stream was approximately $1.5 million (USD).

CH2M HILL designed the treatment system for the backwash water before it is recycled to the upstream end of the Water Treatment Facility. Some pathogens have been detected in Fort Collins Poudre River supply prior to treatment, and several alternatives were considered for reuse of the backwash water. Of the alternatives considered, UV disinfection was selected because of its capability to disinfect pathogens including *Giardia*, *Cryptosporidium*, and enteric viruses. UV was also the most cost-effective alternative evaluated.

Fort Collins Utilities UV disinfection system was designed with a design UV dose of 40 mJ/cm² (based on an MS2 RED) for a flow rate of 3.0 mgd (11.4 MLD). In addition, the design provided the capability to double the capacity or disinfection capability in the future. A process flow schematic of the system is shown in Figure 3.

The UV disinfection system has been operating since 2003, and since start-up, it has enabled backwash recycling of 2.7 billion gallons of water, which otherwise would have been discharged. Fort Collins Utilities has produced an average of 23.5 mgd (89 MLD) over this same time period, meaning that UV disinfection has been used to recycle 4.5 percent of the plant flow over its 7 years of operation. The UV system has provided regular, trouble-free operation during this time, and Fort Collins Utilities has ‘peace of mind’ regarding the potential recycling of pathogens. Water is only recycled if the UV system is operational.

### UV advanced oxidation to destroy emerging contaminants

As described by Swaim (2008), the City of Aurora, CO, is constructing a new water delivery and purification system known as the Prairie Waters Project. This $750 million USD project will increase Aurora’s water supply by 20%, and will utilize a unique combination of natural and man-made purification systems to meet Aurora’s stringent water quality goals. A critical component of this multiple purification system is the Peter Binney Water Purification Facility (PBWPF). The PBWPF includes a UV advanced oxidation process (AOP) as part of a multiple barrier approach to purification of South Platte River water, as shown in Figure 4.

Upstream of UV AOP, Aurora’s multi-barrier purification approach includes riverbank filtration, aquifer recharge and
recovery, precipitative softening, and recarbonation. Following UV AOP, purification processes include biologically-active carbon (BAC) filtration, granular activated carbon (GAC) adsorption, blending, and final disinfection with monochloramine.

Purification alternatives for the Prairie Waters Project incorporated an AOP step, and AOP options were evaluated based on their ability to achieve the multiple objectives of providing:

1. Primary disinfection of Cryptosporidium and Giardia
2. Destruction of N-nitrosodimethylamine (NDMA) and other nitrosamines
3. Control of organics and micro-pollutants

The candidate purification processes to meet these three objectives provide both disinfection and oxidation, so they are referred to as the ‘disinfection/oxidation process’. In addition, the disinfection/oxidation process must not lead to excessive formation of other by-products, such as bromate, at levels that will compromise regulatory compliance or meeting the City’s goal of delivering a water that provides comparable protection of public health when compared to current water supplies.

The most viable options identified to meet the defined objectives for the disinfection/oxidation process at the ARWPF consisted of:

1. Ozone advanced oxidation process followed by UV disinfection.
2. UV AOP.

The ozone advanced oxidation process (AOP) utilizes ozone and hydrogen peroxide addition for advanced oxidation, and UV disinfection would also be necessary for this option to provide Cryptosporidium inactivation without excessive bromate formation. This option would not provide significant destruction of NDMA.

Of these options, UV AOP was selected because of its capability of achieving all of the City’s disinfection/oxidation objectives simultaneously. UV AOP offers the following benefits for the PBWPF:

- Superior disinfection capability, compared to ozone, in a single unit process.
- Destruction of NDMA.
- Advanced oxidation as part of a multiple barrier strategy for micro-pollutants.
- Minimal formation of regulated by-products such as bromate.

Additional testing and analysis was conducted to establish design criteria for UV AOP. Bench-scale testing was conducted on South Platte River water at CH2M HILL’s Applied Sciences Laboratory. The water collected for this bench-scale testing was sampled from an alluvial well that Aurora operated for over 18 months to demonstrate the performance of riverbank filtration.

