INTERNATIONAL OZONE ASSOCIATION

European
African
Asian
Australasian
Group

INTERNATIONAL CONFERENCE & EXHIBITION

EA3G2018

5 – 7 September 2018, Lausanne, Switzerland

OZONE AND ADVANCED OXIDATION

SOLUTIONS FOR EMERGING POLLUTANTS OF CONCERN TO THE WATER AND THE ENVIRONMENT

With the support

Service de l'eau
VILLE DE LAUSANNE

suez

OTV VEOLIA

WABAG

PROGRAMME
BOOK OF ABSTRACTS

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WELCOME ADDRESS

The European African Asian Australasian Group of the International Ozone Association presents its EA3G2018 International Conference & Exhibition on Ozone and Advanced Oxidation - Solutions for Emerging Pollutants of concern to the Water and the Environment.

This event was organised to be held in Lausanne thanks to the collaboration with Service de l'eau, Ville de Lausanne, Switzerland.

EA3G2018 continues a long series of successful conferences organised to provide an international forum for all concerned with fundamental, engineering and applied aspects of oxidation techniques involving ozone and related oxidants. One can particularly remember the well-attended conference focused on the micropollutants issue which also took place in Switzerland as pioneer country in the development of solutions (Geneva, 2010).

Health risks associated with contaminated water and wastewater, continuous degradation of aquatic environment, and water scarcity issues contribute to the increase of advanced technologies implementation upon legislative impetus. In a near future, the elimination of emerging pollutants of concern (i.e., pharmaceuticals, endocrine-disrupting compounds, surfactants, plasticizers, disinfection by-products and other chemicals) will drive the selection of advanced water and wastewater treatment processes.

EA3G2018 conference will present an overview of the current state of knowledge and latest advances regarding the use of Ozone and Advanced Oxidation to provide solutions for the control of emerging parameters including persistent organic pollutants, hazardous substances and microbiological contaminants in any water.

We would like to express our gratitude and thanks to all of you who contributed to make this event possible: Service de l'Eau, Ville de Lausanne staff under the leadership of M. Christophe MECHOUK, authors, exhibitors, sponsors, Association' members, chairpersons and members of the Committees.

We wish you a very enjoyable and fruitful Conference.

On behalf of the IOA-EA$_3$G Organising Committee

Frédéric VIOLLEAU
IOA-EA$_3$G President

> The Organizer IOA, EA$_3$G

The International Ozone Association is a non-profit organization dedicated to the development of educational and scientific activities to respond at the best to the needs of industry and research community in the field of ozone and derived oxidants. Since its foundation in 1973, the IOA is at the forefront in connecting professionals around the globe involved and interested in ozone-related issues including scientists, researchers, engineers, system designers, technologists, equipment manufacturers, consultants, users and members of governmental agencies.

Typical topics covered in the activities program are ozone generation, secondary oxidant generation, gas mass transfer, chemical reactions of ozone in gas and liquid phases, engineering aspects, water treatment for disinfection and pollutants removal, oxidation for food processing, for pulp bleaching, for products manufacture and conditioning, development of analytical procedures and materials, development of equipments for ozone use, development and applications of advanced oxidation processes, safety and health effects.

The EA$_3$G group of IOA manages IOA membership in Europe, Africa, Asia and Australasia.

For more information, please visit www.ioa-ea3g.org/

COMMITTEES

> Programme Committee

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Dr. Sylvie Baig | Head of Scientific Innovation, Suez, France
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Pr. Santiago Esplugas | Department Manager, University of Barcelona, Spain
Pr. Urs Von Gunten | National Institute Eawag and Ecole Polytechnique Fédérale de Lausanne, Switzerland
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Béatrice Bernard | IOA-EA3G Secretary, Poitiers, France
Christophe Mechouk | Division Manager, Sevice de l'eau, Ville de Lausanne, Switzerland
Dr. Tony Merle | Project Manager, Holinger, Switzerland

SPECIAL ACKNOWLEDGEMENTS AND CONTRIBUTIONS

The success in the organization of this event results from the strong and faithful involvement of many individuals, from the support of exhibiting companies, from the generous contribution of the sponsors and from the partnership with Ville de Lausanne.

The Organizers would like herewith to acknowledge the support given by the following partners:

Service de l'eau - Ville de Lausanne
Organization partner

www.lausanne.ch/eau

SUEZ WATER TECHNOLOGIES & SOLUTIONS
General Sponsor / Exhibitor

www.ozonia.com
www.suez.com

Our experts partner with customers around the world to provide solutions for the toughest water and process challenges. Leverage our water treatment systems and technology to reduce costs, meet environmental regula1ons and prepare for changing demands.
SUEZ's ozonia® ozone technology porJolio includes products from the laboratory scale to the largest ozone systems ever built. SUEZ uses our extensive ozone technology experience to provide the industry's most reliable and robust products.
We have been the ozone industry pioneer for over 25 years. Trust us to deliver the highest quality ozone solu1ons to meet your treatment challenges.

WABAG Water Technology Ltd.
General Sponsor / Exhibitor

www.wabag.com

WABAG Water Technology Ltd. is the leading plant contractor for drinking water and wastewater treatment in Switzerland. Originating from the Sulzer Group and active in plant construction for over 60 years, we can be proud of more than 140 reference plants in Switzerland alone. Our portfolio includes all aspects of classical plant construction; furthermore, we have our own laboratory, a research and development department, process engineering competence for drinking- and wastewater processes including our own processes and patents and a competent, client-oriented service group. Therefore, we can offer a wide range of services ranging from studies and pilot tests to turnkey plant planning and implementation.
WABAG Water Technology Ltd. is the technology hub of the WABAG group with over 2000 employees worldwide and over 1400 plants built in the past 20 years.

www.otv.fr

www.veoliawatertechnologies.com/en

OTV

General Sponsor

WATER TREATMENT FROM A TO Z

OTV, a subsidiary of Veolia, develops Veolia Water Technologies engineering and construction activities for the municipal and industrial market in France and in French overseas departments and territories.OTV's expertise and know-how enable it to address all water treatment issues, from the installation of water treatment technical solutions to the management of small and large capacity projects.

