2nd North American Conference on Ozone, Ultraviolet and Advanced Oxidation Technologies 2011

Toronto, Ontario, Canada
18-21 September 2011

# TABLE OF CONTENTS

## SESSION 1 – DISINFECTION AND DISINFECTION BYPRODUCTS
**Moderator:** Daniel W. Smith

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages of Combined Oxidants in Water Treatment</td>
<td>1</td>
</tr>
<tr>
<td><strong>Douglas Rittmann</strong></td>
<td></td>
</tr>
<tr>
<td>Multi Benefits of Intermediate Ozone at Four Surface Water Treatment Plants in Southern California</td>
<td>23</td>
</tr>
<tr>
<td><strong>Michael A. Oneby, Richard Lin, James H. Borchardt</strong></td>
<td></td>
</tr>
<tr>
<td>Disinfection Byproducts in Wastewater Effluent and Technology Approaches to Meet Developing Regulations</td>
<td>24</td>
</tr>
<tr>
<td><strong>Christopher S. Carr, Larry Schimmoller, Mike Witwer, Jenny Reina</strong></td>
<td></td>
</tr>
<tr>
<td>Comparison Between Conventional Treatments and Advanced Oxidation Processes Used in Disinfection of Treated Wastewater</td>
<td>39</td>
</tr>
</tbody>
</table>

## SESSION 2 – UV VALIDATION AND MONITORING I
**Moderator:** Linda Gowman

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of a High-Resistance Challenge Organism for Validation of Low Pressure, High Output UV Reactors for Virus Inactivation</td>
<td>50</td>
</tr>
<tr>
<td><strong>B. Petri, Stewart Hayes, Adam Festger, P. Chan, O. Karl Schieble, C. Shen, P. Patil, C. Olegaard, I. Gobulukoglu</strong></td>
<td></td>
</tr>
<tr>
<td>How Low Can You Go: Impact of UV Turndown Capabilities on Operating Efficiency</td>
<td>53</td>
</tr>
<tr>
<td><strong>Bryan Townsend, Donnie Ginn, Andrew Schipper, Adam Westerman, Xi Zhao</strong></td>
<td></td>
</tr>
<tr>
<td>Wastewater UV Disinfection Systems – Lessons Learned during Performance Testing</td>
<td>64</td>
</tr>
<tr>
<td><strong>Cody L. Charnas, Katherine Y. Bell, Daie Adams, Jed Chambers, Dean Cohrs, Dan Hammer, Pat Schmidt</strong></td>
<td></td>
</tr>
<tr>
<td>Operation, Maintenance, and Reporting Activities for Municipal Drinking Water UV Disinfection Facilities</td>
<td>75</td>
</tr>
<tr>
<td><strong>Todd Elliott, Alex Chen, David Euler, Andrew Niblock, Eric Kiefer, Enoch Nicholson, Paul Swaim</strong></td>
<td></td>
</tr>
</tbody>
</table>

## SESSION 3 – AOP METHODS
**Moderator:** Fernando Rosario-Ortiz

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalytic Ozonation of 2,4-Dichlorophenoxyacetic Acid in Water using Ni/SiO2</td>
<td>79</td>
</tr>
<tr>
<td><strong>J.L. Rodriguez, T. Poznyak, H. Tiznado, M.A. Valenzuela, D. Magallanes</strong></td>
<td></td>
</tr>
<tr>
<td>Composite Titania Photocatalyst Coating for Vacuum UV Photoreactor</td>
<td>91</td>
</tr>
<tr>
<td><strong>C. Duca, G. Imoberdorf, M. Moksoni</strong></td>
<td></td>
</tr>
<tr>
<td>Advanced Oxidation of Drinking Water Using Ultraviolet Light and Alternative Solid Forms of Hydrogen Peroxide</td>
<td>95</td>
</tr>
<tr>
<td><strong>Zachary Monge, Erik Rosenfeldt</strong></td>
<td></td>
</tr>
<tr>
<td>Development of an Integrated UV/Self-Generated Ozone Advanced Oxidation Reactor for Water Treatment</td>
<td>101</td>
</tr>
<tr>
<td><strong>Jingyun Fang, Hai Liu, Chui Shang, Minzhen Zeng, Zhi Chen, Menglin Ni, Wei Liu</strong></td>
<td></td>
</tr>
</tbody>
</table>

