IUVA NEWS

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FEATURES

ARTICLES

UV Disinfection in Moscow Metro Public Transport Systems

UV/H2O2 Treatment of Drinking Water: Impacts on NOM Characteristics

INTERNATIONAL IUVA ULTRAVIOLET ASSOCIATION

in the next issue . . . *Conference/Congress Updates and Global Perspectives*

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CONTENTS

ARTICLES

Cover Photo
Dam Square and Royal Palace, Amsterdam, The Netherlands, 5th UV World Congress

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INDEX OF ADVERTISERS

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Mr. Paul Overbeck

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EDITORIAL
Paul Overbeck
Editor-in-Chief


Paul Overbeck

We are well into 2009 and while the global economy has tightened, we are seeing signs of governmental spending in infrastructure areas important to the UV industry.

Under the U.S. stimulus plan, the American Recovery and Reinvestment Act (ARRA) of 2009 specifically includes $7.22B for drinking water and wastewater infrastructure programs administered by the EPA.

These ARRA funds will aid municipalities large and small whose funding, tied to municipal borrowing, had tightened dramatically in 2008. Top-rated municipal borrowers of 10-year maturities paid interest rates of 3.65% at the end of March 2009, up from 3.28% on 12 February according to Municipal Market Advisors data and down from a one-year high of 4.71% on 16 October 2008.

Internationally, governments are signaling increased spending on infrastructure. China has a $500+B total infrastructure plan in place, while EU countries individually and collectively finalize pending action. The amounts set aside for water and wastewater/reuse are yet to be identified.

Reuse will continue to grow as a response to decreasing water availability in areas with normally low annual rain fall and those impacted by unexpected draught conditions such as the southeastern and southwestern United States, the Mediterranean, Africa, Australia and the Middle East.

One shining example of how UV technology will thrive in reuse is the Orange County Water District's Reclamation and Replenishment facility. It recently won the U.S. Environmental Protection Agency 2008 Clean Water State Revolving Fund "Pisces" award, recognizing projects that advance clean and safe water through exceptional planning, management and financing.

This is one of many awards the OCWD has recently been awarded, including the 2008 Stockholm Industry Water Award from the Stockholm International Water Institute, the 2008 U.S. EPA Water Efficiency Leader Award, Water Agency of the Year from the International Desalination Association, and Water Agency of the Year from WateReuse Association. We were pleased that Mehul Patel from OCWD was able to present, *"UV Advanced Oxidation for Groundwater Injection-OCWD Case Study"* at our March workshop in Long Beach, California.

And let's not forget the commercial and industrial (C-I) sector. 70 people attended our C-I workshop during the WQA-Aquatech conference in Chicago. Industry is looking for green alternatives that deliver a payback. A return on investment coupled with the potential for "good corporate citizenship" in the public eye can drive investment in UV technology.

IUVA and its members will continue to spread the word at many more events in 2009, including the upcoming North American Conference on Ultraviolet and Ozone Technologies, AWWA, SIWW, the 5th Ultraviolet World Congress, WEFTEC and the Water Quality Technology Conference.

Drs. Regina Sommer, James Malley, Joop Kruithof and Andreas Kolch are putting together an excellent UV World Congress Technical program. Please check www.iuva.org often for updates.

As always, we welcome your participation and support at our many workshops and conferences. It is through your feedback, Application Notes and articles/papers right here in UV News that we advance together as an industry.

Paul

A MESSAGE
from the IUVA President
Linda Gowman


Linda Gowman

Dear Water Industry Colleagues

In my last president's message the international financial markets had just collapsed and I brought you a message of encouragement to continue doing what we do- spreading the word about UV and how it is right for our time.

In that regard, many of our members have been very busy. Dr. Jamal Awad helped IUVA by organizing an excellent workshop in California on March 12, 2009, bringing further education and communication to those interested in UV. On June 22, 2009, IUVA will be holding a one-day workshop on UV as part of the Singapore International Water Week, a direct result of the tireless effort of member Dr. Rongjing Xie.

Of course, our next large conference and our next board meeting is in Boston, USA, May 3-6, 2009, and I hope to see many of you there as part of the joint IOA/IUVA conference.

Our 10th Anniversary will be celebrated at our 5th UV World Congress in Amsterdam, Netherlands, September 21-23, 2009. We have had a very good submission of abstracts, and Dr. Regina Sommer, Dr. Joop Kruithof, Dr. Jim Malley, and Dr. Andreas Kolch on the technical selection committee have done an outstanding job of diligently reading and assessing the submissions and organizing the agenda. Thank you to them.

It may be the case that attendance will be down a bit, but what I have witnessed in response is an unparalleled effort from many within the IUVA to work together and make our offerings and attendance as excellent as possible in spite of the challenges. That can only bode well for us as an organization and as an industry. Indeed, I am particularly buoyed by the story of a delegate who is coming to our Boston conference. This individual, unable to come due to budgetary constraints imposed by a government agency, is taking vacation time to attend personally. That is dedication to professionalism and to an industry. I take encouragement from that and pass it on to you- as we all seek to provide the best possible offerings to this delegate and all others. Let's stay the course.

UV INDUSTRY NEWS

The following are some of the more interesting items from the IUVA Member Announcements:

25 March 2009: World's first medium pressure, closed Vessel UV systems gains California Title 22 validation for wastewater reuse.

www.bersonuv.com, www.aquionics.com

Berson's InLine+ medium pressure, closed vessel UV systems are the first in the world to gain formal approval for wastewater reuse applications. The Berson UV system underwent extensive third party testing by Carollo Engineers in the USA. They have been formally approved for post-filtration and reverse osmosis applications by the California Department of Public Health (Title-22 validation) and are now validated for wastewater reuse applications in accordance with AwwaRF/NWRI* guidelines. Berson's UV systems are sold in North America by its sister company Aquionics, Inc.

Wastewater reuse has been practiced in various forms for decades, with the USA leading the way in reuse research. It is now a major issue worldwide, with large areas of western and southern USA experiencing chronic water shortages. Large-scale reuse projects are now also being considered in other water-poor regions of the world such as Australia, Singapore, China and southern Europe.

The most common method of wastewater disinfection for reuse has long been chlorination. Despite chlorine's impressive track record, concerns regarding disinfection by-products (DBPs) and, more recently, disinfection performance with respect to pathogen inactivation, are driving the conversion from chlorine disinfection to other disinfection methods such as UV, which does not produce any significant DBPs.

Potential applications for wastewater reuse are extremely wide-ranging and include any instance where water is needed for non-potable use. The most popular and widespread use is for agricultural irrigation and for other irrigation applications such as golf courses, parks, fountains and lawns. Reclaimed wastewater is also used for groundwater recharge applications such as aquifer storage and recovery or preventing saltwater intrusion in coastal aquifers. Other uses include toilet and urinal flushing, fire fighting, foundation stabilization in the construction industry and artificial snow generation. In all these applications, reused wastewater relieves the burden on existing potable supplies.

16 March 2009: Trojan Technologies announced residential water treatment business unit name change to VIQUA™ – a Trojan Technologies Company. www.viqua.com

Key product lines Sterilight® and Trojan UVMAX™ will lead the VIQUA business toward a strict focus on residential water treatment solutions, advanced research and development and only the highest quality customer support. Trojan Technologies acquired R-Can Environmental Inc in August 2008. The residential business will continue to operate out of Guelph, Ontario with approximately 90 employees.

"This will allow us to better position the company's market-facing business," says Ron Braun, managing director. "As the residential centre for water treatment excellence, we provide a broad spectrum of solutions to our customers who are facing water quality issues. This new brand will allow us more flexibility as we grow and expand that market".

12 March 2009: Ultraviolet Sciences Inc. Acquires Certifications for Its UV Water Purification Product Line

www.wateronline.com

Ultraviolet Sciences Inc., manufacturer of a new generation of innovative UV water treatment solutions, has received certification from TUV certifying the UVS series product line to worldwide safety and EMI standards. Additionally Ultraviolet Sciences Inc. (UVSI) has completed NSF (National Sanitation Foundation) testing of this new generation of water treatment solutions. UVSI designs, manufactures and sells UV systems for commercial and industrial industries with emphasis in the beverage, semiconductor, pharmaceutical, waste water, and water reclamation sectors.

"Completing this series of certification and testing clearly demonstrates that UVSI has designed and produced a truly innovative UV water disinfection system", says Dr. J.R. Cooper, President of UVSI. "Our products have exceeded our expectations in both disinfection capability and TOC and Urea removal. Our unique, patented flow chamber design is fundamental to this performance."

24 February 2009: Ocean Optics' New Remora Delivers Spectrometer Remote Access Capabilities

www.oceanoptics.com

OceanOptics, an industry leader in miniature photonics, has used the emergence of powerful yet inexpensive microprocessors to turn its spectrometers into web servers that can wirelessly exchange data and operation parameters. The new Remora is a plug and play adapter that makes connecting to an Ocean Optics Spectrometer as easy as putting a URL into a browser. Users can access Remora over a Wi-Fi or Ethernet network to capture real-time data and control their spectrometer's parameters.

2 February 2009: Ken Sturgess joins Nedap Light Controls as U.S. Sales and Marketing Manager and introduces specialty electronic ballasts to North America.

www.nedaplightcontrls.com

Nedap Light Controls, a division of Nedap N.V., announced the they have named Ken Sturgess to head their sales and marketing efforts in the United States and Canada. Mr. Sturgess has a long history in marketing power electronics with special emphasis on applications involving the use of ultraviolet light in curing and germicidal applications

Nedap Light Controls designs and manufactures high-quality, easy-to-use, energy saving intelligent electronic ballasts, ranging 15W to 48kW, used to control UV light for various curing and disinfection applications.

30 January 2009: Memorial Sloan-Kettering Cancer Center Implements New Lab Disinfection System using UV.
http://www.vigilairsystems.com/applications/rss.html

The gene therapy research community is turning to a novel technology to keep their lab free from contamination. Gene therapy research labs require extremely high standards for cleanliness. Traditionally researchers at Memorial Sloan-Kettering Cancer Center (MSKCC) relied on manual surface cleaning using caustic chemicals to meet those standards. Managers at the Gene Transfer and Somatic Cell Engineering Facility were looking for an alternative because the existing cleaning procedure is labor intensive, costly and yields mixed results.

Continued on page 7

NEW *IUVA* MEMBERS

The International Ultraviolet Association takes great pleasure in welcoming these new members... Thank you for joining us in 2008!