These tests were performed to provide information on the performance of the UV AOP. The key identified tasks related to UV AOP addressed the following:

- Assessing water quality to assist in establishing UV AOP design criteria
- Conducting tests to evaluate the removal of micro-pollutants, taste and odor causing compounds, and pathogens through the UV advanced oxidation process
- Evaluating the formation of DBPs through UV AOP
- Evaluating downstream treatment approaches for quenching the hydrogen peroxide residual
- Determining the removal of background micro-pollutants through UV AOP (and through the entire PBWPF process)

The UV AOP testing was performed using two side-by-side collimated beam devices, each utilizing a low-pressure, mercury-vapor UV lamp. For the micro-pollutant tests, NDMA, 1,4-dioxane, and atrazine were selected as the micro-pollutants of interest. These specific compounds were selected because all are of some interest in the source water, and because the destruction mechanism is different for each compound. The destruction of NDMA is dominated by photolysis, the destruction of 1,4-dioxane is due entirely to oxidation, and atrazine destruction occurs via both photolysis and oxidation. For the micro-pollutant spiking tests, a series of UV doses were applied to the spiked solution. The UV doses were selected based on target levels of NDMA destruction including 0.25-log, 0.5-log, 1.0-log, and 2.0-log.

The test results, described in detail elsewhere (Swaim et al., 2008) demonstrated that destruction of spiked NDMA occurred by photolysis, as expected, and the UV AOP performance for NDMA destruction was predictable and repeatable. In addition, at the UV doses necessary for NDMA destruction, substantial destruction of atrazine, 1,4-dioxane, and taste and odor causing compounds also occurred. For these compounds, the UV AOP performance is highly dependent on the peroxide dose. For this test, a hydrogen peroxide dose of 5 mg/L was applied, and destruction of these compounds would increase with increasing hydrogen peroxide dose. From a test with a mixture of multiple contaminants and pathogens, UV AOP provided simultaneous disinfection and destruction of micro-pollutants and other compounds of concern.

In additional treatability testing, nine nitrosamines were spiked into samples and tested using the low-pressure collimated beam UV device over a series of UV doses. The results are shown in Figure 5. As shown, the destruction of NDMA exceeded the destruction of the other nitrosamines tested at the same UV dose. From these results, and from sampling results (not included herein), among the nitrosamines, NDMA represented a conservative indicator.
both for presence and for removal by UV photolysis. Low-pressure, high-output UV equipment was selected for the full-scale equipment because it is most cost-effective for year-round operation. Downstream, biological filters and GAC contactors provide quenching of the remaining hydrogen peroxide residual.

CONCLUSIONS

These unique UV applications encompassed treatment goals in addition to Cryptosporidium inactivation. These projects provide starting points for other site-specific applications of UV light at water treatment facilities.

Each of these projects required proactive communications with primacy regulators, upfront discussions with UV manufacturers, and site-specific design approaches. In addition, performance testing and validation testing approaches were developed individually for each project to ensure validated conditions extended to the intended application and to ensure that performance at each facility achieved the site-specific treatment objectives.
REFERENCES

Enhanced UV inactivation of adenoviruses under
polychromatic UV lamps, Appl. Environ. Microbiol.,
73(23), 7571–7574.

Effectiveness of UV Advanced Oxidation for Destruction of

United States Environmental Protection Agency.
Economic Analysis for the Final LT2ESWTR
(EPA-815-R-06-001), 2006.

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**INTRODUCTION AND BACKGROUND**

The treatment objective of an ultraviolet disinfection system used in a wastewater application is to protect aquatic and ecological environments. To ensure this objective is adequately met it is important to validate, or verify equipment performance for a specific application. The widely accepted method for completing this validation is by determining the UV dose delivery performance using biodosimetry. Whilst several protocols exist for completing biodosimetry tests, or bioassays, for different applications, only two methods are in wide scale use in the industry worldwide;

- Ultraviolet Disinfection Guidelines for Drinking Water and Reuse, 2nd Edition, published by the National Water Research Institute (NWRI) in collaboration with the Water Research Foundation (WRF previously AwwaRF). Specifically, chapter two; Water Reuse and chapter three; Protocols. Hereafter referred to as NWRI/AwwaRF.
- Ultraviolet Disinfection Guidance Manual, published by the US EPA. Hereafter referred to as UVDGM.

Both guidelines follow similar formats (see Table 1) and are in wide scale use by UV Manufacturers, Engineering Consultants and Regulators. However, neither specifically makes reference to the particular challenges associated with completing bioassays in wastewater applications as defined below. The term wastewater applications means for the purpose of this document a biological treatment plant that is achieving an average effluent quality of less than 30 mg/L BOD/TSS and disinfection requirements of 126 cfu/100 mL E. coli over a 30 day geometric mean or 200 cfu/100 mL fecal coliforms over a 30 day geometric mean. Many stakeholders within the UV industry have called for such a uniform protocol for wastewater UV applications that can be widely adopted by industry and regulatory bodies.