OTV'S TRADES. As an expert in water treatment engineering, OTV offers its customers audacious, creative, sustainable and, first and foremost, pragmatic solutions for all steps in the water cycle: drinking water treatment; wastewater treatment; sludge treatment; desalination; stormwater treatment; odor management; territorial methanization; household waste treatment and reuse.

www.bmt-berlin.de

BMT MESSTECHNIK GMBH

Exhibitor

Since more than 30 years BMT is specialized on photometric measurement of ozone in air, in oxygen, and in water. BMT is a technology leader in the measurement of ozone in moist off-gas and moist vent-gas, and ozone in water. An exhaustive range of accessories is offered to support single source design. And we are supplying small but advanced air cooled ozone generators for ozone experiments and for small scale ozone systems. Our ozone instruments are used worldwide in many kinds of ozone applications such as: semiconductor, pharmaceutical, ballast water treatment, medical, and chemical. For ozone treatment of water and waste water we are offering complete solutions for all points of ozone measurement in the plant.

www.denora.com

www.BBCommunicationsGroup.com

DE NORA Water Technology Italy

Exhibitor

The pioneer of modern electrochemistry technology, De Nora brings a long history of innovation to familiar water treatment products like the Capital Controls® original all-vacuum gas chlorinator, which introduced groundbreaking chlorination safety in 1960 and continues to be the industry benchmark today. De Nora applies decades of product innovation and experience to a growing portfolio of disinfection and filtration technologies, including ozone and advanced oxidation. A trusted supplier to more than 1,300 installations globally, Capital Control® Ozone from De Nora brings expertise to oxidation for disinfection, biological sludge reduction, color and odor removal, and micropollutant treatment in drinking water, wastewater, and industrial process water. Systems offer capacity up to 6,000 lb/day and proprietary XTL™ dielectric that decreases maintenance and increases uptime. Skid-mounted and containerized systems provide excellent design flexibility.

www.ozonosan.de

Dr. Hänsler Ozonosan

Exhibitor

For more than 60 years **Dr. Hänsler OZONOSAN** is specialized in Ozone-Oxygen-Therapy; in addition to ozone technology, the company has also devoted itself to basic scientific research and clarification on the application forms of ozone therapy, thus developing a safe, simple and effective treatment method now recognized everywhere:
The perfect systems for the use of ozone in hygiene, clinics, hospitals and research.
All our units, the OZONOSAN line, are setting new standards: the integration of a photometric measuring unit with autocalibration and continuous ozone level control are an absolute guarantee for permanent quality control.
Hänsler OZONOSAN is certified according to DIN EN ISO 13485, on the basis of the European Directives for Medical Devices MDD (93/42EWG), all the products are marked CE 0123.

www.statiflo.com

STATIFLO

Exhibitor

Statiflo is a world leader in the development and application of static mixers, gas dispersion systems, flow conditioners and associated technologies. The company was founded in 1983 and since then we have established an extensive list of satisfied customers and have a wealth of experience in the design and supply of process equipment. We are a privately owned company with the Head Office situated in Macclesfield, England, consisting principally of Chemical and Mechanical Engineers. Statiflo have branch offices in the USA, Germany and Canada as well as distributor offices world-wide and we are proud to be approved to Quality control standard ISO 9001. All of our units are custom designed and built to suit the individual requirements of each customer. To date, we have supplied static mixing equipment to over 80 countries world-wide, to every process industry and have an excellent reputation for the supply of high quality equipment world-wide. The Statiflo gas dispersion system is ideal for new facilities as well as retrofitting applications and has been proven to continually meet or exceed our guaranteed 95% mass transfer efficiency.

Powerful combinations

For safe use and reuse of water.

Health

In order to achieve sustainable water treatment, we have developed advanced technologies for the removal of micropollutants from water and wastewater and have also completed the efficient integration of biological systems and highly effective processes such as oxidation, membrane filtration and adsorption:

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GENERAL INFORMATION

> Language

The official language will be English.

> Conference venue

Casino of Montbenon
3 allée Ernest Ansermet
1003 Lausanne
Switzerland

Ph.: +41 21 315 21 50 – Fax: +41 21 315 21 65
www.lausanne.ch/casino

Just 5 minutes' walk from the city centre and set in magnificent gardens, this centre for cultural and social activities was inaugurated in 1908 and enjoys unobstructed views of the mountains and Lake Geneva.

> Registration categories

There are 8 categories of registration with associated fees as follows:

- IOA Member - Full registration
- Non-member - Full registration
- Member Student - Full registration
- Non-member Student - Full registration
- One-day registration – Member, 5 or 6 September
- One-day registration - non-Member, 5 or 6 September
- Conference dinner
- Technical Tour

The full registration fee covers scientific sessions, electronic proceedings, abstracts book, lunches and refreshments.
A special discount rate is available for IOA members. Valid student ID is required for student registration. Additional registration is required for the Conference dinner and technical tour. These two options are opened to accompanying person.

> Welcoming desk

It will be opened during the conference as follow:

- Wednesday, September 5 07:30 – 18:00
- Thursday, September 6 08:30 – 18:00

> Badges

The wearing of a badge is compulsory during the conference. They are necessary to access all scientific sessions, exhibition and lunch room.

> Coffee breaks & Lunch

Complimentary coffee and drinks will be available at the scheduled break times. Each day, lunch will be offered in the same building as the conference.

> Liability and insurance

Registration for the Conference implies that the delegate agrees that neither the Organizers assume any liability whatsoever. Delegates are requested to make their own arrangements for medical, travel and personal insurance.

> Disclaimer

The Organizers may at any time, with or without giving notice, in their absolute discretion and without giving any reason, change the Conference programme and withdraw any invitation to attend. In any case, neither the organizers nor any of their officers employees, agents, members or representatives shall be liable for any loss, liability, damage or expense suffered or incurred by any person, nor will they return any money paid to them in connection with the Conference unless they are satisfied not only that the money in question remains under their control, but also that the person who paid it has been unfairly prejudiced (as to which the decision shall be in their sole and unfettered discretion, and when announced, final and conclusive).

GENERAL PROGRAMME

The conference will include:

- 2-day scientific and technical sessions including keynote lectures, oral presentations and posters session
- Key lectures and speakers
  Enhanced municipal wastewater treatment for micropollutant abatement by ozone by Urs von Gunten (Switzerland)
  Global Water Crisis; Contaminants and Shortages, a Shared Responsibility by Saad Y. Jasim (Canada)
  A tour through the European Regulations for ozone treatment by Bernhard Paolini, Tim Pühmeier, Jörg Mielcke, Matthias Rothe, Matthias Hoffmann and Jaak Ryckeboer (Switzerland, Germany)
  Mastering ozonation fundamentals to ensure the micropollutant removal and control byproducts release by Sylvie Baig and Michel Roustan (France)
- 2-day exhibition of ozone related products and services,
- 1-day technical visit of full-scale applications,
- Conference dinner and Awards ceremony for delegates and their guests.