Australia
Iain Johnson
Cardinia Puraflo
Technologies Pty Ltd.
Emerald, Australia

Andrei Gareev
SVAROG
Wollongong, Australia

Peter James
Ultra Violet Products
(AUST) PTY. LTD.
Keswick, Australia

Austria
Martin Wesian
Wien, Austria

Brazil
Rogerio Alves
Sibrape
Ribeiraio Preto, Brazil

Canada
John Gruber
Westridge Utilities, Inc.
Calgary, Canada

Hector Larrazabal
Novachem
Calgary, Canada

Erin Devries
UVDynamics Inc.
London, Canada

Pieter Devries
UVDynamics Inc.
London, Canada

Martin Arsenault
Drummondville, Canada

China
Ethan Hung
CNlight Co. Ltd.
Foshan, China

Blue Shou
Fujian Newland EnTech Co. Ltd.
Fuzhou, China

Minyi Han
Fujian Newland EnTech Co. Ltd.
Fuzhou, China

Yu Wang
Fujian Newland EnTech Co. Ltd.
Fuzhou, China

Peter Wu
Fujian Newland EnTech Co. Ltd.
Fuzhou, China

Meiting Guo
Fujian Newland EnTech Co. Ltd.
Fuzhou, China

France
Frederick Cousin
Degremont Technologies
Rueil Malmaison, France

Germany
Klaus Andre
Siemens - Wallace & Tiernan GmbH
Günzburg, Germany

Sandra Kerth
eta plus electronic gmbh Nuertingen,
Germany

Andreas Kolch
Hytecon Gmbh
Herford, Germany

Uwe Hofer
Dipl Ing Uwe Hofer
Lohne, Germany

Italy
Aldo Santi
Light Process
Anghiari, Italy

Norway
Bjornar Eikebrokk
SINTEF
Trondheim, Norway

South Africa
Guy Kebble
Surepure
Cape Town, South Africa

South Korea
Joon-Wun Kang
Wonju, South Korea

Yoon Hahn
Seoul, South Korea

Spain
Jose Gomez Civicos
Sociedad Espanola de Microfilracion S.A.
Madrid, Spain

Switzerland
Christoph Dicks
AQUAFIDES GMBH
Zug, Switzerland

Stephen Robinson
Surepure
Zug, Switzerland

The Netherlands
Ton Van Remmen
Van Remmen UV Techniek
Wijhe, The Netherlands

Jacco van Midwoud
LIT-UV Europe
Den Bosch, The Netherlands

Latif Aksu
Rotterdam, The Netherlands

Erwin Beerendonk
KWR Watercycle
Research Institute
Wadenoijen, The Netherlands

United Kingdom
Clive Dean
Siemens
Kent, United Kingdom

Clayton Sampson
Cyan UV Limited
Oxford, United Kingdom

Terence Crocker
South West Water
Exeter, United Kingdom

Jeff Hayes
South East Water
Frimley, United Kingdom

Barrie Holden
Anglian Water Group
Peterborough, United Kingdom

Andrew Wetherill
Yorkshire Water
Bradford, United Kingdom

Ian Helmore
Helmore Water
Baldock, United Kingdom

Dennis Downie
Severn Trent Services
Sutton, United Kingdom

Azael Capetillo
Leeds University
Bradford, United Kingdom

Catherine Noakes
Leeds University
Old Malton, United Kingdom

John Christmas
Crux Easton, United Kingdom

United States of America

Thomas Mooney
Siemens
Allendale, NJ

Andrew Reid
AECOM
Concord, MA

Ken Munoz
Radiant Source Technology
San Jose, CA

Mehul Patel
Orange County Water District
Fountain Valley, CA

Bruce Jacobs
Cedar Rapids Water Dept. - Water Div.
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Aquionics Incorporated
Erlanger, KY

Marc Scanlon
Aquionics Incorporated
Erlanger, KY

Kevin Shannon
Aquionics Incorporated
Erlanger, KY

Mark Jackson
Lennox Industries
Carrollton, TX

Chuck Dunn
Lumalier
Memphis, TN

Karl Platzer
Light Sources, Inc.
Orange, CT

Michael Santelli
Light Sources, Inc.
Orange, CT

Laura Rose
Centers for Disease Control
Decatur, GA

Andrew Lux
WaterHealth International, Inc.
Irvine, CA

Tim Bettles
Crystal IS
Green Island, NY

Mark Bertler
Pentair Water
Hanover Park, IL

Jeffrey Mosher
National Water Research Institute
Fountain Valley, CA

Bryan McCarty
MM Consulting LLC
Evergreen, CO

Joe Giannone
Degremont Technologies - Infilco
Richmond, VA

Robert Kelly
Degremont Technologies - Infilco
Richmond ,VA

Wei Yang
Degremont Technologies - Infilco
Richmond, VA

David Murray
Brown & Caldwell
Portland, OR

Victoria Georgakas
Milwaukee School of Engineering
Greenfield, WI

UV INDUSTRY NEWS

Continued from page 5

A VIGILAIR® Room Surface Sterilization System (RSS) was installed in the lab to determine its efficacy in reducing microorganisms that could contaminate the work area. Separate tests by MSKCC and VIGILAIR® showed the RSS system provided a 5-log or greater reduction on target pathogens.

RSS uses Ultraviolet energy (UV-C) to deactivate microorganisms that contaminate surfaces. UV-C emitters are strategically placed to bathe the entire lab with germicidal UV-C energy. RSS features sophisticated controls that turn off the emitters when a predetermined UV dose is achieved. The system also prevents lab workers from being accidentally exposed to UV.

"The testing results are very encouraging, " says VIGILAIR Systems Inc. President Peter Bjorkman. "The results clearly demonstrate that our UV technology is a safe and cost effective alternative to manual cleaning."

9 January 2009: TrojanUV Rated China's Top Disinfection Equipment Again

www.trojanuv.com

Trojan Technologies has once again been rated number one in the category of "Outstanding Water Disinfection Equipment Brand" in the annual independent Outstanding Equipment Survey conducted by China Water Net, the most influential online resource for China's water industry.

Based on a sample of more than 220 water treatment equipment customers, manufacturers or brands were listed in order of number of votes received and evaluated in the categories of: 1) most recognized brand that a customer knows; 2) most used brand by a customer; 3) customer satisfaction on the quality of the equipment; 4) customer satisfaction on after sales service; and, 5) good value for price. Of the 21 measuring indexes for the survey, Trojan scored in the top three spots for each category.

"Receiving this recognition for the second year in a row is a reflection of our talented and focused group in China. The Trojan team has worked diligently to bring reliable and cost-effective UV-based disinfection solutions to our global community," says Marvin DeVries, Trojan president. "We are honoured to have received this prestigious recognition."

18 December 2008: WEDECO announces TMO-IV UV Transmittance Monitor

http://www.wateronline.com/product.mvc/WEDECO-TMO-IV-UV-Transmittance-Monitor-0002

ITT-Wedeco announced that the TMO-IV is specifically designed for continuous on-line monitoring of UV transmittance (254 nm) in drinking water applications.

NEWS FROM *IUVA*

LONG BEACH WORKSHOP

On 12 March the IUVA held a one day workshop titled, "UV Advanced Oxidation and UV New Applications." The workshop was organized by Dr. Jamal Awad of MWH and was graciously hosted by the City of Long Beach, California at its Ground Water Treatment plant. The 51 attendees listened intently to technical presentations on:

- Advanced Oxidation Principles -- Karl Linden, University of Colorado at Boulder
- Regulatory Framework -- Brian Bernados, California Department of Public Health
- Exploring design of UV AOP - More than just a really big disinfection reactor -- Erik Rosenfeldt, University of Massachusetts - Amherst
- UV Advanced Oxidation for Emerging Contaminants -- Joan Oppenheimer, MWH
- Use Of UV for Membrane Bio-Fouling Reduction -- Tai Tseng, Long Beach Water Department
- Use Of Bench Testing and Modeling for the Effect Of Peroxide, Hydroxyl Scavenging, UV Path Length, and Hydrodynamics (CFD) to Size a Full Scale System -- Brian Altland, Calgon Carbon
- Implementing an Effective UV Advanced Oxidation Process - Lessons Learned From 3 Full-Scale Projects -- Paul Swaim, CH2M HILL
- UV Advanced Oxidation for Groundwater Injection-OCWD Case Study -- Mehul Patel/Orange County Water District

- Comparison of UV And Ozone Advance Oxidation – Christine Cotton, Malcolm Pirnie
- Advanced Oxidation for Taste and Odor Control – Brian Petri, Trojan Technologies

Erik Rosenfeldt commented, "I thought the audience was a great blend of manufacturers, consultants, regulators, and utility people, so the conversations during the breaks and at lunch were very interesting. I came away from the conference with a whole new set of questions to think about in my research. Even as a presenter, I feel like I gained a lot of useful information and insights from the other talks."

WQA-AQUATECH WORKSHOP

The 70 people attending the IUVA Workshop on Residential and Commercial-Industrial Applications on Tuesday, 17 March chose learning about UV technology over enjoying the unusually balmy 70+ °F temperatures in Chicago by strolling Navy Peer, the Magnificent Mile or the Lake Michigan shoreline.

Topics and speakers included:

- Introduction to Ultraviolet Treatment - Bruce Laing, VIQUA™ – a Trojan Technologies Company
- Residential - Bruce Laing, VIQUA™ – a Trojan Technologies Company
- Swimming Pools – Robert Kappel, Siemens Water Technologies
- Food and Beverage - Marc Scanlon, Aquionics Incorporated.
- Remediation and Air Treatment - Steve Schmidt, The Ozone Man, Inc.
- Small Municipal - Marc Scanlon, Aquionics Incorporated

The Water Quality Association (WQA) is a not-for-profit international trade association representing the residential, commercial, industrial, and small community water treatment industry. WQA maintains a close dialogue with other organizations representing different aspects of the water industry in order to best serve consumers, government officials, and industry members. WQA is a resource and information source, a voice for the industry, an educator for professionals, a laboratory for product testing, and a communicator to the public.

This was the first IUVA workshop co-located with Water Quality Association-Aquatech and based on the response may well become an annual event.

IUVA thanks those who volunteered their time and energy to put on these excellent technology transfer workshops. Copies of the speaker presentations are available from the IUVA on CD ROM'S for each workshop ($35 each). Contact Diana at DianaS@iuva.org for details.

IUVA's upcoming workshops will be on 03 May in Boston prior to the North American Conference on UV and Ozone Technologies and on 22 June as part of Singapore International Water Week.

Please visit www.iuva.org for workshop and World Congress details and registration information.

HOT UV NEWS

The following are interesting media items that may affect the UV Industry

19 March 2009: U.S. House Panel to Discuss Urban Storm Water Runoff

The U.S. House Transportation and Infrastructure Committee started to examine efforts to address urban storm water runoff after the critical National Research Council report last year.

The U.S. Environmental Protection Agency (EPA) is looking at overhauling its storm water program after a critical report by the National Research Council in October. The report, which EPA requested in order to improve its Clean Water Act regulations for storm water pollution, says the agency must make radical changes to its storm water program in order to reverse degradation of freshwater resources, and recommended that EPA base discharge permits on watershed boundaries rather than political boundaries. The study also suggests integrating storm water management and land management practices.