In an effort to provide a positive contribution to the industry in this matter, the International Ultraviolet Association (IUVA) Manufacturers Council formed a task force in 2007.

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**US EPA UVDGM NWRI/AWWARF GUIDELINES**

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The objectives of this group were to:

- Evaluate the existing protocols to identify aspects that could be of use for a uniform wastewater protocol.
- Facilitate discussion with both regulators and engineering consultants on the issue of a uniform wastewater protocol.
- Outline a position on a potential solution for uniform wastewater protocol.

After undertaking reviews and discussions with interested parties, this document represents the final portion of the task force objectives.

A proposed protocol format is detailed in Table 2, following a similar format to that used in the UVDGM.

**Table 2: Proposed Format for Uniform Wastewater UV Validation Protocol**

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The treatment objectives for the wastewater and the UV dose or fluence that is required must be determined before this bioassay method can be used to size the UV equipment. This may be done through long term measurements of the flow rate, UVT, TSS etc., as suggested in NWRI/AwwaRF protocol. The UV dose requirements may also be determined by doing studies with a collimated beam to determine the required UV dose or fluence with the lowest quality of wastewater.

1.0 PLANNING AND PREPARATION
In all cases it is important to understand clearly what are the goals of the testing, how they will be completed and within what limitations. This section describes the key elements of the planning and preparation stage of validation testing. The details of the test plan (in addition to the final validation report) must be reviewed by a third party so that they conform with the bioassay protocol or regulatory requirements. Validation testing of UV equipment for wastewater applications can be conducted at a Wastewater Treatment Plant (WWTP) or a dedicated testing facility (manufacturer owned, or third party).

1.1 TEST UV SYSTEM CHARACTERISTICS
A typical wastewater bioassay test stand is shown in Figure 1. In general the following criteria should be followed in relation to the test equipment configuration:

• The test unit must be equivalent in configuration and operation to the commercial unit, both in terms of components, i.e. lamp, ballast, quartz sleeve, sensor, control systems, and automatic cleaning device and other fixed or moving devices, that is, baffle, support bars, etc.
• The test unit must be hydraulically scale able or a commercially available full-scale module as per the NWRI/AwwaRF recommendations. However, it is recognized that additional analysis using field measurements and/or advanced tools described in Section 4.0, could be used to justify operational variations. Closed vessel UV systems may not be hydraulically scaled.
• A single reactor can be used (equivalent to one bank) for validation.

1.1.1 Challenge Organism
It is critical that the challenge microorganism have the following properties:
• Is non pathogenic to humans.
• Should be easy to grow in high concentrations and simple to enumerate.
• Demonstrates repeatable results and stability over long time periods.
• Has a known action spectrum that correlates to the target pathogen or indicator organism.
• Is pre-defined, to ensure valid comparisons between bioassays.
• Is analyzed only within the linear region of the UV dose-response curve.
• Must have UV inactivation kinetics that are similar to the indicator organisms or pathogens or two organisms must be used that span the UV inactivation kinetics of the indicator organisms or pathogens.
• Must not be an indigenous organism since the UV inactivation kinetics vary from site to site.

Based on the above criteria the following challenge microorganisms are permissible and it is preferable to use two that span the UV inactivation kinetics of the indicator organisms or pathogens of concern:

• T1
• Q phage
• MS2 phage

The microorganisms must be prepared and used in accordance with the NWRI/AwwaRF and UVDGM procedures.

1.1.2 Water Source

Key Characteristics:

• Finished water supply (potable water) and/or filtered (cloth or granular) wastewater treatment plant effluent (secondary or tertiary), or a blend of both.
• Turbidity < 2 NTU or < 5 mg/L total suspended solids in all cases. Since suspended solids are different in every wastewater treatment plant a filtered effluent should be used or potable water.
• Must not contain any disinfectant residuals that could affect the microorganisms used for the testing of the UV dose.
• Any quenching agents or their byproducts should not impact UV transmittance in the 200 to 300 nm range, and the quenching agent should not affect the challenge organism.
• The water supply must be de-chlorinated (e.g. with thiosulfate or biosulfite) before being used for the bioassay with residual chlorine levels non-detectable with a 0.05 mg/L detection limit.
• pH after UVT and de-chlorination adjustment should be within ± 0.5 pH units of the initial pH; otherwise buffering is required.
• Impact of additives on polychromatic absorbance shall be measured and documented. It is recommended not to use additives that may have an adverse effect on the polychromatic absorbance.