Wednesday 5 September		
8h00-8h45	Registration	
8h30-9h00	Welcome and opening addresses	
9h00-11h00	Session 1. Introductory Keynote lectures	
11h00-11h30	Coffee break	
11h30-12h10	Session 2. Fundamentals	
12h10-14h00	Lunch	Exhibition
14h00-15h40	Session 3. Fundamentals *(cont'd)*	
15h40-16h10	Coffee break	
16h10-16h50	Session 4. Fundamentals *(cont'd)*	
16h50-18h30	Session 5. Poster session	
20h00	Conference dinner	
Thursday 6 September		
8h30-10h30	Session 6. Process development	
10h30-11h00	Coffee break	
11h00-12h40	Session 7. Process engineering	
12h40-14h00	Lunch	Exhibition
14h00-15h40	Session 8. Process engineering *(cont'd)*	
15h40-16h10	Coffee break	
16h10-17h10	Session 9. Process engineering *(cont'd)*	
17h10-18h00	Closing session and Award Ceremony	
Friday 7 September		
9h00-16h00	Technical tour: Drinking Water Plant of the Bret Lake Lunch in a local restaurant	

> Publications and scientific awards

To encourage young researchers, the Programme Committee will select and award a prize to the best paper presented by a doctorate student during the Conference.

All accepted papers will be printed in the conference proceedings that will be handed out to participants at registration. After the conference, the editors of the Ozone: Science & Engineering Journal will make the final selection among the papers presented for possible publication in this IOA peer-reviewed journal.

> Conference dinner - Wednesday 5, 20h00

A conference dinner & drinks reception will be proposed to delegates on Wednesday 5 September at the Brasserie Lausanne-Moudon.

The conviviality « Made in Swizerland »!

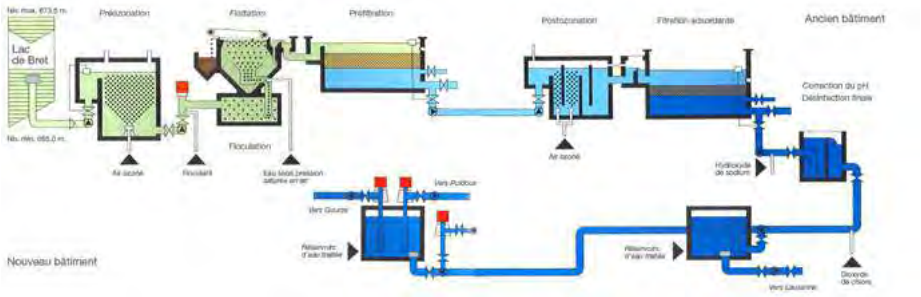
> Technical Tour at Drinking Water Plant of the Bret Lake – Friday 7, full day

The opportunity to discover also the Lausanne area.

The tour will feature the Drinking Water Plant located at the Bret Lake. “Lac de Bret” is in the municipality of Puidoux, in the Vaud canton, north of Lake Geneva.

The natural lake is used as a drinking water reservoir for the city of Lausanne. The first dam was built in 1875 to supply water for the Lausanne-Ouchy funicular.

The Bret plant can produce 19 000 m^3/d. The quality of the water is very good because the treatment process is modern and very complete: preozonation, flocculation, flotation, two-layer sand filtration, ozonation, activated carbon filtration and final chlorination.



The main asset of the Bret plant is its altitude (670 m), which allows water to be transported to the next Chailly reservoir (614 m) without pumping.

The operation of the Bret plant by the Service de l’eau of the Ville de Lausanne (Water Service of the City of Lausanne) currently provides:

- The production of 5 to 6 million m^3, the great majority of which flows by gravity towards Lausanne;
- The emergency water supply of 24 communes, Puidoux and A.I.E.J (Intercommunal Association of Jorat Waters);
- The production of water in case of crisis thanks to the presence of a generator and the gravity of water transport to Lausanne.

It also ensures:

- The management of the lake, in particular in order to avoid its overflow;
- The management and maintenance of the shores of the lake, because the water service owns the parcel surrounding the lake.

This tour will depart from and return to the Conference center. Special registration will be required. The fee will include bus transfer and lunch at the Restaurant du Lac.

Visitors will have to provide copy of ID card or passport. Wearing of trousers and closed-in walking shoes is recommended. The organisers reserve the right to cancel or limit attendance at any tour with monies refunded subject to minimum and maximum registration numbers.

> Enjoy your stay in Lausanne

Lausanne is a great destination for visitors and residents alike, benefitting from a wonderful location on the coast of the Geneva lake (Lac Léman) and face to French Alps.

Situated at the heart of the Lausanne-Morges agglomeration, the capital of the canton of Vaud is in the throes of development, with business, urban planning, public transport and mobility all sectors undergoing transformation.

The fourth-largest city in Switzerland, Lausanne is set apart by its vocation as an Olympic city, a sustainable city and a place of training and culture.

A very popular tourist destination, the city is also home to many international companies, particularly the headquarters of multinationals.

Quality of life and economic attractiveness combine to multiple effect!

The organizing Committee encourage conference participants to discover Lausanne and its area. Many opportunities of sightseeing tours can be found at www.lausanne-tourisme.ch/en/


challenging effluents and micropollutants removal require advanced treatment technologies
we are ready with ozonia® oxidation and advanced oxidation solutions
Communities and regulators around the world understand the importance of wastewater treatment because treatment solutions directly effect citizens and the local environment. As standards become more stringent, new tools are needed.
Every water treatment challenge is unique. From laboratory testing, to pilot studies, to design and engineering, our dedicated teams craft ozone solutions to meet your treatment objectives:
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odor
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www.suezwatertechnologies.com
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SCIENTIFIC AND TECHNICAL PROGRAMME