An amendment to H.R. 1262 would require states using state revolving fund cash to give priority to projects that construct natural, vegetation-based systems to filter and store storm water runoff and floodwaters for recharging of natural aquifers, and would also provide technical assistance and funding to communities that include green infrastructure in their water management plans and infrastructure improvements.

Another amendment would require states to set aside 20% of their combined sewer and sanitary sewer grants for communities that implement green infrastructure or other water- and energy-efficient improvements.

Committee Chairman James Oberstar (D-Minn.) also promised that his committee will closely monitor how states use the $6 billion in cash for the state revolving funds contained in the recent economic stimulus package.

The National Research Council report is available at http://dels.nas.edu/dels/rpt_briefs/stormwater_discharge_final.pdf.

13 March 2009: Top 100 Infrastructure Projects of The Americas Released, Representing $64.6B And 2.8 Million New Jobs

www.cg-la.com

CG/LA Infrastructure LLC, the world leader in strategic infrastructure project identification and development, released the list of the Top 100 Infrastructure Projects in Latin America. The total estimated value of the projects is $64.6B, equivalent to almost 2% of Latin American GDP, and total job creation is projected at 2.8 million

Strategic Infrastructure Projects: World class projects are drawn from eight infrastructure sectors, including top 5 projects in ports & logistics, oil & gas, water & wastewater, electricity generation, urban mass transit, digital infrastructure, new energy and highways. Projects are drawn from 12 countries, including the Panama Canal Expansion ($5.2 B); The Eastern Aqueduct in the Dominican Republic ($1 B); the Metropolitan Electric Train in Costa Rica ($520 MM); Sao Paulo's 'Metropolis' project (US$1.2 B); and the transformative Multimodal Corridor Mazatlan-Matamoros in Mexico ($1.4 B).

According to Norman F. Anderson, President & CEO of CG/LA, these projects are critical to Latin America's future: "Investing in infrastructure is central to protecting the region's real economies from the financial crisis, seizing the 'opportunity in the crisis' to build productivity and competitiveness." According to Anderson, these countercyclical projects will double the region's investment in infrastructure, immediately creating needed new jobs throughout the region.

13 March 2009: Polyurethane Coating Self-Heals In UV Light

The Discovery Channel reported on "a new polyurethane film developed by scientists from the University of Southern Mississippi" that uses "a new macromolecule" to create a polymer that "is capable of repairing itself" when exposed to ultraviolet light. "The new coating is 99.99 percent standard polyurethane," and "the remaining 0.01 percent is either a four-molecule oxetane ring or a long rod of chitosan," which "is closely related to chitin." While scientists say "that it should be able to repair most scratches indefinitely," they added that "since the material is so new, they haven't been able to conduct long-term tests." The relative cheapness and availability of chitosan, as well as its low cost and environmental friendliness, are also pointed out.

BBC News explains, "Scratches or damage to the polyurethane coat split the oxetane rings, revealing loose ends that are highly likely to chemically react. In the ultraviolet light provided by the sun, the chitosan molecules split in two, joining to the oxetane's reactive ends." The researchers described the chemistry involved as "not very complicated," and according to the article "the well-established nature of polyurethane in such a wide range of manufacturing could see a number of benefits, not least the self-healing car paint job." The UK's Press Association, New Scientist and the Wired (3/12) Science blog also report the story.

12 March 2009: Most Companies Don't Assess Comprehensive Water Footprint

www.pacinst.org

According to a recent report from the Pacific Institute, a majority of companies do a poor job of assessing their water footprints across the entire business supply chain, leading to risks associated with water scarcity.

Researchers at the Oakland, Calif.-based think tank surveyed 110 companies in 11 sectors and found that only 15% had approached water scarcity issues in a comprehensive manner. Sectors studied include the beverage, mining, food product, pharmaceutical and forestry industries.

The United Nations' CEO Water Mandate commissioned the report. The Water Mandate is a program established by the U.N. secretary general to help the private sector address the water resources management. The program is meant to prepare the business community for future water supply shortages. The report found that most of the companies did not examine how water use affects them outside of their direct operations, ignoring overall supply-chain performance and regional or local effects of water use.

5 March 2009: Chandler, Arizona will add UV to 6 Pools even as City Grapples with Plummeting Tax Revenues.

"Our first priority is to maintain existing facilities and service levels," said Management Services Director Dennis Strachota after weeks of delivering increasingly grim financial news to the City Council. At the

top of the to-do list is installation of ultraviolet water purification systems in six pools to prevent Cryptosporidium parasite outbreaks like those that forced cities around the Valley to close public pools last summer

That project is covered by $2.8 million set aside for "aquatic facility safety requirement" expenses.

The Maricopa County Assessor's recent property valuation notices were the latest evidence that the recession will take a serious bite out of revenues. Since property taxes paid to cities and other jurisdictions two years from now are based on these recent valuations, Chandler must change long-term capital improvement plans to avoid shortfalls, Strachota said.

5 March 2009: U.S. Stimulus Plan to increase Funding for Protection of Public Health

The $787 billion economic recovery plan signed by President Obama targeted to create 3 to 4 million quality, sustainable jobs with many protecting public health and the environment.

The American Recovery and Reinvestment Act of 2009 (ARRA) specifically includes $7.22B for drinking water and wastewater infrastructure programs administered by EPA. These programs will protect and promote both green jobs and a healthier environment.

Following a number of revisions, the final $787 billion package of tax cuts and government spending includes significant emergency funding for public works infrastructure, including over $7 billion for drinking water and wastewater projects. The U.S. Environmental Protection Agency's (EPA) clean water and drinking water state revolving fund (SRF) programs will receive $6 billion, including $4 billion for the clean water SRF and $2 billion for the drinking water SRF. In addition, the USDA Rural Water and Waste Disposal program will receive $1.38 billion for loans and grants.

According to recent analysis from the McIlvaine Company, the ARRA could fast track 400 wastewater projects valued at $6 billion which otherwise would have remained on hold due to lack of funding.

Additionally, following passage of HR 1, the American Recovery and Reinvestment Act (ARRA) by the House and Senate, the Water Environment Federation (WEF) started advising local and state government officials on next steps for securing and distributing the newly awarded stimulus funds for wastewater projects.

"Although this investment is just a small portion of the estimated $500 billion funding shortfall for water infrastructure over the next 20 years, WEF believes this package will help bridge the funding gap and generate thousands of construction, manufacturing, and engineering jobs across the country," said Tim Williams, WEF's Director of Government Affairs.

As next steps, WEF is encouraging local government officials to contact their state clean water or drinking water program or the state revolving fund program managers to make sure that any projects they would like to have funded are on the state's priority list. Many states have already sent letters to municipalities outlining the process or contingency plans they are developing for awarding stimulus monies.

The stimulus funding will be distributed through the State Revolving Loan programs. States are required to give priority in funding to projects that are ready to proceed to construction within 12 months. The stimulus bill will penalize states that don't put the federal money to work -- monies that are not under contract or construction within 12 months will be reallocated to other states.

To help get things moving, the stimulus bill waives the 20 percent state matching requirement for SRF projects, and directs states to use not less than 50 percent of their capitalization grants for "additional subsidization" assistance, such as principal forgiveness, negative interest loans, or grants.

The bill requires that up to 20 percent of SRF stimulus monies be used for projects to address green infrastructure, water and/or energy efficiency, innovative water quality improvements, decentralized wastewater treatment, stormwater runoff mitigation, and water conservation.

4 March 2009: Research on Emerging Contaminants continues with Statement that Levels of Trace Pharmaceuticals in Drinking Water Too Low to Impact Human Health According to Water Research Foundation Study

http://www.waterresearchfoundation.org/theFoundation/ourPrograms/ResearchProgramSIEDCPPCP.aspx

The Water Research Foundation, a leading U.S. drinking water research organization stated, "The concentrations of pharmaceutical drugs and endocrine-disrupting compounds found in our public drinking water are likely too low to impact human health". Endocrine-disrupting compounds (EDCs) encompass a variety of chemical classes, including hormones, plant constituents (phytoestrogens), pesticides, compounds used in the plastics industry and in consumer products, and other industrial by-products.

There is growing public attention and concern about the possibility of health effects from trace amounts of EDCs and drugs that are flushed down the toilet or enter the water supply through human and livestock waste. The Water Research Foundation report examined not only the presence of trace levels of EDCs and drugs in water, but explored if there is a potential link between the levels of these compounds found in water and effects on human health.

The report, titled Toxicological Relevance of Endocrine Disruptors and Pharmaceuticals in Drinking Water, concludes three years of research in collaboration with 17 water utilities. "Even the most advanced treatment processes that we've studied won't achieve an absolute zero level of contaminants," said study researcher Shane Snyder, Ph.D., research and development project manager for Southern Nevada Water Authority. "Therefore, it's vital that we look at the real risks before we spend a tremendous amount of resources on the issue."

The study's objective was to inform water utilities, regulators, scientists, and the public about the occurrence and potential human health relevance of pharmaceuticals and EDCs in drinking water.

3 February, 2009: California State Water Board Adopts Recycled Water Policy

http://www.swrcb.ca.gov/water_issues/programs/water_recycling_policy/.

California's State Water Resources Control Board adopted a statewide "Recycled Water Policy" on February 3, 2009, to establish uniform requirements for the use of recycled water.

The purpose of the Recycled Water Policy is to increase the use of recycled water from municipal wastewater sources. When used in compliance with the Recycled Water Policy, Title 22, and all applicable state and federal water quality laws, recycled water is considered by the State Water Board as safe for approved uses and as a safe alternative to potable water for such approved uses.

The Policy is intended to provide direction to the Regional Water Quality Control Boards, agencies with recycled water projects, and the public on the appropriate criteria to be used by the State Water Board and Regional Water Boards in issuing permits for recycled water projects.

Continued on page 12

HOT UV NEWS

Continued from page 11

23 January 2009: More Cities Considering Wastewater Reclamation to Tap Water during time of drought

http://www3.signonsandiego.com/stories/2009/jan/23/1m23reclaim23151-wastewater-tap-water/?zIndex=41716

Escondido, California is considering reclaiming wastewater for use as drinking water to augment its water supply. In addition, the inland city stands to save hundreds of millions of dollars by avoiding upgrades to its sewage treatment plant and an ocean outfall pipe if the plan succeeds.

Escondido conducting a feasibility study at the Helix Water District, which serves parts of East County, and the city of San Diego in considering the contentious idea, sometimes derided as "toilet to tap."

The Helix board has approved an $80 million project in hopes of supplying 12 to 15 percent of the district's drinking water. An environmental review is being conducted.