## SESSION 4 – OZONE IN DRINKING WATER TREATMENT
**Moderator:** Kerwin L. Rakness

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seven Years of Using Ozone as a Cost Effective Treatment Strategy</td>
<td>106</td>
</tr>
<tr>
<td><strong>Gord Devine, Bill Mundy</strong></td>
<td></td>
</tr>
<tr>
<td>Designing Ozone Systems for the Great Lakes Water – State of the Art and Lessons Learned from 10 Years of Experience</td>
<td>115</td>
</tr>
<tr>
<td><strong>Helen Jin, Quirien Maybewyck, Ed Minchew</strong></td>
<td></td>
</tr>
<tr>
<td>Upgrading the Largest WTP Plant in the Czech Republic – Experiences Gained in Design, Start up and Operation of a State of the Art Ozonation System</td>
<td>120</td>
</tr>
<tr>
<td><strong>Radka Haskova, Jiri Benes, Philip Puge, Florian Axt, Michael Ziegler</strong></td>
<td></td>
</tr>
<tr>
<td>Implementing Ozone at the Frank J. Horgan Water Treatment Plant</td>
<td>135</td>
</tr>
<tr>
<td><strong>Liza Ballantyne, Alex Yukosavljevic, G. Mitchell</strong></td>
<td></td>
</tr>
<tr>
<td>Implementing Ozone Training and Maintenance Integration at the Frank J. Horgan Water Treatment Plant</td>
<td>149</td>
</tr>
<tr>
<td><strong>Alex Yukosavljevic, Liza Ballantyne, G. Mitchell</strong></td>
<td></td>
</tr>
</tbody>
</table>
Mitigation of Anoxic Hypolimnetic Water in a Drinking Water Reservoir by Bottom Water Withdrawal and Treatment – Bench-Scale Ozone Test and Full-Scale Water Treatment

Keisuke Ikehata, Andrew T. Komor, Philip F. Bogdanoff

Assessing Raw Water Ozonation for Taste and Odor Removal, Manganese Oxidation, and DAF Preconditioning

Joseph Huang, Robert Biehler, Dean Gregory, Alan G. LeBlanc

SESSION 5 – UV VALIDATION AND MONITORING II

Moderator: Tom Hargy / Karl Linden

Yikes! What the UVDGM Does Not Address on UV Disinfection

H. Wright, Mark Heath, J. Bandy

Evaluating Piping Layout Impacts on UV Does Delivery

Christopher Schulz, Mike Hyland, Mark Allen, David Werth, Inder Singh

UV System Checkpoint Bioassays: Challenges from the Field, Comparison Methodology, and Proof of Scale-Up

B. Petri, J. An, Y. Lawryshyn, V. Moreland

Impact of Low Wavelength UV Light on UV Dose Monitoring and Validation

H. Wright, J. Bandy, Mark Heath, C. Bokermann, R. Bemus

Practical UV Light Source Diagnostic Tools for Measuring Uniformity, Intensity and Fluence

Todd Lizotte

Using Microbial Surrogates for the Wrong Reasons: The Risk in T1 as UV Challenge Microbe for Waste Water