Wednesday 5 September

7h30-8h30	**Registration**	
8h30-9h00	**Welcome and opening address** *Pierre-Antoine Hildbrand, Director of Security and Economy, Ville de Lausanne (Switzerland)* *Frédéric Violleau, IOA-EA3G President (France)*	
9h00-11h00	**Session 1. Introductory Keynote lectures** | **Chair: F. Violleau**	Exhibition
9h00	**Enhanced municipal wastewater treatment for micropollutant abatement by ozone** *Urs von Gunten (Switzerland)*	
9h30	**Global Water Crisis; Contaminants and Shortages, a Shared Responsibility** *Saad Y. Jasim (Canada)*	
10h00	**A tour through the European Regulations for ozone treatment** *Bernhard Paolini, Tim Pühmeier, Jörg Mielcke, Matthias Rothe, Matthias Hoffmann, Jaak Ryckeboer (Switzerland, Germany)*	
10h30	**Mastering ozonation fundamentals to ensure the micropollutant removal and control byproducts release** *Sylvie Baig, Michel Roustan (France)*	
11h00-11h30	**Coffee break, poster session and exhibition**	
11h30-12h10	**Session 2. Fundamentals - Chair: S. Esplugas**	
11h30-11h50	**Comparison of O_3, ferrate, ClO_2, and permanganate pre-treatment on NOM's characteristics and formation of DBPs** *V. Rougé, S. Allard, U. von Gunten, J.P. Croué (Australia, Switzerland)*	
11h50-12h10	**Quantification of electron-donating capacities for the assessment of oxidative water treatment** *Linda Önnby, Elisabeth Salhi, Urs von Gunten (Switzerland, Sweden)*	
12h10-14h00	**Lunch**	
14h00-15h40	**Session 3. Fundamentals (cont'd)** | **Chair: S. Esplugas**	Exhibition
14h00-14h20	**Microbial Counts and Antibiotic Resistances during Conventional Wastewater Treatment and Wastewater Ozonation** *K. Kirchner, I. Brückner, K. Klaer, M. Hammers-Wirtz, J. Pinnekamp, M. A. Rosenbaum (Germany)*	
14h20-14h40	**Virus inactivation by ozone natural matrices: potential proxies for viral inactivation** *Camille Wolf, Annalisa Pavese, Urs von Gunten, Tamar Kohn (Switzerland)*	
14h40-15h00	**Determining viral inactivation after ozone treatment using a novel transfection-based most probable number assay** *Jason Torrey, Urs von Gunten, Tamar Kohn (Switzerland)*	
15h00-15h20	**A review on the research and application of ozone catalytic oxidation** *Pingxin Liu, Jun Ma, Yueming Ren (PR China)*	
15h20-15h40	**Solar simulated radiation assisted photolytic ozonation for the removal of aqueous anthropogenic pollutants** *Rafael Solís, Javier Rivas, Olga Gimeno, Fernando Beltrán (Spain)*	
15h40-16h10	**Coffee break, poster session and exhibition**	
16h10-16h50	**Session 4. Fundamentals (cont'd)** | **Chair: M. Roustan**	Exhibition
16h10-16h30	**Degradation of iopromide by the UV-chlorine process** *Cécilia Falantin, Justine Criquet, Sébastien Allard (Australia, France)*	
16h30-16h50	**Photo-induced persulfate oxidation of emerging micropollutants in water matrices** *Niina Dulova, Eneliis Kattel, Balpreet Kaur, Marina Trapido (Estonia)*	

Wednesday 5 September

16h50-18h30 **Session 5. Poster session** | **Chair: M. Roustan**

16h50-17h10 **Poster exhibition overview**
Michel Roustan (France)

Fundamentals

Reaction of aliphatic amines with ozone
Sungeun Lim, Christa S. McArdell, Urs von Gunten (Switzerland)

Profilomic, large scale screening of emerging pollutants and far beyond
David Halter, Maite Sarter, Fereshteh Rouholahnejad (France)

Comparison of different advanced oxidation processes used to the decomposition of organic pollutants in real thermal wastewater
Ákos Fazekas, Gábor Veréb, Szabolcs Kertész, Sándor Beszédes, Cecilia Hodúr, Zsuzsanna László (Hungary)

On the mechanism and phytotoxicity evolution during solar photolytic enhanced ozonation of tritosulfuron in water
Rafael Solís, Javier Rivas, Olga Gimeno, Fernando Beltrán (Spain)

Mechanisms of reaction of ozone and ozone-UV with 2,5-dichlorophenol
Jacqueline C. Alexander, Cirilo García-Martinez, Clementina R. Ramírez-Cortina, Isaías Hernández-Perez (Mexico)

Simultaneous dosing of ozone and hydrogen peroxide for advanced oxidation treatment of municipal wastewater effluents
Alberto Cruz-Alcalde, Santiago Esplugas, Carme Sans (Spain)

Protection mechanism of rubbers from ozone attack
Franco Cataldo (Italy)

Assessment of ozone and solar-light based AOPs in the removal of NOM and DBPs formation potential
Ana Rey, Eva-María Rodríguez, Rafael Solís, Fernando Beltrán (Spain)

Electrochemical generation of ozone over nickel, niobium doped tin oxide electrode
Matte Venkata Sivaiah, Abirami Devadas, How Ghee Ang (Singapore)

Heterogeneous catalytic ozonation of diclofenac using $Fe_3O4/SiO_2/Co_3O_4$
Li Wei Lu, Cheng Nan Chang, Yen Ping Peng (Taiwan)

Degradation of two antihypertensives by hydroxyl and sulfate radicals
Maria Clara Starling, Patrício Patterson, Annaïg Le Person, Camila Costa de Amorim, Justine Criquet (Brazil, France)

Ozone in nuclear physics detectors at accelerators
V. Kramarenko, I. Tkachenko, S. Tkachenko (Russia)

Comparative study of conventional and advanced disinfection processes applied to urban wastewaters
Pilar Valero, Rosa Mosteo, José L. Ovelleiro, Maria P. Ormad (Spain)

Researches on active and passive monitoring of the aeromicroflora in bakery units and the results obtained from the use of the GF 3XO - AW8 ozone generator
Popa Ioan Eugen, Puchianu Gheorghe, Enache Dorin Valter, Necula Valentin (Romania)

Aldehyde abatement based on ozonation in homogenous gas phase
Leticia Vitola Pasetto, Frédéric Violleau, Romain Richard, Jean-Stéphane Pic, Valérie Simon, Marie-Hélène Manero (France)

Process development

Hard COD Removal in Textile Dye Effluent with a 2 Stage Treatment Applying Ozone Followed by Peroxone
Bruno Heiniger, Laurent De Franceschi (Switzerland)

Cyanide recovery from thiocyanate by ozonation of mining effluent
Bruno Heiniger, Laurent De Franceschi, Amanda Murillo (Switzerland)

Process Engineering

Effects of pre-ozonation on ultrafiltration of oil-in-water emulsions using different hydrophilic and hydrophobic membranes
Gábor Veréb, Júlia Végh, Szabolcs Kertész, Sándor Beszédes, Cecilia Hodúr, Zsuzsanna László (Hungary)

Thermal Vent Ozone Destructor Technology using Heat Recovery Process Improves Resistance to Hard Process and Operating Conditions
Christopher Huynh, Walter Uttinger, Elodie Aubin, Hanspeter Fellmann (Switzerland)

Catalytic protection against ozone of drift detectors of the atlas installation of the large hadron collider
S. Tkachenko, V. Kramarenko, I. Tkachenko, E. Golosman, V. Lunin (Russia)