The city of San Diego has temporarily increased water rates to help pay for an $11.8 million demonstration project at the North City Reclamation Plant at Eastgate Mall in University City. But San Diego's demonstration project has faced protests. Opponents cited national studies indicating that reclaimed water can contain minute traces of hormones, drugs and chemicals, some of which are carcinogenic.

"If it's made clean enough and safe enough to drink, I wouldn't be opposed to it," Councilwoman Olga Diaz said.

Escondido's utilities director, Lori Vereker, said the reclamation project would be similar to Orange County's, which uses a three-step purifying process to produce what she calls "ultra-pure" water.

"In Orange County, the water is first cleaned to a standard fit for irrigation, and then put through reverse osmosis to remove salt. Finally, it is treated with ultraviolet light and hydrogen peroxide to kill any remaining bacteria, said Shivaji Deshmukh, program manager for the Groundwater Replenishment system of the Orange County Water District. Tests have shown that the product is cleaner than drinking water from the Colorado River, which has treated wastewater dumped into it by cities along its path", he said..

Escondido's project would be governed by state regulations now being drafted to ensure the safe use of reclaimed water for drinking, a state Department of Public Health official said.

By reusing all of the city's wastewater, cash-strapped Escondido also could avoid upgrading its aging wastewater treatment plant and spending $300 million to increase the size of an outfall pipe used to discharge treated wastewater into the ocean, Vereker said. Both the plant and the pipe are nearing capacity.

21 January 2009: U.S. EPA honors Orange County for innovative groundwater management / Water district receives "Pisces" award for wastewater and drinking water projects

http://yosemite.epa.gov/opa/admpress.nsf/2dd7f669225439b78525735900400c31/4330f220f16a6337852575450066299 6!OpenDocument

The U.S. Environmental Protection Agency honored the Orange County Water District with its 2008 Clean Water State Revolving Fund "Pisces" award, which recognizes projects that advance clean and safe water through exceptional planning, management, and financing.

"The EPA recognizes the Orange County Water District for its foresight and dedication in providing a locally controlled, drought-resistant water supply to serve over 500,000 residents," said Alexis Strauss, director of the Water Division for the EPA's Pacific Southwest region. "Projects such as this provide clean safe water at a cost lower than imported supplies without sacrificing water quality."

"The Orange County Water District deserves recognition for their superior work in demonstrating an innovative approach to project implementation with groundwater replenishment," said Tam M. Doduc, Chair, State Water Resources Control Board.

The Orange County Water District supplies water to more than 20 cities and water agencies, serving more than 2.3 million Orange County residents.

Thanks to a partnership with the Orange County Sanitation District, and the use of microfiltration, reverse osmosis and advanced oxidation processes, the award-winning project treats clarified secondary effluent – which would have been discharged into the Pacific Ocean – into water exceeding all federal and state water regulations.

This processed water is pumped into injection wells and recharge basins, where the water naturally percolates into the ground and blends with Orange County's other sources of groundwater.

Nationally, the EPA's Clean Water State Revolving Fund program has provided more that $63 billion dollars funding projects for wastewater treatment, nonpoint source pollution control, watershed and estuary management, and energy and water sustainability projects.

12 January 2009: Research names top 11 compounds in tap water http://www.newscientist.com/article/dn16397-top-11-compounds-in-us-drinking-water.html

New research has identified the 11 most frequently detected pharmaceutical and hormonally active chemical compounds in the drinking water of 19 US water utilities. Researchers Shane Snyder and colleagues at the Southern Nevada Water Authority in Las Vegas screened tap water from 19 US water utilities for 51 different compounds. The research, which is scheduled to appear in the next issue of the journal Environmental Science & Technology, indicates that all of the 11 most frequently detected compounds were found at extremely low concentrations.

According to the NewScientist.com article, the 11 most frequently detected compounds were:

- Atenolol, a beta-blocker used to treat cardiovascular disease
- Atrazine, an organic herbicide banned in the European Union but still used in the United States, which has been implicated in the decline of fish stocks and in changes in animal behavior
- Carbamazepine, a mood-stabilizing drug used to treat bipolar disorder, among other things
- Estrone, an oestrogen hormone secreted by the ovaries and blamed for causing gender-bending changes in fish
- Gemfibrozil, an anti-cholesterol drug
- Meprobamate, a tranquilizer used in psychiatric treatment
- Naproxen, a painkiller and anti-inflammatory linked to increases in asthma incidence
- Phenytoin, an anticonvulsant that has been used to treat epilepsy
- Sulfamethoxazole, an antibiotic used against the Streptococcus bacteria, which is responsible for tonsillitis and other diseases
- TCEP, a reducing agent used in molecular biology
- Trimethoprim, an antibiotic.

Christian Daughton, Ph.D., of the US Environmental Protection Agency's (EPA) National Exposure Research Laboratory, said in the report that neither this nor other recent water assessments give cause for health concern. He added, "But several point to the potential for risk — especially for the fetus and those with severely compromised health."

APPLICATION NOTE

Editor's Note: UV companies are welcome to submit "Application Notes" for this column. We also request comments on Applications Notes and Articles. Send either to paul.overbeck@iuva.org

UV IN AQUATICS: WELLNESS FOR THE NOSE - BREAKDOWN OF CHLORAMINES IN PUBLIC BATHS

from **Heraeus Noblelight, Hanau, Germany** www.heraeus-noblelight.com

Humans love to relax and soak the body and soul in warm water and loose the cares of the day in the whirlpool. Now, imagine the happy sounds of children on the water slide and seeing the really small splash about gleefully in comfortably warm baby pools. Today, modern public baths are often much more than pure sports facilities, they are places for relaxation and well-being for big and small alike. The typical swimming pool chlorine smell, which formerly used to sting our nose when we entered the swimming pool, along with the red and irritated eyes of children, are no longer in tune with the wellness concept of modern swimming centres.

CHLORAMINES AS TRIGGERS

Chlorine is routinely used for disinfection in public baths. The classic disinfection mechanism cannot be completely substituted, as with other solutions the high disinfection power and the necessary germ killing speed cannot be achieved. In the on-going operation of baths using chlorine, chloramines such as NH2Cl (Monochloramin) are produced as by-products of the disinfection process through free chlorine and reactions with substances such as skin shedding into the pool water. These chloramines, also known as "combined chlorine", are responsible for the typical swimming bath smells and irritation of the eyes and the mucous membranes under contact with the water. The concentration of the chloramines is dependent on several factors: water temperature, pool temperature, number of bathers and their level of activity and the process of water treatment. Theoretically, the greater the number of bathers, the greater their level of activity, the higher the water temperature and the smaller the pool size created higher chloramine levels. The upper limit of combined chlorine is given in German DIN 19643 at 0.2 mg per litre (mg/L).

Fig. 1: *The Chlorominator uses modern UV technology to break down chloramines photochemically and disinfect swimming pool water. (Copyright: Grünbeck GmbH, Höchstädt/Donau, Germany)*

Fig. 2: *Example of a 400 Watt UV medium pressure lamp (Copyright: Heraeus Noblelight GmbH, Hanau, Germany)*

PHOTOCHEMICAL REACTION WITH UV RADIATION

One good option for reducing the concentration of disinfection by-products in the water circuit is the so-called Chlorominator from the water treatment specialist Grünbeck in Höchstädt an der Donau. In this system, the combined chlorine is broken down photochemically. With the help of "high energy" UV emitters, the molecular bonds of the chloramines are broken, resulting in harmless substances such as chloride and nitrogen. In practice, the system consists essentially of a pressure tube with two overlapping UV irradiation zones. In the influent zone, according to the capacity of the system, there are up to six 400 Watt UV medium pressure lamps from the specialist light source manufacturer Heraeus Noblelight. Because of the polychromatic lamp spectrum in the UV-C spectral range from 200 to 280 nm, which is effective for the application, and because of a specific electrical emitter power of more than 45 W/cm, the UV lamps break the chloramines molecular bonds and so destroy the combined chlorine in the bath water (Add Fig. 3). As this process relies exclusively on the application of UV technology and requires no additional substances, the chloramines destruction is extremely environmentally friendly. Virtually all of the heat generated is fed to the bath water and this makes the process

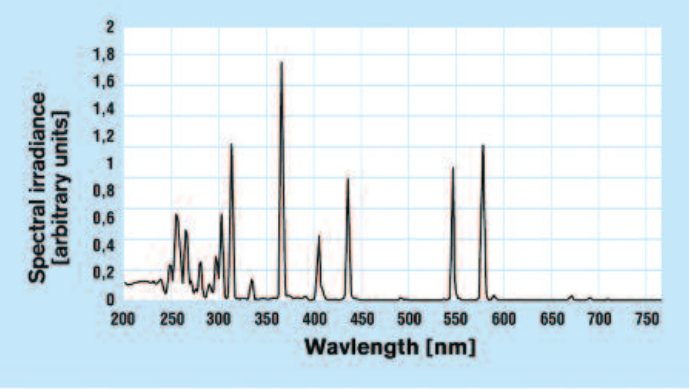

Fig. 3: *Typical polychromatic lamp spectrum of UV medium pressure lamps. (Copyright: Heraeus Noblelight GmbH, Hanau, Germany)*

energy-efficient and economical. The high radiation flux of the UV medium pressure lamps allows the construction of compact water treatment systems. Specifically, the 400 Watt UV medium pressure lamps are only 140 mm in length with a diameter of around 16 mm.

UV TECHNOLOGY REDUCES THE USE OF CHLORINE.

As well as destroying chloramines, the use of UV lamps also allows for a reduction in the amount of chlorine required. The treatment of water with UV radiation is a very effective physical process for the disinfection of water and the destruction of pollutants. "High energy" UVC radiation in the range 200 to 280 nm is very effective at destroying the bonds of the DNA helix. This means that UV radiation inactivates in seconds the cells of pathogens such as viruses, bacteria and microbes which can be present in water. These same pathogens are also unable to develop a resistance against UV light at dechloramination dosage. Consequently, the germ count in the swimming bath water can be reliably reduced and there is need for less chlorine.

To further increase this effect, the Chlorominator also features up to 12 Heraeus Noblelight low pressure Amalgam lamps as well as the UV medium pressure lamps and these are located in the outlet of the irradiation chamber. With their quasi- monochromatic spectrum of 254 nm and high efficiency of around 35%, they are well suited to disinfection of the water in swimming baths Compared with conventional mercury low pressure lamps of the same geometry, Amalgam lamps offer significantly greater power. While mercury low pressure lamps typically have a specific electrical power of 0.3 to 0.5 W/cm of illuminated length, Amalgam lamps approach 6 W/cm. The reason for this is the different pressure/temperature ratio. Mercury low pressure lamps achieve their optimal mercury vapour pressure of 0.8 Pa, and hence their maximum UVC output, at around 40°C. Increasing or reducing the temperature by increasing or reducing the electrical input power only leads to a reduced UVC output. The Amalgam lamp also reaches its optimum vapour pressure at 0.8 Pa, but this is at a corresponding temperature of 90 - 130°C (dependent on model). This higher temperature level is responsible for the higher specific electrical power of the Amalgam lamp and thus for its higher UVC output per centimetre of illuminated length. This means that Amalgam lamps are much more compact than mercury lamps of the same output. Consequently system builders can scale down their equipment, as they need fewer lamps and casings and hence less space. A smaller number of power supply units is also another area of potential saving.