B. Petri, Wayne Lem, Mike Shortt

SESSION 6 – AOPs APPLICATIONS

Moderator: Susan Andrews / Yuri Lawryshyn

Degradation of Carbamazepine during UV/H2O2 Treatment of Wastewater

Olya Keen, Seungyun Baik, Karl Linden, Diana Aga, Nancy G. Love

Removal of Cylindrospermopsin from Water by Photochemical Oxidation

Xuexiang He, Armah A. de la Cruz, Dionysios D. Dionysiou

Fate and Residual Toxicity of Pharmaceuticals in Oxidation Processes

Viviane Yargeau, Deniz Nasuoglou, Simone Larcher, Angela Rodayan

Methylene Blue Bleaching by a Solar Driven Advanced Oxidation Process

Po Yee Chan, James R. Bolton, Mohamed Gamal El-Din

Micropollutant Degradation in Tap Water by UV, Ozone and UV/Ozone Processes

Jingyun Fang, Zhi Chen, Minzhen Zeng, Chii Shang, Wei Liu

Pesticides Removal by Advanced Oxidation Processes in the Water Reclamation Process

N. Miguel, J. Sarasa, J. Rodriguez-Chueca, Isabel Garcia-Suescun, M.P. Ormad

Cresols Oxidation with Fenton’s Reagent, Ozone and Combination Ozone-Fenton’s Reagent

Clementina Rita Ramirez-Cortina, Ma. Angela Sánchez-Aguilar, Maria Soledad Alonso-Gutiérrez

SESSION 7 – OZONE IN WASTEWATER TREATMENT

Moderator: Saad Jasim

Treatment of Irrigation Return-Flow Water Containing Pesticides Using Ozone

Pamela Chelme-Ayala, Daniel W. Smith, Mohamed Gamal El-Din

Study of Anaerobic Effluent Disinfected with Ozone


Examining the Role of Effluent Organic Matter Components on the Decomposition of Ozone and Formation of Hydroxyl Radical in Wastewater

Sarah Gonzales, Andria Peña, Fernando L. Rosario-Ortiz

Enhanced Coagulation Pre-treatment to Improve Ozone Efficiency in Wastewater

Eric C Wert, Sarah Gonzales, Jeff Neemann, Fernando L. Rosario-Ortiz

Degradation of the Lignin Derivatives in Pulp and Paper Mill Effluent with Conventional Ozonation

J. Amacosta, T. Poczyňák

Ozone-Enhanced Biological Treatment of Landfill Leachates

Claudio Di Iaconi, A. Lopez, Achim Ried
The BISCO Concept: Biological-Compatible In-Situ Chemical Oxidation with Coated Microbubble Ozone (Gas Exchange) Sparging ................................................................. 329
William B. Kerfoot

SESSION 8 – UV DESIGN
Moderator: Jim Bolton

Design, Commissioning, and Operation of Cedar Rapids UV Disinfection Facilities ........................................... 334
Todd Elliott, Bruce Jacobs, Tony Myers

Sensor-Based Control – The Way for Safe, Energy-Efficient UV System Operation ........................................... 337
Mike Newberry, Paul Ropic

The Role of UV Disinfection in Meeting U.S. Regulatory Requirements at an Existing Ozone Facility ............... 345
Paul Swaim, Joseph Zalla, Brad Johnson, Joe Pomroy, Harvey Johnson, Wayne Pearson

New Design Lamp Drivers for Low Pressure Lamps ......................................................................................... 361
Tonnie Telgenhof Oude Koehorst, Gerhard van Eerden

Scale-Up of UV AOP Reactors from Bench Tests Using CFD Modeling ......................................................... 368
Keith Bircher, Mai Vuong, Brad Crawford, Mark Heath, J. Bandy

Assessing the UV Dose Delivered from Two UV Reactors in Series: Can you Always Assume Doubling the UV Dose from Individual Reactor Validations? ........................................... 380
Joel Ducoste, Scott Alpert

Point-of-Use Ultraviolet Disinfection: Shedding Light on Appropriate Technologies for Developing Communities .................................................................................................................. 396
Christina K. Barstow, Aaron D. Dotson, Karl Linden

SESSION 9 – AOPs IN DRINKING WATER TREATMENT
Moderators: Madjid Mohseni / Ron Hofmann