20h00 **Conference Dinner**

Exhibition

Thursday 6 September

8h30-10h30	**Session 6. Process development** | **Chair: U. Von Gunten**	Exhibition
8h30-8h50	**A practical approach for the control of micropollutants removal during wastewater ozonation using kinetic and water quality parameters** *Alberto Cruz-Alcalde, Santiago Esplugas, Carme Sans (Spain)*	
8h50-9h10	**Ozonation performance for micropollutants removal from source-separated urine** *Hui Deng, Christelle Guigui, Jean-Stéphane Pic (France)*	
9h10-9h30	**Successful landfill leachate wastewater treatment using the sequence of ozonation, adsorption on charcoal and photo-ozonolysis** *Franco Cataldo (Italy)*	
9h30-9h50	**UV/H_2O_2 before biological treatment in drinking water: effects on the removal of micropollutants and biodegradability** *Robin Wünsch, David Cayon, Fabienne Eugster, Julia Plattner, Jens Gebhardt, Richard Wülser, Urs von Gunten, Thomas Wintgens (Switzerland, Germany)*	
9h50-10h10	**Ozone, O_3 Plus AOP: an Optimized Treatment Line for COD & TOC Removal: Wanhua** *Liu Fan, Laurent de Franceschi, Stéphanie Foucher, Bruno Heiniger, Cindy Ji, Michael Wang, Katia Wasiak, Jesse Yu (PR. China, Switzerland)*	
10h10-10h30	**BIOTECH PROJECT: Hospital effluents treatment by oxidation with ozone and catalytic ozonation processes - elimination of biocides** *F. Pontlevoy, F. Lasek, N Karpel Vel Leitner, L. Blanchier, S. Ayraud Thevenot, O. Castel, C. Printemps-Vacquier, P. Plaire, C. Pagotto, H. Reisser, T. Trotouin, S. Cormery, N. Della-Valle, S. Bouchonnet, S. Bourcier, E. Nicol, S. Vujovic, G. Rauwel, M. Deborde (France)*	
10h30-11h00	**Coffee break, poster session and exhibition**	
11h00-12h40	**Session 7. Process engineering** | **Chair: S. Baig**	Exhibition
11h00-11h20	**Construction of a new treatment chain at the Saint-Sulpice drinking water treatment plant: ozonation and advanced oxydation pilot tests** *Christophe Mechouk, Alexandra Hauret, Laura Piccinini, Fereidoun Khajehnouri (Switzerland)*	
11h20-11h40	**Foam fractionation and ozone in modern aquaculture systems: valuable tools for clear water production and farm management** *Jaime Orellana, Bert Wecker, Uwe Waller (Germany)*	
11h40-12h00	**Degradation of plant protection products from wastewater with advanced oxidation processes (AOP)** *Agnieszka Mos-Hummel, Klaus Nonnenmacher (Germany)*	
12h00-12h20	**Closing the water cycle applying suspended ion exchange and ozonation for pharmaceutical control** *Bram Martijn, Dan Farley, George Zoutberg, Jim Malley, Joop Kruithof (The Netherlands)*	
12h20-12h40	**UVA_{254nm} based ozone dosage control with one in –situ measurement sensor** *Vignesh Thiyagarajan, Achim Ried, Michael Stapf, Jan Schuetz (Germany)*	
12h40-14h00	**Lunch**	
14h00-15h40	**Session 8. Process engineering (cont'd)** | **Chair: S. Jasim**	Exhibition
14h00-14h20	**Micropollutants treatment at the vidy WWTP: feasibility of implementing ozonation with regard to by-products formation** *Christophe Mechouk, Alexandra Hauret, Laura Piccinini, Fadi Kadri, Fereidoun Khajehnouri (Switzerland)*	
14h20-14h40	**Micropollutant removal by ozonation at Sophia Antipolis wastewater facility: assessment of performances and reduction of toxicity** *Y. Penru, N. Creusot, J. Couteau, C. Miège, A. Guillon, M. Esperanza, M. Masson, A. Roussel-Galle, M. Coquery, S. Martin Ruel, S. Baig, J.M. Choubert, S. Aït-Aïssa (France)*	
14h40-15h00	**Micropollutant removal from WWTP effluent using the O_3-step filter** *Coen de Jong, Tsz Kit Liu, Arjen Van Nieuwenhuijzen, René van der Aa, Manon Bechger, Jan Peter van der Hoek (The Netherlands)*	
15h00-15h20	**Coupling ozone and activated carbon adsorption for organic micropollutants removal in advanced wastewater treatment** *Ronan Guillossou, Johnny Gasperi, Julien Le Roux, Romain Mailler, Stephan Brosillon, Emmanuelle Vulliet, Catherine Morlay, Fabrice Nauleau, Vincent Rocher (France)*	
15h20-15h40	**Where to go next to advance the design and operation of ozonation and advanced oxidation of secondary effluent and surface water** *Wim Audenaert, Usman Rehman, Ingmar Nopens, Achim Ried (Belgium, Germany)*	
15h40-16h10	**Coffee break, poster session and exhibition**	

16h10-17h10	**Session 9. Process engineering (cont'd)** | **Chair: S. Brosillon**	
16h10-16h30	**Diffusion of Gas with Bubble Column in fully Turbulent Flow** *Pierre-André Liechti, Robert Hausler (Switzerland, Canada)*	
16h30-16h50	**How new generator technology can contribute to expanding ozone applications** *Elodie Aubin, Luca Ramoino, Walter Uttinger, Hanspeter Fellmann, Christopher Huynh (Switzerland)*	
16h50-17h10	**Numerical simulation of the efficiency of full-scale ozone contactor** *Elamine Gheffari, Sylvie Baig, Daniel Pierrat (France)*	
17h10-18h00	**Closing session and Award Ceremony**	

Exhibition

Friday 7 September

9h00-16h00	**Technical tour with lunch** **Technical visit of Drinking Water Plant of the Bret Lake** **Lunch at Restaurant du Lac**

KEY NOTE SPEAKERS

Prof. Dr. Urs Von Gunten has a joint appointment between Eawag, the Swiss Federal Institute of Aquatic Science and Ecole Polytechnique Fédérale de Lausanne (EPFL) where he is a full professor. He is an internationally recognized expert on oxidation processes and has co-authored one book and more than 200 publications. He has received several international awards among them the distinction of being listed as a Thompson Reuter Highly Cited Researcher in 2014 and 2015. Besides his academic activities, he collaborates regularly with practitioners from the water sector; from 2004-2008 he was the head of the trans-disciplinary project "Water supply for the 21st century" and from 2013-2016 he was the head of the trans-disciplinary project "Regional Water Supply Basel-Country", one of the Swiss cantons (states). In the last two decades he was strongly involved in the application of ozone for enhanced municipal wastewater treatment for micropollutant abatement, which is now implemented in Switzerland.