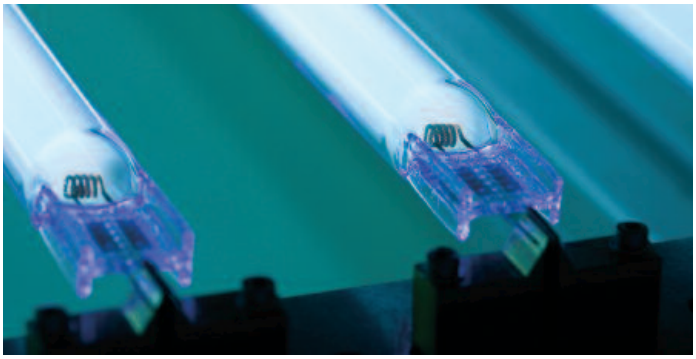

Fig. 4: *Amalgam low pressure lamps are very effective in killing viruses, bacteria and pathogens in swimming pool water. (Copyright: Heraeus Noblelight GmbH, Hanau, Germany)*

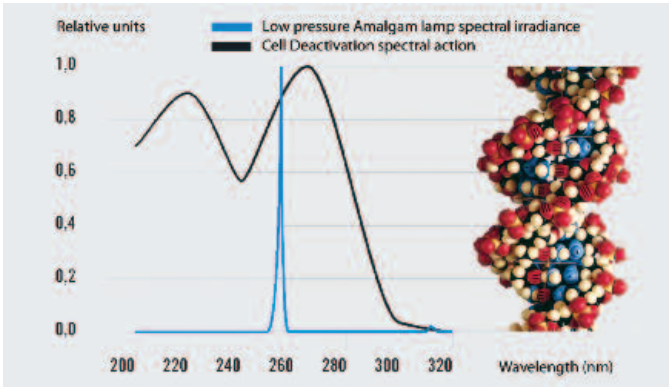

Fig. 5: *254nm spectrum of a UV Amalgam lamp and an effective spectrum for killing bacteria (e-coli as in DIN 1031 Part 10). (Copyright: Heraeus Noblelight GmbH, Hanau, Germany)*

CASE STUDY

The Chlorominator, with its advanced UV technology, is already being used in a large number of swimming bath installations. Recently, the newly built spa centre at Bad Liebenstein in Thuringia, Germany received two Chlorominators. This new spa will be opened in Spring 2009. Amongst other things, it offers a swimming pool, specialty showers, a sauna suite with ice tubs and immersion pools and relaxation baths using the local spa water. Here the oldest spa and curative bath in Thuringia, (the healing and curative effect of the water from the Casimir spring has been acknowledged since 1601) is now using modern water treatment with UV technology. Medium pressure and Amalgam low pressure lamps reduce the chloramines in the water and help water disinfection, so that the users of the facilities can safely and peacefully relax, from top to toe, and already start to look forward to their next visit.

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UV Disinfection in Moscow Metro Public Transport Systems

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ABSTRACT

Growing concerns about the hygienic situation and air contamination in the often heavily populated Moscow Metro underground railway system were reason to investigate the effects of UV disinfection on the internal surfaces of train carriages, escalator handrails and the air in passage ways and platforms of railway stations. The adequate UV doses to inactivate micro-organisms and parasites were determined for all three situations.

The required UV doses to disinfect the surfaces of carriage interiors and handrails were much higher than expected, due to the fact that micro-organisms are embedded and protected against UV by layers mainly consisting of proteins. Devices, providing high UV irradiances, equipped with Low Pressure High Output (LPHO) mercury amalgam lamps were introduced to meet the requirements.

Key words: UV disinfection; Public transport; Air disinfection; Surface disinfection; Amalgam UV lamps.

INTRODUCTION

During the last fifteen years, UV disinfection has rapidly gained popularity for water and air treatment. The advantages are well illustrated in the mean time. No chemicals are added, the reaction time is very short and the method does not alter smell or taste. Ultraviolet radiation is very effective to inactivate air or waterborne pathogens, viruses, but also pathogens like Cryptosporidium, due to the high absorption of DNA for UV radiation. UV-C radiation damages the DNA of micro-organisms, destroying their ability to replicate and thus rendering them non-infectious.

The Moscow Metro is one of the oldest and, with up to 9 million passengers per day, one of the most frequently used underground train systems in the world. Growing concerns over deteriorating indoor air quality and possible cross-infections via airborne micro-organisms or indirect contacts induced Moscow authorities to introduce effective and permanent solutions.

1.1 AIR AND SURFACE TREATMENT

Indoor air in offices, factories, homes hospitals and other public buildings is trapped, often re-circulated and always full of contaminants such as bacteria, viruses and moulds. Most people live and work in buildings which are sealed as much as possible to preserve energy. The indoor environment is controlled by automated heating, air-conditioning and ventilation. Microbial contamination plays an important role in the health problems, related to these environments.

This was reason for intensive investigations for the effect of disinfection of air and surfaces by UV radiation. The wealth of research reports which have been published over the last 100 years provided the basis to show that ultraviolet germicidal irradiation decreases the concentration of airborne organisms in buildings. Some infectious agents that affect human respiratory systems and that are susceptible to UV radiation are tuberculosis, measles, adenovirus and smallpox.

LIT Technologies and the Russian Research Institute of Railway Hygiene have teamed up to investigate the possibilities of UVGI (Ultraviolet Germicidal Irradiance) in a few distinct areas:

- Internal surfaces of train carriages
- Escalator hand rails
- Air in passage ways and platforms in railway stations

The adequate UV doses to inactivate micro-organisms and pathogens were determined for all three typical situations.

2. SURFACE TREATMENT

Attempts to eliminate surface contaminates from railway carriages range from antiseptic swaps to fumigation. Such methods are time consuming, hazardous and environmentally unwise. The UVGI process would be much simpler. It was found however, that micro-organisms on surfaces are always embedded in and shielded by protective layers of proteins.

Aromatic amino acids are the main agents causing UV absorption between 220 and 280 nm. Around 254 nm (the optimum UVGI efficiency wavelength), the absorption is determined by sulfhydryl (–SH) and disulfate (–SS–) groups of cysteine/cystine proteins.

Apart from the media in which the target micro-organisms are hidden, also the type and structure of typical interior components like imitation-leather seats, linoleum, rubber escalator hand rails, as well as glass and metal surfaces have a strong influence. As fig. 1 demonstrates the uneven relief structure of rubber (a) and linoleum (b) will create shadows for the UV radiation; the overall UVGI efficiency will drop.

a) b)

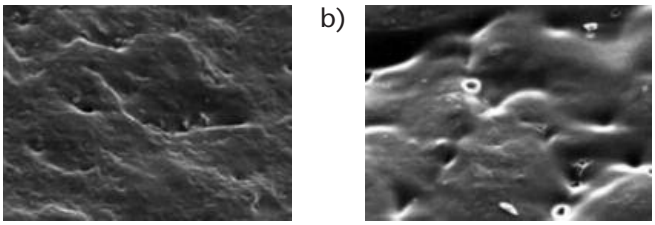

Figure 1. *Microstructure of surface of rubber (a) and linoleum (b)*

In-vitro tests were carried out at the Russian Scientific Research Institute of Railway Hygiene, to establish lethal UV doses. Target micro-organisms were immersed in protein-containing media, modelled after real-life Moscow Metro conditions.

Figure 2 represents the medium UV transmittance factor at 253.7 nm versus concentration levels in distilled water (V_{pm}/V_{dw} - ratio of protein content in the medium and distilled water).

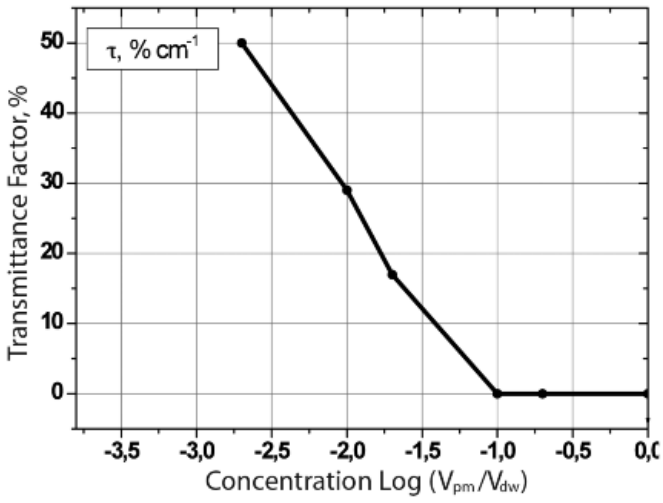

Figure 2. *Experimental UVT (at 253,7 nm) of protective protein medium vs. Distilled water concentration levels.*

The *Staphylococcus aureus* (strain 906) organism was used for the tests. Imitation leather, rubber and plastic were used as test surfaces. Figure 3 shows the UVGI disinfection efficiency for the test culture in a protective protein environment on rubber. It also represents the reference values of UVGI doses for *Staphylococcus aureus* in "ideal laboratory conditions".

Relevant, frequently touched surfaces in the metro system may be contaminated up to 1000 CFU/cm^2. It required 300-450 J/m^2 to achieve a disinfection rate of more than 90%. This is 5 to 10 times higher than in ideal situations.

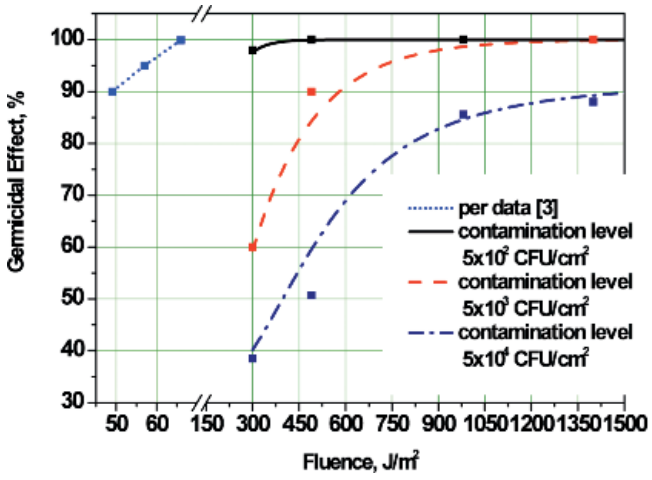

Figure 3. *UV effectiveness vs. Initial seeding densities of protein-protected test-culture of St. aureus on rubber surfaces.*

Yet higher UV doses are required to inactivate pathogens such as viable ascaride eggs *(Ascaris suum)*, pinworms *(Enterobius vermicularis)* and lamblia cysts *(Lamblia (Giardia) intestinalis)*. During the tests these microorganisms were placed on typical test surfaces such as imitation leather, plastic, wood, chrome plated metal, rubber, and glass. Various UV doses at 253.7 nm were used to disinfect the microorganisms. The type of materials influences the effectiveness of UVGI disinfection to a great extent. Figure 4 shows the relative dependency of the UV dose versus the type of surface.