1.1.3 Absorbing Chemical

Where a UV absorbing chemical is used to simulate the range of UVT values defined in the test plan, it is critical that it have the following properties:

• An absorbance spectrum similar to the background filtered effluent/water used for validation. (Note a full UVC spectral scan is required if polychromatic lamps are used.)
• Known and uniform impact on all relevant parameters.
• Not be toxic to the bio-surrogate (‘challenge microorganism’; see note above).
• Known spectral absorbance in the UVC wavelength range.
• Solubility should not be affected by lamp heat dissipation.

Based on the above criteria the following UV absorbing compounds are permissible:

• Coffee
• Lignin Sulfonic Acid (LSA)
• Humic Acids such as Superhume™

MSDS sheets should be included in the report for these compounds.

1.1.4 Mixing and Sampling

It is critical that any UV absorbing chemical or challenge microorganism injected into the flow stream be uniformly dispersed at both the influent and effluent sampling points, therefore the following guidance is provided:

• The effluent sampling point must be far enough downstream of the reactor exit, so that all fluid streamlines exiting the reactor have had the opportunity to fully mix/disperse with each other,
so that the effluent samples are representative of the bulk of the post-reactor effluent.

- In-line mixing, with one mixer before the influent sample point and one mixer before effluent sample point is required for closed vessel systems. The same is preferred for open channel systems; however, if a mixer is only used before the bank of UV lights then sampling must take place after the level control device.

- The effluent sample point, particularly for open channel systems, should be in such a location so as to eliminate free surfaces and wall edge effects.

Verification of mixing should be completed in accordance with the method described in the UVDGM and be fully documented in the final validation report.

1.1.5 Lamp Variability and UV Sensor Port Window Testing

To account for lamp variability the UV system supplier must include the NWRI/AwwaRF test results for end of lamp life testing. It is recommended that the designer use the average lamp output. Only lamps that have been running in a quartz sleeve under water and tested in the same condition will be acceptable. Air testing is not acceptable. Lamps that have not been tested or run this way should not be grandfathered. Closed vessel systems should follow the UVDGM procedures. UV sensor port window testing should follow the UVDGM.

1.1.6 Measurement Equipment

It is critical that all key process parameters are monitored and recorded. This includes: flow, UVT, electrical power consumption, power input to the lamps if possible but power to the lamps and ballasts can be substituted, UV intensity, water temperature, pressure (for enclosed vessels) and headloss. The methods described in the UVDGM are comprehensive and should be adopted.

1.2 INLET/OUTLET PIPING

The configuration of the inlet and outlet conditions must be documented in the validation report as per UVDGM for closed vessels and as per NWRI/AwwaRF for open channel systems.

If the site specific installation is shown to be ‘different’ than the validation testing, then the velocity profile or, preferably the UV dose and or UV dose distribution should be shown to be equivalent or better than that observed for the bioassay validation. This should be completed by one or more of the following methods, as appropriate:

- Velocity profile as described in the NWRI/AwwaRF guidelines
- CFD as per Section 4.0 of this document.
- Check-point bioassay.

1.3 TEST LAMPS

For wastewater applications all UV lamps should be documented to have been seasoned/burnt-in for a period of at least 100 hours. Inlet power and UVT parameters should be adjusted to account for lamp aging and quartz sleeve fouling. Equipment verification protocols for these two variables are discussed in Section 4.2 of this document.

1.4 TEST CONDITIONS AND QA/QC SAMPLES

The validation test conditions should reflect as many variables as possible with respect to the wastewater and UV equipment. Some of these are described in the NWRI/AwwaRF Guidelines and UVDGM. Therefore, the test matrix should be designed to a specified range of water qualities (defined by UVT), flows and powers regardless of the ultimate operating philosophy: UV dose pacing, intensity pacing or confirming existing validation equations (check-point bioassay).

The challenge microorganism should be injected into the flow upstream of the UV reactor under steady state conditions. In general good sampling practices should be followed to collect at least three (3) influent and three (3) effluent samples for each test condition. An example would be three samples over 15 minutes or three volume changes of the UV system. The following process measurements should be taken for each sampling event:

- Flow rate
- UV Intensity from all sensors
- Calculated UV Dose
- Percent Lamp Current or Power
- UV Transmittance
- Electrical power

Where any of the above parameters change in value by more than the error of measurement (See Section 5.5 of UVDGM for error of measurement), over the course of each test condition, the test should be repeated.