Dr. Saad Y. Jasim, P.Eng. is Manager, Utilities for Engineering and Municipal Operations, City of White Rock, British Columbia, Canada.He served as an Acting Research Director and Principal Investigator at the Qatar Environment and Energy Research Institute (QEERI). Before joining QEERI, Dr Jasim was the President of SJ Environmental Consultants (Windsor) Inc. (1993-2005 and 2013-2015) and Adjunct Research Professor at the University of Western University, Canada from 2009. He is also Adjunct Professor, University of Windsor since 1996 and serves on the Editorial Board of OS&E Journal and on the Editorial Board for Water Process Engineering. He also worked on the Editorial Board of the Desalination Journal from 2009 to 2012. Dr. Jasim served as Director of the Great Lakes Regional Office-International Joint Commission. He managed the operation of the Scientific and Technical programs, initiated strategic partnerships and alliances with the stakeholders. Served as the Founding CEO for the Walkerton Clean Water Centre, developing it to be one of the leading research and training institutes for water treatment in Canada. He was also the past president of the International Ozone Association-PAG. Saad Jasim received his masters and Ph.D. degrees on Chemical Engineering from the University of Wales in Swansea, UK, and is the recipient of several awards such as the recognition award from the International Network for the Advancement of Water & Wastewater Education (2013) and the Harvey Rosen Award for Best Publication (2011) about Ozone. He supervised PHD and master students and has many papers in peer reviewed journal publications and international conferences. He is President-elect of the International Ozone Association.

Mr. Bernhard Paolini has a degree in Mechanical Engineering from the University of Applied Science of Zürich with specialty in the field of thermal process engineering. He also had advanced studies in business administration, national economy, legislation and finance. He became technical director of a company producing control and safety devices for oil and gas burners and Vice President of a company in the field of pressure die casting. In 2001, he joined Ozonia as Vice President, Technology and was later appointed CEO of Degrémont Technologies AG Switzerland. He was instrumental in development of the new ozone generation technology for Ozonia/Degrémont. In addition to his current responsibilities with Ozonia/Degremont/Suez, Mr. Paolini has been active with several other organizations in working for approval of ozone as a biocide in the European Union. In this context, he has been appointed volunteer Chairman of EurO3zon, the group coordinating the approval process. He is President of the International Ozone Association.

Dr. Sylvie Baig received her degree as a chemical engineer in 1989 and obtained three years after her PhD from the National Superior School of Chemistry at Toulouse, part of National Polytechnic Institute of Toulouse, France. In 1992, she joined the company Degrémont, subsidiairy of Suez, as Research Engineer. She is currently Head of Scientific Innovation at the Suez, Strategic Development Department, in charge of collaborative innovation with academia and industry partners, innovation valorization through scientific and technical communication and acting as referent for R & D/industrialization projects and expert for business projects. Through these missions, she works on treatment technologies for water, sludge, air in both industrial and municipal areas. She is co-author of the Suez's degremont water handbook, active in events in the water field and in the international network of associations and institutions. She is Past President and Honorary Member of the International Ozone Association and particularly leads its Ozone Engineering Group.

Prof. Michel Roustan is currently Emeritus Professor, INSA (National Institute of Applied Sciences) Toulouse, France. After having obtained the graduate of Engineer INSA of Toulouse (Chemical Engineering), Michel Roustan is named lecturer, associated professor and Professor in 1983. He carried out his career with the INSA of Toulouse, a French engineer school INSA at the Process Engineering Department. Teaching activities concern the lessons in the following fields of chemical engineering: basic concepts of mass transfer, gas-liquid chemical engineering reactor (hydrodynamic, kinetic and transfer), unit operations (absorption, mixing, fluidisation….), basic concepts for water and gas treatments. The research themes are related to the study of the multiphase reactors (gas-liquid-solid) applied to the field of water treatment (drinking water, urban and industrial waste water) and gas effluents. The originality is to apply the basic concepts of the chemical engineering for the conception and design of new equipments and processes more efficient, compact and safety, for the resolution of environmental problems in the field of aqueous and gas pollutions. He has been supervisor for 47 PhD thesis. He is Vice-President of the International Ozone Association, EA^3G Group and Honorary Member of the Association.

ABSTRACTS OF PRESENTATIONS

Session 1. Introductory Keynote lectures

1.1. Enhanced municipal wastewater treatment for micropollutant abatement by ozone

U. VON GUNTEN (Switzerland)

The presence of micropollutants in water resources and the urban water cycle from many sources such as agriculture, municipal wastewater and industry has raised concerns about the eco- and human toxicity of these compounds. The options for the reduction of the micropollutant load are manifold and range from source control (e.g., stricter regulations) to end of pipe solutions (wastewater and drinking water treatment). In Switzerland it has been decided to upgrade municipal wastewater treatment plants with an additional polishing step, either by ozonation or by activated carbon (powdered activated carbon, granular activated carbon) to reduce the discharge of micropollutants to the aquatic environment. This talk will focus on ozonation.

There are 4 factors which need to be consider to assess ozonation processes for micropollutant abatement in wastewaters: (i) reaction kinetics, which control the efficiency of the process, (ii) elucidation of the formation of transfomation products by experimental and theoretical approaches, (iii) formation of oxidation by-products (e.g., bromate) from the matrix, (iv) biological effects after ozonation, resulting from transformation products and/or oxidation by-products. To cope with all these issues, recently, a practical test system has been developed to assess the feasibility of an ozonation for a particular wastewater.

1.2. Global Water Crisis; Contaminants and Shortages, a Shared Responsibility

S. Y. JASIM (Canada)

Sustainable and equitable management for water sources and supply are key factors for a successful rational decision making. The United Nations expects demand for water to increase by nearly one-third by 2050. The increase in water demand should be met with the will to accept change. There are significant challenges facing fresh water supply such as harmful algal blooms, the discharge of chemicals of emerging concern (pharmaceuticals, personal care products and endocrine disrupting chemicals) which impact the health of humans, wildlife and the ecosystem.

Urban growth and the impact of Climate change should not be absent from sustainable planning. The investment in improvement of infrastructure should be considered in a serious manner. The growth of agricultural and animal farms is expected to lead to higher consumption of water and an increase in waste discharge.

Advanced water treatment technologies play a key role to address challenges facing local authorities and water system professionals to meet new targets for water quality and combat climate change. The investment in infrastructure can be achieved by collaboration between governments, private sector, academia and water system authorities which represent a significant joint approach to address the need to provide financial and technical support to provide sustainability of safe and reliable water supplies. Recent Government of Canada and Government of British Columbia grants provided strong examples of such collaboration.