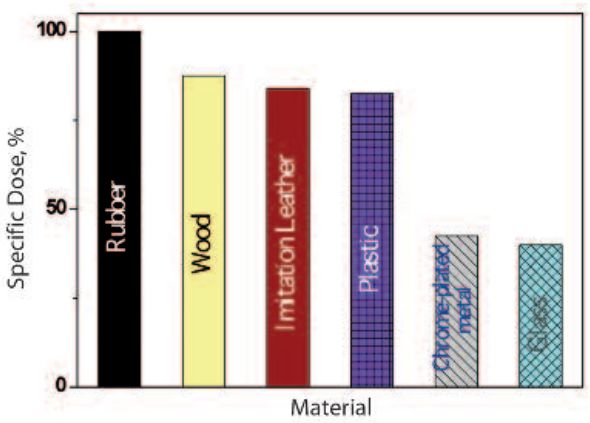

Figure 4. ***Relative changes in UV doses providing 90% inactivation in test pathogens vs. type of surface.***

Black rubber escalator handrail surface and window seals in train carriages require a two times higher dose for the same disinfection rate than required for glass and metals. Plastic, wood, and imitation leather score values in-between. To define the required UV doses in the Metro system, we will refer to the UV doses for inactivation of microorganisms on black rubber surfaces.

Figure 5 represents the inactivation efficiency of UVGI for 3 pathogens on black rubber surfaces.

For 99% disinfection, the required UV dose was established to be 4500 J/m^2.

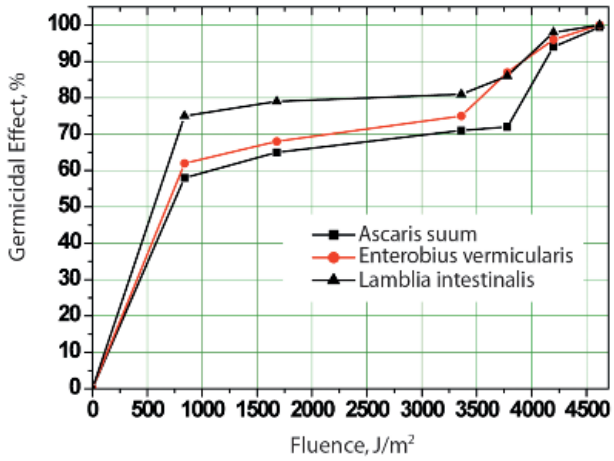

Figure 5. ***Germicidal UV effectiveness for three pathogens on black rubber surfaces.***

After the first stage of the research program it became clear that it is possible to employ UVGI technology to effectively disinfect relevant surfaces of the metro interior. However, the required UV doses are very much higher than expected on theoretical grounds. Practically, it is not possible to use conventional UV equipment low pressure mercury UV lamps. The energy efficiency of medium pressure lamps was considered to be too low. LIT Technology developed a series of straight and U-shaped LPHO "Amalgam" UV lamps, coated on the inside to restrict UV depreciation, tailored especially for Metro disinfection applications.

2.1 AMALGAM UV LAMPS

Low pressure mercury lamps are very attractive due to their extremely good UV efficiency, but their output, specified as UV-watts per unit of length, is very low. Increasing the specific UV output by increasing the lamp power will increase the lamp temperature, hence the (saturated) mercury pressure in the lamp; the UV efficiency will drop progressively.

It is a well-known fact that the mercury pressure can be decreased spectacularly by applying certain alloys, which combine with mercury to form so-called amalgams. In practice, this means that higher bulb temperatures are allowed and that the lamps can be "overpowered". Instead of the standard low pressure mercury lamp currents of up to 800 mA, now typical currents up to 4000 mA are possible. An additional advantage is that, in accidental case that the lamp breaks, no liquid mercury is released. The saturated mercury pressure at room temperature above the amalgam is much lower than above metallic mercury.

It goes without saying that the relevant lamp components have to be adapted to the higher power setting. Especially the choice of electrodes and inert gas filling plays an important role for the conservation of lamp efficiency and lamp life. Neon additions to the standard Argon filling gas determine the lamp power, judiciously keeping an eye on lamp life, typically between 10.000 and 15.000 hours.

Quite a few potential amalgams, each with their typical temperature requirements, are available. The tertiary type InAgHg, applicable with bulb wall temperatures between 115 and 140 ˚C is popular for lamps, ranging between 200 and 400 W. Four- and five component amalgams broaden the possible temperature area, allowing amalgam lamps to be used in a wide variation of temperatures and applications like UV air and surface treatment. Such lamps can be regulated in a wide variation of lamp powers.

2.2 SURFACE DISINFECTION OF CARRIAGE INTERIORS IN PRACTICE

A special trolley was developed to disinfect the air and surfaces in metro train carriages, incorporating two 170 W U-shaped amalgam lamps and equipped with a timer, to shut off the system after disinfection (Figure 6.).

Figure 6. *UV system for interior disinfection, with two U-shaped 170 W UV lamps.*

A series of experiments were carried out, aimed to reveal the impact of UV irradiation on materials used in the metro carriages. Four different materials were tested: imitation leather used for seats in carriages, plastic used for carriage floors, imitation-wood plastic for the walls and coated tin plates used for the carriage ceilings.

The samples were treated with a UV dose of 3.7 x 10^6 J/m^2, which effectively corresponds to 514 UVGI cycles with a maximum calculated dose of 7200 J/m^2.The tests revealed no physical or chemical changes in materials. It can be concluded that the materials tested showed a high resistance to UV irradiation.

Another series of tests revealed that no harmful chemical compounds or odors were formed by UV irradiation (Table I).

Table I. *CHEMICAL ANALYSIS RESULTS OF AIR IN METRO CARRIAGES PRIOR TO AND AFTER 25-MINUTE UV TREATMENT USING UOP VOZUF-170-P-2 (2 * 170W) LIT SYSTEM, WITHOUT VENTILATION.*

No	Chemical	Chemical concentrations								
		Max contaminant level, (MCL) mg/m3	Carriage No.1 before UV	MCL compliance	Carriage No.1 after UV	MCL compliance	Carriage No.2 before UV	MCL compliance	Carriage No.2 after UV	MCL compliance
1.	Benzol	0,300	0,057	yes	no	yes	0,035	yes	no	yes
2.	Xylol	0,200	1,680	no	no	yes	0,481	no	no	yes
3.	Ethyl benzol	0,020	0,441	no	0,249	no	0,246	no	no	yes
4.	Ethyl acetate	0,100	1,53	no	0,310	no	0,631	no	no	yes
5.	Styrol	0,040	0,279	no	no	yes	0,121	no	no	yes
6.	Toluol	0,600	1,11	no	0,653	no	0,320	yes	no	yes
7.	Phenol	0,01	no	yes	no	yes	no	yes	no	yes
8.	Formaldehyde	0,035	0,001	yes	0,001	yes	no	yes	no	yes
9.	Methyl-metacrylat	0,100	0,016	yes	no	yes	0,008	yes	no	yes
10.	M-cresol	0,005	0,025	no	0,021	no	0,009	no	no	yes
11.	Vinyl-chloride	0,01*	0,002	yes	no	yes	0,001	yes	no	yes
12.	Acrolein	0,03	0,054	no	0,017	yes	0,015	yes	0,011	yes
13.	Acetone	0,35	3,63	no	1,21	no	1,99	no	no	yes
14.	Ammonia	0,20	0,045	yes	0,052	yes	0,120	yes	0,122	yes
15.	Ozone	0,16	no	yes	0,15	yes	no	yes	0,14	yes

* Average daily concentration was taken as peak concentration value was not available

The effect of UV irradiation on disinfection of train carriage surfaces was established by practical examples. Overall microbial contamination levels as well as concentrations of the test-culture S. aureus (strain 906) were measured before and after administering doses of UV radiation, by means of the imprint method. See table II

Table II

#	Sampling area		Contamination, CFU/100 cm^2		
			Surface contamination prior to UV	**After UV treatment**	**reduction (%)**
Irradiation cycle - 21 min, UV dose -4025-4600 J/m^2 for seats; -5750-7475 J/m^2 for the backs of the seats					
1	Left end of the carriage	seat	1 x l0^3	30	99,7
2		back	8 x 10^2	20	97,5
3	Middle of the carriage	seat	1 x 10^3	8	99,2
4		back	8 x 10^2	40	95
5		seat	1 x 10^2	8	92,0
6		back	5 x 10^2	4	92,8
7	Right end of the carriage	seat	8 x 10^2	4	95,0
8		back	8 x 10^2	4	99,5
Irradiation cycle - 15 min UV dose -2625-3000 J/m^2 for seats; -5750-7475 J/m^2 for the backs of the seats					
1	Left end of the carriage	seat	1 x 10^2	4	96,0
2		back	8 x 10^2	16	98,0
3	Middle of the carriage	seat	1 x 10^3	24	97,6
4		back	2 x 10^2	16	92
5	Right end of the carriage	seat	8 x 10^2	32	96
6		back	8 x 10^1 - 8 x 10^2	0	100,0
Irradiation cycle –6 min UV dose - 1 155-1320 J/m^2 for seats; - 1650-2145 J/m^2 for the backs of the seats					
1	Left end of the carriage	seat	8 x 10^2	2 x 10^2	Non disinfected
3	Middle of the carriage	seat	5 x 10^2	2 x 10^2	Non disinfected
5	Right end of the carriage	seat	8 x 10^2	1 x 10^3	Non disinfected
Irradiation cycle - 3 min UV dose - 190-216 J/m^2 for seats; 270-350 J/m^2 for the backs of the seats					
1	Left end of the carriage	seat	1 x 10^2	1 x 10^2	Non disinfected
2		back	2 x 10^2	2 x 10^2	
3	Middle of the carriage	seat	1 x 10^2	1 x 10^2	
4		back	2 x 10^2	2 x 10^2	
5	Right end of the carriage	seat	1 x 10^2	1 x 10^2	

The results confirmed the germicidal effectiveness of the applied UV treatment.

Train interiors are at present regularly exposed to 25 minute doses of UV-C. Key benefits of this operation are a reduced amount of chemicals used, time and labor costs savings and an improved environment within the metro depot. Figure 7 shows a few pictures of UV disinfection systems in operation at the "Kaluzhskoe" metro depot.