The following standard quality control samples should be taken:

- Reactor Controls: With lamps off; Log Inactivation equivalent to RED < 3% of lowest RED tested.
- Reactor Blanks: Without surrogate addition take one sample per day. The measured densities should be negligible.
- Trip Controls: One sample bottle of challenge microorganism stock solution should travel with the stock solution used for validation testing from the microbiological laboratory to the location of reactor testing and back to the laboratory. The change in the log concentration of the challenge microorganism in the trip control should be within the measurement error. (i.e., the change in concentration over the test run should be negligible. This is typically on the order of 3 to 5 percent. e.g., at 1 x 1011, Log = 11. +/- 5% equivalent to ~10.5 to 11.5.
- Method Blanks: Normal laboratory blanks generated by plating with distilled reagent water.
- Stability Blanks: Purpose is to show no degradation
of the surrogate with time in the UVT and water matrix.

1.5 THIRD PARTY OVERSIGHT
An independent third party must provide oversight to ensure that validation testing and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV reactor manufacturer should oversee validation testing. Individuals qualified for such oversight include engineers experienced in testing and evaluating UV reactors and scientists experienced in the microbial aspects of biodosimetry. Appropriate individuals should have no real or apparent conflicts of interest regarding the ultimate use of the UV reactor being tested. A qualified third party should be present for and direct all testing, analyze data and author a detailed report. The final report should include the names and qualifications of all persons involved in the testing and their role. The independent third party should review the validation report before its release. When appropriate, the third party should rely on additional outside experts to review various aspects of UV validation testing, such as lamp physics, optics, hydraulics, microbiology, and electronics.

2.0 MICROBIOLOGICAL TESTING
The UVDGM contains a more comprehensive microbiological testing protocol than the NWRI/AwwaRF guidelines and reflects the latest understanding of UV disinfection technology; therefore it is proposed that this guideline be adopted in its entirety for the uniform validation testing of wastewater applications. However, it is recognized that specific unique challenges apply to microbiological testing with wastewater and therefore the following issues should be considered:

- Preparing the Challenge Microorganism
- Stability - Stability should be checked, and consistent recovery from seeded effluent should be confirmed, particularly in a treated wastewater effluent matrix. The challenge microorganism concentrations should be stable over the holding time between sampling and completion of the assays. If they are not stable, the data collected will be unusable because distinguishing the sources of inactivation—exposure to UV light and die-off in holding—will be impossible. Stability verification can help ensure that the bioassay and challenge microorganism samples will be viable and the data usable.

- Refer to Section 1.1.1 for a list of recommended challenge microorganisms.

- Verifying UV Reactor Properties
- The water temperature must be measured during the bioassay. Since the water temperature cannot be varied during the testing the UV manufacturer must submit UV intensity testing by a third party of the same lamp, ballast and quartz sleeve combination at water temperatures from 5 to 30°C.

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• For medium-pressure (MP) systems, a temperature sensor and safety cut-off switch to prevent overheating should be provided by the manufacturer.

• UV Intensity Sensors Performance

• Higher variability should be permitted if additional operational safety factors (i.e. set points) are included.

• Measuring UV Dose Delivery

• UV T (UVT) should be within ± 2% of the target UVT.

• Water temperature variability shall be within 0.5 °C.

• Sampling shall not proceed until a minimum of 5 x total void volume exchanges have passed. This flush volume is calculated between the microorganism’s injection point and the effluent sampling point.

• At least three (3) influent and three (3) effluent samples for each test condition should be collected. Influent and effluent samples are not collected at the same time, but collected in an alternating sequence at times that approximate the time of travel across the system. There should be at least one volume exchange between samples.

• Influent sample must be taken from the batch tank, the tap from the feed pipe, or from the channel; effluent sample must be taken from the reactor outflow or the channel after the effluent weir, or a sample tap, which is representative of the entire outflow.

• Plating should be at a minimum of two dilutions, with at least two plates per dilution.

• The following parameters should be measured and recorded: flow rate through the reactor, UV intensity, on-line UVT, calculated UV dose values both before and after the samples are collected, UVT as measured by a UV spectrophotometer with each influent sample electrical power consumed by the lamps and or ballasts, ambient air temperature, water temperature for each test.