Removal of Pharmaceuticals, Personal Care Products and Endocrine Disrupting Compounds and Reduction of Disinfection By-products Using Ozone/H2O2 and UV/H2O2 Processes ................................................................. 406
Devendra Borikar, Saud Jasim, M. Mohseni, Leslie Bragg, Mark Servos, Souleymane Ndione, Larry Moore

Advanced Oxidation Treatment of Drinking Water: Part I. Occurrence and Removal of Pharmaceuticals and Endocrine-Disrupting Compounds from Lake Huron Water ................................................................. 424
Mohammad Feisal Rahman, Earnest K. Yanful, Saud Jasim, Leslie Bragg, Mark Servos, Souleymane Ndione, Devendra Borikar

Combination of O3/H2O2 and UV for Multiple Barrier Micropollutant Treatment – An Economic Attractive Option ................................................................................................................................. 425
Jens Scheideler, Karin Lekkerkerker-Teunissen, Ton Knol, Achim Ried, Jasper Verberk, Hans van Dijk

Advanced Oxidation for Surface Water Treatment in Cornwall – A New Lighthouse Project in Europe ........................................................................................................................................ 435
Chris Rockey, Andreas Kolch, Alan Royce, Colin Tinkler, Tim Ball

UV Advanced Oxidation for Taste and Odor Control: Understanding Life-Cycle Cost and Sustainability ...................................................................................................................................................... 454
Paul Swaim, Matt Ridens, Adam Festger, Alan Royce

Inactivation of Adenovirus Using Low-Dose Ultraviolet/H2O2 Advanced Oxidation ........................................... 465
Sarah Bounty, Luke Martin, Karl Linden

The Effectiveness of UV+Chlorine Treatment of Trichloroethylene in Drinking Water ........................................... 470
Ding Wang, Tim Walton, Leigh McDermott, Susan Andrews, R. Hofmann

SESSION 10 – UV CASE STUDIES AND RESEARCH
Moderators: Jane Bonsteel / Ghassan Ghali

Energy Efficient UV Upgrade at the Arrowhead Ranch Water Reclamation Facility ........................................... 477
Gary L. Hunter, Andrew J. Mally, Dan Buhrmaster, Larry Broutman, Arif Rahman

Integrating Ozonation and UV Disinfection for an Unfiltered System to Comply with LT2ESWTR ................. 483
Jeff Neemann, Bryan Townsend, Mario Francucci, Kathy Moriarty, Rick Pershken, Kevin Potte, Dina Page

Hurdles and Progress in UV-C LED Technology for Water Disinfection ............................................................... 492
Jennifer G. Pagan, Oliver Lawal, Paolo Batoni

12-Month UV Fouling Study on Unfiltered Source Water ...................................................................................... 495
Chad Talbot, Mark Heath, H. Wright, David Peters

Photochemical Fate of Oil Dispersants Used in the Gulf Oil Spill Clean-Up .......................................................... 518
Austa M. Parker, Caitlin M. Glover, Fernando L. Rosario-Ortiz, Karl Linden
Algae Control Methods Compared: The Importance of Successful Algae Control for Facilities with UV Disinfection

David Drobot, Brent R. Gill, Shawna Gill, Joseph Nestico

Adopting and Adapting to Advanced Treatment Technologies

Jane Bonsteel, Andrew Farr, Jeff Honnings

SESSION 11 – OZONE RESEARCH AND DESIGN

Moderators: Pamela Chelme-Ayala / Souleymane Ndiongue

Study of Ozone Application for the Degradation of Paraquat Dissolved in Water

Patricia Reynoso Quispe, Roberto J. Carvalho, Wifredo I. Urruchi

Decomposition Kinetics of Ozone Dissolved in Different Aqueous Solutions

A. Pérez, T. Poznyak, I. Chairez

Computational Fluid Dynamics Analysis Optimizes Pipeline Flash Reactor Design

Celia Mazzei, Mike Spillner

Ozone Sidestream Injection: Solving Start-Up Problems Using Underwater Video and Engineering Creativity