Figure 7. *UV disinfection in operation*

2.3 DISINFECTION OF ESCALATOR HANDRAILS

Another UV system, with again two LIT U-shaped amalgam 170W lamps, was developed to disinfect the surfaces of escalator handrails automatically. (See Figure 8.)

It was established through a series of tests on these handrails that it takes an exposure time of only 10 seconds under two lamps of 170 W to achieve 99 % disinfection.

Figure 8. *UV system mounted on a handrail return stretch at the "Kitai-Gorod" metro station.*

3. IMPROVEMENT OF AIR QUALITY

Three different principles of UV air treatment have proven their effect these days.

- Closed, stand-alone devices, recycling the air in occupied spaces via well-selected types of UV germicidal lamps provide a simple way to improve the indoor air quality. They dilute the microbial contaminant concentration and act in principle similar to extra ventilation, in a controlled and very efficient way. Such units, which may range in capacity from 150 till 20.000 m^3 per hour, are easy to install and do not harm people or affect furniture and surroundings.
- UV segments, incorporated in air ducts, decrease the concentration of airborne pathogens and protect against microbial pollution via the incoming air inlets. These UV units are available in the most popular geometrical duct sizes. Typical capacities are between 3.000 and 35.000 m^3 per hour.
- Air conditioning cooling coils are almost always wet and dusty and thus serve as ideal breeding grounds for moulds. Coil irradiation with UV drastically reduces or prohibits growth of these moulds. At the same time heat exchange efficiency is improved and the pressure drops decrease.

The air quality in often heavily populated underground railway stations forms a constant source of concern. The Moscow Metro is one of the oldest and, with up to 9 million passengers per day, one of the most frequently used underground train systems in the world. Growing concerns over deteriorating indoor air quality and possible cross-infections via airborne micro-organisms or indirect contacts induced Moscow authorities to introduce effective and permanent solutions.

Powerful UV disinfection air re-circulators with a capacity of 400 m^3/h were developed to be mounted in the underground premises. These systems allow for UV disinfection to be carried out with people inside the facility, for a 24/7 operation. Figure 9 shows how a re-circulator of type AR-UF-170P-2 (with two 170W lamps inside) is mounted in a passenger passage connecting two Moscow metro stations "Paveletskaya-Radial'naya" and "Paveletskaya-Koltsevaya".

Figure 9. ***Recirculator AR-UF-170-2 mounted in the passage between "Paveletskaya-Radial'naya" and Paveletskaya-Koltsevaya".***

One re-circulator of type AR-UF-170-2 with a capacity of 400 m^3/h is used for every 80 m2 of the passages and platforms. The 1260 square meter passage of the "Paveletskaya" metro station was equipped with 16 of these UV re-circulators. The air contamination during peak passenger hours was reduced on average by a factor 2,5.

4. CONCLUSIONS

By means of both laboratory and field tests, the feasibility of UV disinfection for the Moscow Metro system was proven. New generations of UV equipment, fitted with effective LPHO amalgam lamps, were developed for the occasion. The microbial air quality was improved. Replacing labor sensitive, hazardous and environmentally unfriendly disinfection methods, Moscow Metro was glad to embrace the new technology. Introduction of LIT UV systems will provide an extra and reliable barrier for infectious diseases in Moscow's congested public transport system.

Key words:

UV disinfection; Public transport; Air disinfection; Surface disinfection; Amalgam UV lamps

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UV/H2O2 Treatment of Drinking Water: Impacts on NOM Characteristics

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ABSTRACT

The impact of ultraviolet/hydrogen peroxide (UV/H_2O_2) advanced oxidation process (AOP) on natural organic matter (NOM) was evaluated. Operating conditions were selected based on those feasible for commercial drinking water applications. Results showed that at fluences less than or equal to 2000 mJ/cm^2 and initial H_2O_2 concentrations less than or equal to 15 mg/L NOM was not completely mineralized. Yet, UV/H_2O_2 partially oxidized NOM leading to the breakdown of aromatic structures. UV/H_2O_2 preferentially reacted with high molecular weight species leading the formation of lower molecular weight species. Formed low molecular compounds included aldehydes, which increased by up to 7 times from the concentration present in untreated water.

Key words: UV/H_2O_2; natural organic matter; advanced oxidation; drinking water treatment

INTRODUCTION

Ultraviolet (UV) based advanced oxidation processes (AOPs) are increasingly being considered as effective alternatives for the removal of organic compounds in water and wastewater. In drinking water, the ultraviolet/hydrogen peroxide (UV/H_2O_2) AOP has already been applied commercially for the removal of organic micro-pollutants (Sarathy and Mohseni, 2006) and the number of drinking water applications has been steadily increasing since the dawn of the 21st century. UV/H_2O_2 has been demonstrated to be an effective technology for treating organic micro-pollutants, such as pesticides and taste and odour compounds, and carrying out primary disinfection.

One of the key parameters affecting the performance of UV/H_2O_2 AOP is the presence of natural organic matter (NOM) in source water. NOM scavenges hydroxyl radicals necessary for contaminant degradation, absorbs UV that would otherwise be available for photolysis of H_2O_2, and may undergo changes in structure that could possibly affect the water's biological regrowth potential (BRP) and NOM's potential to form chlorination disinfection by-products (DBPs). Raw surface waters can contain substantial NOM that serves as a precursor to the DBPs (Oliver and Lawrence, 1979). The main DBPs identified in drinking water have been trihalomethanes (THMs) and haloacetic acids (HAAs), which are documented to adversely impact human health (Richardson, 1998).

While much research has focused on developing applications for UV/H_2O_2, little attempt has been made to evaluate the impact of UV/H_2O_2 on NOM. Specifically, the results of hydroxyl radical ($^{\bullet}OH$) reaction with NOM have not garnered much attention. This is of particular importance since NOM plays a critical role in the treatment and distribution of drinking water, contributing to BRP and the formation of DBPs. Past studies have demonstrated that substantial reduction of DBP formation potential (DBP-FP) could be achieved using UV/H_2O_2 (Wang et al., 2000; Kleiser and Frimmel, 2000; Liu et al., 2002; Thomson et al., 2004b; Toor and Mohseni, 2007). But, all these studies mainly focussed on strong advanced oxidation conditions made possible by very long UV exposures (i.e. fluence) and/or high H_2O_2 concentration. Under such conditions NOM is mineralised leading to a reduction in the concentration of NOM. Such operating parameters are not economically feasible when scaled up. Little attempt has been made to evaluate the UV/H_2O_2 impact on NOM under conditions representing large-scale applications, which are not likely to exceed an operating fluence of 2000 mJ/cm^2 and a H_2O_2 concentration of 20 mg/L.

EXPERIMENTAL

Source Water

Water used in all experiments was obtained from the Capilano Reservoir, serving the Greater Vancouver Region, British Columbia, Canada. The damming of the Capilano River, which is fed by fall and winter rain runoff and the spring snowmelt, forms the reservoir. Given the low total organic carbon (TOC) and absorbance of 254 nm UV (A_{254}) (Table I) Capilano water (CW) is a surface water of very high quality and presently undergoes no coagulation/

flocculation or filtration prior to chlorine disinfection. However, high turbidity events do occur during which time the reservoir's supply is shutdown until turbidity levels return to normal (Table I).

Table I. ***Physical and chemical parameters for water originating from Capilano Reservoir during 2005. (source: the GreaterVvancouverWater District Quality Control Annual Report, 2005)***

Parameter	Average	Range
Alkalinity as $CaCO_3$ (mg/L)	2.7	2.1-3.6
Dissolved organic carbon (mg/L)	2.0	1.6-2.7
Total organic carbon (mg/L)	2.0	1.5-2.9
Hardness as $CaCO_3$ (mg/L)	4.10	3.36-4.85
pH	6.5	6.2-6.9
Turbidity (NTU)	1	0.32-5.9
A_{254} (cm^{-1})	0.081	0.055-0.108

UV/H_2O_2 Treatment

A collimated beam apparatus, consisting of low pressure UV lamp (Trojan Technologies, London, ON) positioned 28 cm above a circular stirred reactor chamber was employed for the batch UV/ H_2O_2 studies. The reactor chamber was 3.2 cm in diameter and the water pathlength was 4.66 cm. Samples were irradiated for calculated durations to achieve five different delivered fluences from 0 to 1400 mJ/cm2. H_2O_2 (30%, Fisher Scientific) was added initially to the reactor chamber at the concentrations of 0, 5, 10, 15, and 20 mg/L. Each treatment condition was carried out in duplicate. The entire water sample volume (200 mL) was used for the various analyses described below. H_2O_2 containing samples were quenched of H_2O_2 using 0.2 mg/L bovine liver catalase (Aldrich Canada) prior to A_{254}, TOC, and high performance size exclusion chromatography (HPSEC) measurements and prior to chlorination.

Analytical Methods

Incident UV irradiance of 254 nm light, across the surface of the water ($E_{surface}$), was determined by iodide/iodate actinometry (Rahn, 1997) where potassium iodide (Reagent A.C.S., Fisher Scientific) irradiated by UV led to the formation of triiodide. Potassium iodate (Certified A.C.S., Fisher Scientific) acted as an electron scavenger while sodium borate (Laboratory grade, Fisher Scientific) buffered the reaction at a pH of 9.25 (Rahn, 1997). A radiometer (IL1700, sensor SED240 for 254 nm, International Light Inc.) served as a reference. The fluence rate (E_{avg}) was used to calculate the delivered fluence. Eavg was defined as the product of $E_{surface}$, the reflection factor (RF) equal to 0.975 (Bolton and Linden, 2003), and the water factor (WF) and the divergence factor (DF). WF and DF are based on the water absorbance, path length, and the distance between the lamp and water surface (equations given by Bolton and Linden, 2003).

[1] $E_{avg} = E_{surface} \cdot E_{surface} \cdot WF \cdot DF$

H_2O_2 concentration was measured by reaction with iodide catalyzed by molybdate (Klassen et al., 1994). TOC was measured using a combustion catalytic oxidation/ nondispersive infrared sensor TOC analyzer (Shimadzu TOC-VCPH). Absorbance measurements were determined using a UV-Vis spectrophotometer (Shimadzu UV-Mini 1240) with a cell pathlength of 1 cm.