• Sampling for UVT measurements should be separate; measurements should be taken within 24 hours of collection.

• The concentrations of the challenge microorganisms before and after exposure to UV light should generally be measured within 24 hours of sample collection unless stability studies indicate that the samples can reliably be considered stable over longer periods of time. Samples that are not assayed immediately should be stored in the dark at 4°C. Exposure of samples to visible light should be avoided.

• Collimated-Beam Testing

• The protocols for collimated beam testing should follow those in Bolton and Linden (2003) and the IUVA Excel spreadsheets.

• The UV sensitivity of the challenge microorganism and shape of each UV dose-response curve should be consistent with expected inactivation behavior for that challenge microorganism; accordingly, confidence bands developed for MS2 and other surrogates as a test of the quality of the UV dose response data should be used.

• Challenge Microorganisms with Shoulders or Tailing – In the case of a challenge microorganism with a shoulder or tailing in the UV dose response curve, the UV sensitivity should be defined as the sensitivity over the region of linear log inactivation that occurs between the shoulder and the onset of tailing. It is recommended that organisms with a shoulder not be used for this bioassay. Refer to Section 1.1.1 for a list of recommended challenge microorganisms.

3.0 VALIDATION DATA ANALYSIS

Validation testing of UV reactors produces the following types of data for each experimental test:

• Concentration of the challenge microorganism in the influent and effluent sample.
Continued from pg 31

- UV of water.
- Flow rate.
- UV intensity as measured by the UV sensor.
- Lamp or lamp and ballast power.
- Status (on/off) for each lamp.

All experimental data should be documented, preferably in tabular format, and included in the Validation Report. The Reduction Equivalent Dose (RED) should be calculated for each experimental test using a combination of reactor testing data and collimated beam results. An additional analysis of RED data depends on the reactor’s UV dose-monitoring strategy. For the UV Intensity Set point Approach, RED results are averaged for each test condition and evaluated to identify the minimum value. For the Calculated Dose Approach, all RED values and associated test conditions are used to create a UV dose-monitoring equation.

4.0 ADDITIONAL OPTIONAL ANALYSIS USING ADVANCED TOOLS AND EXISTING DATA

New and emerging technologies are being developed to aid in the validation of UV reactors. Computational Fluid Dynamics and Lagrangian Actinometry with Dyed Microspheres are two such technologies. They are presented here as optional analysis tools to provide greater flexibility and understanding of reactor design, not as alternatives to bioassays.

- Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the millions of calculations required to simulate the interaction of fluids with light and microorganisms in a complex UV system. The results from the CFD model must be calibrated with the results from the bioassay to validate the computer model. Once calibrated, the CFD model can be used to develop a CFD uncertainty factor and this can be used to predict the average and range of UV doses with a UV system. CFD can also be used to calculate the UV dose of a system at parameters (e.g. flow rate, and UV Transmittance), which have not been bioassayed. For more information on modeling UV reactors with CFD see AwwaRF Project #4107 “Evaluation of Computational Fluid Dynamics (CFD) as a Cost –Effective Tool for Assessing UV System Performance”. A comprehensive paper was written on this AwwaRF project titled “Important Factors for Computational Modeling of UV Disinfection Systems” It is in the Proceeding of the AWWA Water Quality Technical Conference 2008.

- Lagrangian Actinometry with Dyed Microspheres (DMS) Lagrangian actinometry is a newly developed test method that uses dyed microspheres to determine the UV dose-distribution of a UV reactor. Microspheres are modified by the attachment of a dye that allows measurement of the UV dose. When subjected to UV radiation, the dye undergoes a photochemical reaction to yield a stable, fluorescent compound that can be easily and accurately differentiated from the non-fluorescent parent compound. By measuring a large population of exposed microspheres, the UV dose-distribution with the reactor can be measured directly.

4.1 GRANDFATHERED PROTOCOLS

It is our recommendation that a similar guideline to that described in the UVDGM is adopted for a uniform wastewater UV validation protocol, namely that UV equipment validated prior to the publication of a uniform wastewater protocol, be recognized within the following limitations:

- The microorganisms used in the previous validation were the same as those recommended in this document.
- QA/QC procedures that are generally inline with this document were followed.
- Data analysis was generally in-line with the methods outlined in this document.
- A qualified third party conducted and certified the results of the bioassay.

4.2 RELATED EQUIPMENT VERIFICATIONS

It should be recognized that in addition to UV dose delivery performance validations, there are other related equipment tests that are used to verify operational performance. These include:

- Lamp output measurement.
- Lamp age factor testing.
- Cleaning mechanism testing (quartz sleeve fouling).