Ozone oxidation of chemicals of emerging concern in water, wastewater or natural waters, emerged as an effective technology to address these challenges facing water reuse applications and need to be studied further to evaluate its effectiveness in the degradation of these compounds under different operational and site conditions.

Cyanotoxins is another global concern for drinking water systems, applications of technologies such as ozone and ozone based advanced oxidation processes are leading technologies to deal with this challenge.

1.3. A tour through the European Regulations for ozone treatment

B. PAOLINI, T. PÜHMEIER, J. MIELCKE, M. ROTHE, M. HOFFMANN, J. RYCKEBOER (Switzerland, Germany)

REACH is a European regulation for mitigating the risk originating from chemicals. However the use of ozone governed for many applications and operators by this new regulation with the obligation to register their production of ozone. This regulation does not necessary affect every end-user as there are some limited exemptions available.

The Biocidal Product Regulation EU/528/2012 (BPR) is in force since September 1st 2013. In the past ozone was already recognized as a biocide, but its registration obligations were exempted following special rules for in-situ produced biocides. This special status was revoked under the BPR. As a result ozone equipment which is placed in the EU market for biocidal applications (i.e. disinfection) requires EU authorization.

This publication does not aim to replace any official EU guidance, but rather to provide focus and overview to REACH and BPR in relationship to the substance ozone. Additionally to extent and share the knowledge about the boundaries of the registration requirements relates to ozone applications.

1.4. Mastering ozonation fundamentals to ensure the micropollutant removal and control byproducts release

S. BAIG, M. ROUSTAN (France)

The question of ozonation performances for micropollutant removal with parallel control of byproducts release can be at best addressed by implementing a rigorous approach that covers: Oxidation kinetics of µpollutants and byproduct precursors, Coupling hydraulics and kinetics for the best performance of ozonation, Combination of ozonation with downstream technologies for control of by-products. Examination of all these aspects leads to a global sound strategy to which one should refer to achieve an optimal treatment solution.

Session 2. Fundamentals

2.1. Comparison of O_3, ferrate, ClO_2, and permanganate pre-treatment on NOM's characteristics and formation of DBPs
V. ROUGÉ, S. ALLARD, U. VON GUNTEN, J.P. CROUÉ (Australia, Switzerland)

Ozone (O_3) is commonly used as pre-treatment prior coagulation, flocculation and/or BAC filtration to enhance DOC removal. Recently, a new analytical technique representing the redox state of DOM, the electron donating capacity (EDC), was developed and it was shown that O_3, chlorine dioxide (ClO_2) and chlorine led to different electrochemical characteristics in DOM.[1, 2] In this study, the EDC, in addition to usual optical measurements, such as the UV absorbance at 254nm (UV_{254}) are used to monitor the changes in DOM properties for different chemical pre-treatment: O_3, ferrate (K_2FeO_4), ClO_2, and permanganate ($KMnO_4$). It was shown previously that pre-oxidation of the waters led to mixed results for DBPs mitigation.[3, 4] Therefore, the impact of these pre-treatment on the formation of DBPs during subsequent chlorination is investigated. Using a combination of UV_{254} and EDC measurements might provide additional information on DOM characteristics and its reactivity with oxidants, especially during pre-treatment with ozone.[5]

2.2. Quantification of electron-donating capacities for the assessment of oxidative water treatment
L. ÖNNBY, E. SALHI, U. VON GUNTEN (Switzerland, Sweden)

Dissolved organic matter (DOM) which is present in all types of water matrices interacts with oxidants such as ozone, chlorine or chlorine dioxide during oxidative water treatment. The result from the DOM-oxidant reactions is in turn lowered oxidation efficiency, less efficient micropollutant abatement and a potential formation of undesired disinfection by-products (DBPs). Recently, studies with regards to the changes of the electronic properties of the DOM, by quantification of the electron-donating capacities (EDC) have led to increased chemical knowledge about both reaction pathways and prediction of DBPs formation during ozonation. In this study, reactions between DOM isolates in the pH range between 2-9 were studied, including a smaller set of reactions with pre-ozonation followed by post-chlorination. Our data showed that a lower pH (2 to 3) a similar abatement of the relative EDC and the relative UV occurs during ozonation. During ozonation at higher pH (7 and 9), a higher relative EDC abatement was observed compared to relative UV abatement. Benzoquinone formation resulting from ozone reactions with phenolic moieties of the DOM explains these observations well. For > 40% relative EDC abatement during pre-ozonation of Suwannee River fulvic acid, a lower chloroform formation could be observed during post-chlorination. Based on this observation relative changes in EDC could potentially be used as an indicative tool for chlorine-induced DBPs formation during oxidative water treatment.

Session 3. Fundamentals (cont'd)

3.1. Microbial Counts and Antibiotic Resistances during Conventional Wastewater Treatment and Wastewater Ozonation
K. KIRCHNER, I. BRÜCKNER, K. KLAER, M. HAMMERS-WIRTZ, J. PINNEKAMP, M. A. ROSENBAUM (Germany)

In view of the increasing interest in the occurrence and spread of antibiotic resistant bacteria due to wastewater treatment systems in the environment, total colony counts and antibiotic resistant bacteria were determined in regard of a conventional wastewater treatment plant and its upgrade with a wastewater ozonation. To cope with the elimination of conventionally not sufficiently decimated micropollutants, the Eifel-Rur Waterboard built a full-scale ozonation plant. To evaluate the effect ozonation has on the receiving water's biocenosis, extensive monitoring of the WWTP and its receiving water, river Wurm, is performed before and after implementation of ozonation and in preliminary pilot scale ozonation experiments. Total colony counts showed no significant difference between the river Wurm upstream and downstream of the WWTP and were slightly below average of comparable investigations. Antibiotic resistances showed only little differences between WWTP and the river samples. Furthermore, no accumulation of antibiotic resistances was found at the conventional WWTP. Pilot scale ozonation yielded a reduction of total colony counts of fecal indicator bacteria *E. coli* and Enterococci after ozone treatment. The pilot scale experiments gave no indication that ozone treatment leads to a rise in antibiotic resistances against selected antibiotics of different antibiotic classes.

3.2. Virus inactivation by ozone natural matrices: potential proxies for viral inactivation
C. WOLF, A. PAVESE, U. VON GUNTEN, T. KOHN (Switzerland)

Ozone is an efficient disinfectant for waterborne viruses. In a previous study, we measured the inactivation of a suite of human viruses and bacteriophages by ozone in well-controlled buffer solutions, and determined inactivation rate constants ($k_{O3\text{-}Virus}$) on the order of 10^6 $M^{-1}s^{-1}$ (*Wolf, 2018*). These buffer solutions have a relatively simple composition, whereas in natural waters, virus inactivation may be inhibited or promoted by different matrix constituents. Therefore we measured the inactivation of MS2 coliphage and coxsackievirus B5 (CVB5) in surface water (SW) and wastewater effluent (WW) as a function of ozone exposure, to determine if matrix constituents influence the inactivation of viruses by ozone.