HPSEC was employed to determine the apparent molecular weight (AMW) distribution of NOM in untreated and treated waters. Following the method described by Pelekani et al. (1999), a Waters 1535 Binary HPLC Pump fitted with a Waters Protein-Pak™ 125 Å column and a Waters 2487 Dual λ Absorbance Detector, set to detection at 260 nm, served as the instrument for HPSEC analysis. The carrier solvent consisted of 0.02 M phosphate buffer (Laboratory grade, Fisher Scientific), at pH 6.8, adjusted with sodium chloride (Certified A.C.S, Fisher Scientific) to 0.1 M ionic strength and the column flowrate was 0.7 mL/min. AMW was correlated to retention time by calibration with polysulfonate standards (7 kDa PSS7K, 4 kDa PSS4K, 2 kDa PSS2K, American Polymer Standards Corporation) and acetone (Certified A.C.S., Fisher Scientific) at a concentration of 1 g/L. HPSEC data were imported into PeakFit which was used for resolution of all

HPSEC chromatograms. The resolved peaks were placed into AMW fractions based on their retention times and then quantified.

Results and Discussion

CW was treated by UV/ H_2O_2 at fluences of 0, 500, 1000, 1500, and 2000 mJ/cm^2 and initial H_2O_2 concentrations close to 0, 5, and 15 mg/L. In the absence of UV, that is only H_2O_2, the concentration and structure of NOM was not significantly altered (data not shown). Thus, H_2O_2 itself has a minimal impact on the oxidation of NOM. Similarly, in the absence of H_2O_2, that is only UV irradiation, NOM did not breakdown by direct photolysis, up to a fluence of 2000 mJ/cm^2 (data not shown). Research conclusively reports that any significant impact of 254 nm UV on NOM begins to be observed at very high fluences (>4,000 mJ/cm^2), which are unfeasible for commercial applications due to energy demand (Thomson et al., 2002a; Thomson et al. 2002b; Parkinson et al., 2003; Buchanan et al., 2004; Thomson et al. 2004a; Thomson et al. 2004b; Buchanan et al., 2005; Buchanan et al., 2006).

Under advanced oxidation conditions, that is a combination of UV and H_2O_2, significant oxidation of NOM was observed. However, this oxidation was not complete since there was no observed decrease in TOC, the concentration of NOM (Figure 1). But, partial oxidation did occur as a reduction in A_{254} was observed, indicating degradation of aromatic species (Figure 2). Aromatic species were further removed as both fluence and initial H_2O_2 concentration increased. As fluence is increased, •OH continue to be generated so aromatic species are degraded further as a result of increased exposure to •OH. As initial H_2O_2 concentration is increased, the steady-state •OH concentration increases (Sharpless and Linden, 2003) so aromatic species are further degraded as a result of increased concentration of •OH.

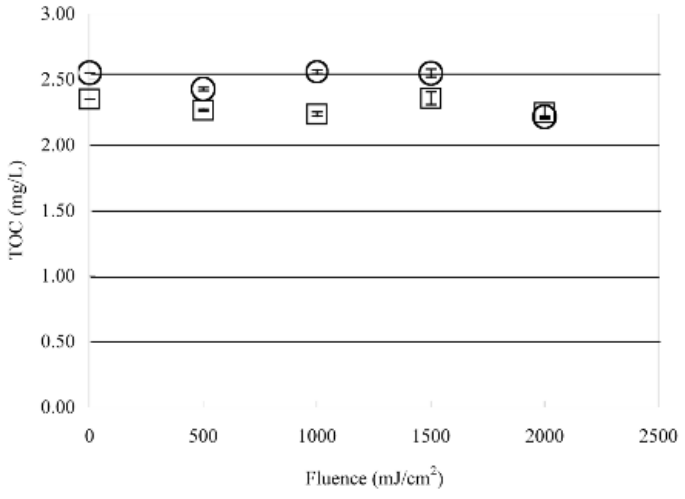

Figure 1. *The impact of fluence and initial H_2O_2 concentrations of 15 (O) and 5 (□) mg/L on TOC. Points represent the average of two samples, each measured three times. Error bars represent the standard deviation between the average measurements for two samples.*

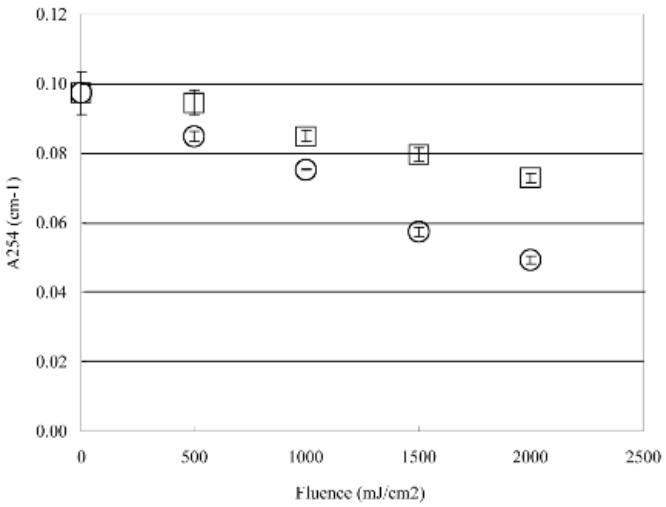

Figure 2. *The impact of fluence and initial H_2O_2 concentrations of 15 (O) and 5 (□) mg/L on A254. Points represent the average of two samples, each measured three times. Error bars represent the standard deviation between the average measurements for two samples.*

The lack of complete oxidation but clear fragmentation of aromatic species suggests that larger NOM was fragmented into smaller species during the UV/H_2O_2 conditions applied. HPSEC was employed to observe the change in AMW distribution of aromatic species. Figure 3 represents the change in AMW of CW treated over a range of fluences at an initial H_2O_2 concentration of 5 mg/L. As the fluence is increased, there is a significant reduction in the highest AMW fraction, >1450 Da, up to a 57% reduction at a fluence of 2000 mJ/cm^2. The next two largest fractions, 1200-1450 Da and 950-1200, also undergo significant reductions but are lower than the reduction seen in the >1450 Da. Moreover, the 950-1200 Da fraction is reduced less than the 1200-1450 a fraction. This suggests that, although •OH is reactively non-specific, the reaction rate constant between •OH and chromophoric NOM is dependent on molecular weight (i.e. size). Therefore, larger molecular weight species react more rapidly with •OH resulting in a greater reduction in these species.

While the larger AMW fractions underwent significant reductions, this was accompanied by the formation of smaller AMW fractions (Figure 3). The 750-950 Da, 550-750 Da, and the <550 Da all increased in concentration after UV/H_2O_2 treatment. Furthermore, the reduction in higher AMW fractions and concomitant formation of smaller AMW fractions led to a shift in molecular size distribution from one with a majority of large species to a more even molecular size distribution.

HPSEC provided the change in molecular weight distribution of aromatic species since the UV detector only detects 254 nm absorbing species. To determine if the observed increase in low AMW fractions was in fact

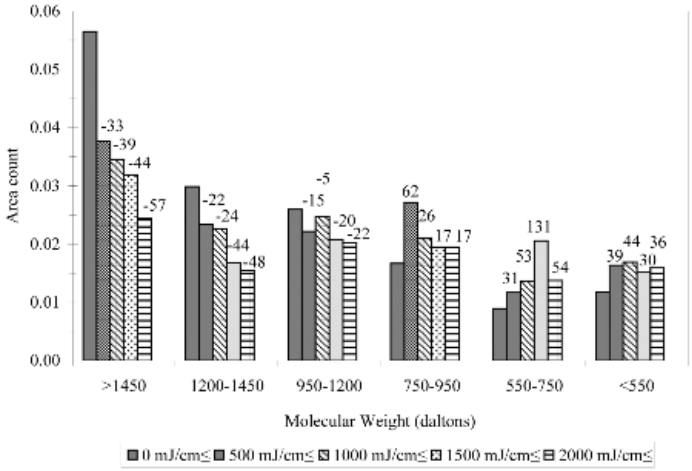

Figure 3. *Change in AMW fractions during the UV/H_2O_2 treatment of CW over a range of fluences and an initial H_2O_2 concentration of 5 mg/L. Bars represent the average of two samples, each measured once. Data labels indicate percent change.*

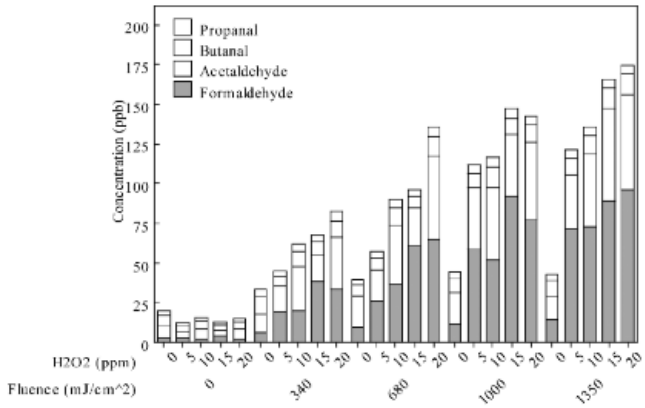

Figure 4. *Change in concentration of aldehydes during the UV/H_2O_2 treatment of CW over a range of fluences and initial H_2O_2 concentrations. Bars represent the average of two samples, each measured twice.*

increasing the concentration of low molecular weight compounds, the change in concentration of aldehydes, during UV/H_2O_2 treatment, was observed (Figure 4). Samples were analysed for 10 different aldehydes but only the 4 smallest aldehydes, formaldehyde, acetaldehyde, butanal, and propanal, were detected. In CW, the concentration of all four aldehydes is below 25 ppb. Exposure to H_2O_2 alone did not change the concentration of aldehydes. In the absence of H_2O_2, that is only UV irradiation, there was an observed increase in the total

concentration of aldehydes up to about 45 ppb at a fluence of 1350 mJ/cm^2. Under advanced oxidation conditions, the concentration of aldehydes increased dramatically. At an initial H_2O_2 concentration of 20 mg/L and a fluence of 1350 mJ/cm^2, the concentration of aldehydes reached close to 175 ppb. Additionally, it was clearly observed that an increase in either initial H_2O_2 concentration or fluence was accompanied by a greater formation of aldehydes. Note that, the increase in aldehydes is mainly due to an increase in formaldehyde and acetaldehyde, with propanal and butanal contributing less so.

CONCLUSIONS

This study investigated the impact of UV/H_2O_2 advanced oxidation on NOM present in untreated surface water. UV fluences and initial H_2O_2 concentrations applied were based on those feasible for commercial drinking water applications. Under such conditions:

- Complete oxidation, or mineralisation, of NOM did not take place as indicated by no observed change in TOC.
- NOM underwent significant partial oxidation as indicated by a reduction in aromatic species.
- $^{\bullet}$OH preferentially reacted with high AMW species leading to the formation of lower AMW species.
- The increase in low AMW species was supported by an observed increase in aldehydes.

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- Residual requirements; pros and cons.
- Technical requirements for a UV disinfection system to be applied in drinking water disinfection
- Determination of the performance of a UV disinfection system. Approval requirements for UV systems.
- Guidelines for the raw water quality when UV disinfection is applied.
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