Whilst these verification tests can be completed separately to bioassay testing, it is recognized that they are used in the final equipment sizing design and as such deserve attention.

The IUVA Manufacturers Council has published a protocol for the measurement of the UV output of low pressure lamps, and it is our recommendation that this be adopted. A similar protocol for medium pressure lamps is pending.

Separate, updated, protocols for lamp aging and quartz fouling are required; however, in the short term it is recommended that the existing NWRI/AwwaRF guideline be followed.

5.0 REPORTING

A formal validation report is an important element of any validation testing. Both the NWRI/AwwaRF guideline and the USEPA UVDGM include reporting guidelines. Since the UVDGM details a more comprehensive outline of the key elements of a validation report, together with checklists helpful for review and approval, this guideline should be adopted for a uniform wastewater UV validation protocol.
SUMMARY

To ensure the objective of environmental protection is adequately met when UV light is being used to disinfect wastewater discharges, it is important to verify equipment performance. The widely accepted method for completing this validation is by determining the UV dose delivery performance using biodosimetry. The preceding proposed protocol takes elements of existing protocols for drinking water and reuse water and applies them to the specific application of wastewater as defined in this document.

However, unlike drinking water or reuse water, the wastewater regulatory community looks to effluent disinfection compliance as the sole target for UV disinfection performance and not system design or system testing processes. Therefore, the components of this document are not designed to propose a regulatory standard, but rather as a tool that allows for direct comparisons of UV systems during the design of such systems and to help to properly size a UV systems.

REFERENCES


Sandia National Laboratories, Not Published,
Evaluation of Computational Fluid Dynamics as a Cost-Effective Tool for Assessing UV System Performance WRF #4107. Water Research Foundation, Denver, Colorado, USA.

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<tr>
<td>Kroll, G R; Fahey, F; Smith, P D,</td>
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<td><strong>Advanced Oxidation Processes, Part 1</strong></td>
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<tr>
<td>Liou, Y H; Chen, S-Y,</td>
<td>“Efficient photodegradation of paracetamol using Fe modified TiO2 mesoporous nanoparticles under visible light irradiation”</td>
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<tr>
<td>Pelaez, M; Falaras, P; Bandala, E R; Dunlop, P; Byrne, J; de la Cruz, A; Dionysiou, D D,</td>
<td>“TiO2 based enhanced photocatalytic degradation and disinfection of water under solar light irradiation”</td>
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<tr>
<td>Maciucă, A; Batiot-Dupeyrat, C; Tatibouët, J M,</td>
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<tr>
<td><strong>UV reactor design and validation, Part 1</strong></td>
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<tr>
<td>Shen, C; Scheible, O K; Blatchley III, E R; Cox, E; Valade, M,</td>
<td>“New York City UV system validation by Lagrangian actinometry using dyed microspheres”</td>
</tr>
<tr>
<td>Wols, B A; Hofman-Caris, R C H M; Harmsen, J H; Beerendonk, E F; van Dijk, J C; Chan, P-S; Blatchley III, E R,</td>
<td>“Comparison of CFD, biodosimetry and Lagrangian actinometry to assess UV reactor performance”</td>
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<tr>
<td>Cabaj, A; Sommer, R; Hirschmann, G; Haider, T,</td>
<td>“Is the REF of UV-Plants for Drinking Water Disinfection Proportional to Lamp Power and Flow Rate?”</td>
</tr>
<tr>
<td>Linden K G; Scheible, K; Shen, C; Gerba, C; Tamimi, A; Posy, P,</td>
<td>“Demonstrating 4-log Adenovirus Inactivation in a Medium Pressure UV Reactor”</td>
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<tr>
<td>Petri, B; An, J; Moreland, V,</td>
<td>“UV System Checkpoint Bioassays: Proof of Scale-Up, Challenges from the Field, and Comparison Methodology”</td>
</tr>
<tr>
<td>Wright, H; Heath, M; Bandy, J,</td>
<td>“Yikes! What the UVDGM Does Not Address on UV Disinfection”</td>
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<td><strong>Advanced Oxidation Processes, Part 2</strong></td>
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<tr>
<td>Bazri, M; Mohseni, M,</td>
<td>“Impact of Combined Coagulation-UV/H2O2 Treatment on Biological Stability of Water”</td>
</tr>
<tr>
<td>Wang, D; Walton, T; MacDermott, L; Hofmann, R,</td>
<td>“Control of TCE Using UV Combined with Hydrogen Peroxide or Chlorine”</td>
</tr>
<tr>
<td>Souza, B S; Dantas, R F; Cruz, A; Esplugas, S; Sans, C; Dezotti, M,</td>
<td>“Application of UV/H2O2 as post-treatment of WWTP secondary effluents for water reuse”</td>
</tr>
<tr>
<td>Stefan, M J; Sarathy, S R,</td>
<td>“A method for quantifying the assimilable organic carbon in water treated with UV/H2O2 and biological activated carbon filtration”</td>
</tr>
<tr>
<td>Hofman-Caris, C H M; Harmsen, D J H; Beerendonk, E F; Heringa, M; Knol, A H; Lekkerkerker-Theunissen, K; Geboers, J; Meyer, M; Metz, D,</td>
<td>“International project on new concepts of UV/H2O2 oxidation”</td>
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**Industrial applications, Part 1**