Alan Domosnake, Gardner Olson

Development and Use of an Ozonation Process Simulator at the Frank J. Horgan Water Treatment Plant

G. Mitchell, Liza Ballantyne, Alec Vukosavljevic, Kerwin L. Rakness

Ozone Retrofit Considerations at the Oakville Water Purification Plant

Elia Edwards, Bill Mundy

Mastering Ozonolysis: Production From Laboratory to Ton Scale in Continuous Flow

Markus Nobis, Dominique M. Roberge

SESSION 12 – UV TREATMENT RESEARCH

Moderators: Bertrand Dussert / Ron Hofmann

IUVA Uniform Protocol for Wastewater UV Validation Applications

G. Elliott Whitby

Biosimetry of a Full-Scale Wastewater UV Disinfection System Using Multiple Surrogate Microorganisms

Bruno Ferran, Wei Yang

When Dose is Not Dose. The Case of UV Disinfection of Adenovirus

Karl Linden, Karl Scheible, Phyllis Posy, Gwy-Am Shin, Jeanette Thurston, Anne Eischeid

Ultraviolet Lamp Efficiencies: Modern Derivation of the Keitz Formula and Other Efficiency Issues

Qing Sheng Ke, James R. Bolton

What is the Impact of UV Absorbing Particles on the Inactivation of Indigenous Bacteria?

R.E. Cantwell, R. Hofmann

UV-LEDs for Water Disinfection – Are We Close?

Colleen Bowker, Scott Alpert, Joel Ducoste

Degradation of N-Nitrosodimethylamine (NDMA) by 222 nm and 254 nm UV Light

Hiroshi Sakai, Tatsuro Takamatsu, Koji Kosaka, Naoyuki Kamiko, Satoshi Takizawa

SESSION 13 – OZONE OPERATION

Moderators: Liza Ballantyne / Bill Mundy

Sustainability and Ozonation: Making the Case for Generator Upgrades

Julie Herzner, Anni Luck, Ian Crossley, Gerard Moerschell

Ozone Cost Implications from Oxygen Supply – Advantages of VSA Technology

David Schneider, Soeren Schmitz

The Ozonation Option for Private Onsite Wastewater Treatment – The WATERCLEAN™ Solution

Thomas W. Bain

Ozone Residual Meter Calibration Approach and Status

Kerwin L. Rakness, Glenn F. Hunter

Liquid Oxygen Specification for Ozone Generation

Derek Miller

Converting a Large Water Treatment Plant to Enhanced Coagulation and Biological Filtration

Mark Simon, Michael Mikeksa, Peter Stencel, Jennifer Cottingham, Nick Burns, Jeff Neemann, George Budd, Randy Romack

After the Dust Settles – Ozone System Operation and Optimization After Start-Up

Glenn F. Hunter
SESSION 14 – GENERAL SESSION AND FOOD APPLICATIONS
Moderator: Ghassan Ghali / Jacque-Ann Grant

Source Area Treatment of a TCE Plume by Coated Microbubble Ozone and Sequential ERD at a Portland, Oregon, Facility ................................................................. 706
Paul Ecker, Paul McBeth, William B. Kerfoot

Photodecomposition Efficacy Validation of a Medium Pressure (MP) UV Reactor for removal of Residual Free Chlorine and Monochloramine in Water .................................................. 710
I. Gobulukoglu

UV Laser Based Longitudinal Illuminated Diffuser (LID) Beam Shaping System ............................................. 711
Todd Lizotte

Pulsed Light Inactivation of Foodborne Pathogens: Fundamentals, Applications and Potential for the Future ............................................................... 721
Carmen I. Moraru

Ultraviolet Light for Safety of Fluid Foods and Beverages .............................................................................. 728
Tatiana Koutchma, Marta Orlowska, Cheryl Defelice

Ozone for Fresh Produce Transit ........................................................................................................ 731
David J. Cope

Plague Elimination and Ozone Effects on Types Stored Corn ............................................................................ 738
Jose G. Llanes, Miguel Angulo

Author Index