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<td>Mayerhofer, I; Anderle, H; Kistner, O; Howard, M K; Kreil, T R; Barrett, P N,</td>
<td>“UV irradiation for the manufacturing of viral vaccines: state-of-the-art and perspectives in modern vaccine processing”</td>
</tr>
<tr>
<td>Kang, J-W; Yoon, Y; Jung, Y,</td>
<td>“Application of O3 and UV for disinfection of seawater in Ballast water treatment”</td>
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<tr>
<td>Xie, R</td>
<td>“Effect of Low Pressure Ultraviolet Irradiation on Barnacle Growth under Open Sea Conditions”</td>
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<tr>
<td>Townsend, B; Hulsey, B; Neemann, J; Zhao, X,</td>
<td>“Impact of advanced validation techniques and dose-monitoring strategies on UV reactor operating efficiency”</td>
</tr>
<tr>
<td>Heath, M; Wright, H; Bandy, J; Gehlen, I; Forsyth, M,</td>
<td>“On-Site Testing Extends Validated Range for Year-Round Operation of a Medium Pressure UV Disinfection System”</td>
</tr>
<tr>
<td>Bircher, K; Sotirakos, B; Salveson, A,</td>
<td>“Development, Challenges and Validation of a High Efficiency UV Unit for Title 22 Reuse”</td>
</tr>
<tr>
<td>Bandy, J; Wright, H; Gaithuma, D; Lawal, O; Larner, S,</td>
<td>“Drinking Water UV Operation Without On-Line UVT Monitoring: The Default UVT and Sensor Setpoint Approaches to Validation”</td>
</tr>
<tr>
<td>Verhoeven, S; Wright, H; Odegaard, C; Shaw, J; Bircher, K,</td>
<td>“Reflections cause measurable error when calculating UV dose in a collimated beam apparatus”</td>
</tr>
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</table>

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<tr>
<td>Hunter, G; Kliewer, A; Hulsey, B; Klinger, C; Carrera, M,</td>
<td>“Application of UV Disinfection to achieve Enterococci Removal at a Trickling Filter Plant”</td>
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**Advanced Oxidation Processes, Part 4**

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<tr>
<td>Lekkerkerker-Teunissen, K; Scheideler, J; Knol, A H; Ried, A; Verberk, J Q J C; van Dijk, J C;</td>
<td>“Combined O3/H2O2 and UV for multiple barrier OMP treatment and bromate formation control – One year pilot plant research”</td>
</tr>
<tr>
<td>Lutze, H; Bircher, S; von Sonntag, C; Schmidt, T C,</td>
<td>“Degradation of atrazine by sulfate radical anions. Reaction ate constants and mechanistic aspects”</td>
</tr>
<tr>
<td>Imoberdorf, G E; Mohseni, M,</td>
<td>“Degradation of pesticides and taste and odor compounds using a flow-through Vacuum UV reactor”</td>
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</table>

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Clean water is a precious resource that we often take for granted. But for many people in the world it's far from guaranteed. That's why Philips' revolutionary new technology is such a cause for celebration. By overcoming all the current limitations of UV technology it will mean a future with safe drinking water at home. Everywhere. Anytime. A true technology breakthrough from the world's leading partner in innovation. Get ready to raise your glass at Aquatech Amsterdam. Together we will celebrate the new business opportunities this revolution brings to all of us!

Make sure you're there at the big launch! Join now and get all latest updates at www.philips.com/uvrevolution