3.3. Determining viral inactivation after ozone treatment using a novel transfection-based most probable number assay
J. TORREY, U. VON GUNTEN, T. KOHN (Switzerland)

Ozone treatment is utilized by several water treatment facilities for disinfection of harmful microorganisms and the control of unwanted taste and odor; more recently, it is becoming recognized for its efficiency in removal of emerging contaminants, such as organic micropollutants. As a strong oxidant, ozone displays broad disinfection efficacy against many microorganisms of interest, including non-filterable pathogens such as viruses. Although ozone possesses potent antimicrobial activity, the main mechanism of action (e.g., disruption of protein coating, damage to genome, etc.) by which ozone inactivates viruses is still unclear. In this study, we propose a method to determine the loss of virus genome functionality using transfection, the act of directly inserting genetic material into a host cell. RNA from ozone treated and untreated viruses was transfected into cells to observe the loss of the virus genome's ability to produce new progeny virus. This reduction was compared with the actual loss of infectious virus (determined by cell culture) as well as the reduction in genome replicability determined by quantitative polymerase chain reaction (qPCR), another method for determining genome functionality loss.

3.4. A review on the research and application of ozone catalytic oxidation

P. LIU, J. MA, Y. REN (PR China)

Thousands of papers focusing on the catalytic ozonation are published every year. Among them, catalvtic ozonation techniques, as a kind of advanced oxidation processes (AOPs), maybe the hottest spot with the number of the papers increasing fivefold in the last ten years. As it owns the advantage of their strong oxidability, high efficiency, on-line preparation, no secondary pollution and widely adaptability in water decontamination. It is vital to understand those factors in order to apply this technique in water treatment at an industrial scale. The latest findings on removing the different pollutants are compared. Some typical catalysts, such as the transition metal ions, the metal metallic oxides, the carbon-based materials, the mesoporous composite catalysts and their derivatives were statistically analyzed. Comparing to heterogeneous catalytic ozonation, the heterogeneous catalyzed ozonation didn't need the restricted reaction condition, the removal step of high concentration metal ions, and it would not cause the secondary pollution. Furthermore, the composite catalysts combining two or more catalysts may gain a synergy for enhancing the catalytic performance. A possible mechanism model is put forward to explain that the vital role of the surface hydroxyl groups and the surface property in catalytic process. Finally, the removal efficiency of different techniques are compared, and the catalytic ozonation systems exhibit the excellent catalyzed performance and inimitable advantages. The results illustrated that the catalytic ozonation systems would play an indispensable role in water treatment.

3.5. Solar simulated radiation assisted photolytic ozonation for the removal of aqueous anthropogenic pollutants

R. SOLÍS, J. RIVAS, O. GIMENO, F. BELTRÁN (Spain)

The solar photo-assisted ozonation using simulated solar radiation has been individually applied to the oxidation of three aqueous anthropogenic organic compounds of environmental concern: bezafibrate, cotinine and iopamidol. The influence of different filters that restrict the radiation to 300-800, 360-800 and 390-800 nm has been explored for the removal of the target compounds and mineralization extent. It was found that solar photolytic ozonation enhances the oxidation of the tested compounds, especially those highly recalcitrant to direct ozonation (cotinine and iopamidol). The order of effective radiation was: 300-800>360-800>390-800 nm. Hence, the more energetic the radiation spectrum was, the faster and higher extent of mineralization was reached. Photolytic ozonation with radiation in the range of 300-800 nm (that is, similar to solar radiation) was capable of mineralize 86.2, 36.9 and 77.7% of bezafibrate, cotinine and iopamidol, respectively.

Session 4. Fundamentals (cont'd)

4.1. Degradation of iopromide by the UV-chlorine process

C. FALANTIN, J. CRIQUET, S. ALLARD (Australia, France)

Iopromide is a X-ray contrast media widely found in the aquatic environment. Iodinated X-ray contrast media are highly stable in the environment and recalcitrant to most treatment processes. In this study, its degradation by the UV/chlorine advanced oxidation process has been tested. This process increases the degradation of iopromide compared to photolysis alone and to the hydrogen peroxide/UV process. Higher amounts of radicals and powerfull chlorine radicals formed explain the higher degradation rate. A great decrease of organic iodine is observed indicating a further degradation of the by-products formed. Iodine is transformed into iodide and into iodate for high dose of chlorine. An increase of I-THMs formation with increasing UV irradiation and chlorine dose has been observed. Furthermore, the presence of natural organic matter largely increases the formation of I-THMs.

4.2. Photo-induced persulfate oxidation of emerging micropollutants in water matrices

N. DULOVA, E. KATTEL, B. KAUR, M. TRAPIDO (Estonia)

The efficacies of UV photolysis, UV-activated persulfate (UV/PS) and combined UV/Fe^{2+}-activated persulfate (UV/PS/Fe^{2+}) systems for degrading of different emerging micropollutants in ultrapure water and groundwater were examined and compared. The studied xenobiotics belonging to the different classes involved an artificial sweetener acesulfame K (ACE), beta-lactam antibiotic amoxicillin (AMX) and endocrine disrupting compound 4-nonylphenol (NP). Among the studied systems, the UV/PS/Fe^{2+} process showed the highest performance both in degradation and in mineralization of ACE (UVA-induced systems) and AMX (UVC-induced systems), followed by the UV/PS process. In the case of NP trials, the application of UVC/PS systems was the most promising, and after careful adjustment of oxidant concentration, it demonstrated a considerable improvement in the target compound degradation compared with the UVC photolysis. Irrespective of the applied UV-induced treatment process, the efficacy of target compounds degradation was lower in groundwater as compared with ultrapure water trials. The results of this study provide valuable information for further full-scale applications of UV-activated PS-based processes for the purification of water matrices with the most effective concentrations of reagents used.

Session 5. Poster session

Fundamentals

5.1. Reaction of aliphatic amines with ozone

S. LIM, C. S. MCARDELL, U. VON GUNTEN (Switzerland)

Ozonation has been proven to efficiently abate the micropollutant load in wastewater treatment. During typical ozonation processes, micropollutants are not fully mineralized but rather transformed into transformation products. Detailed knowledge of ozone reaction mechanisms is required to predict transformation products and assess their potential toxicity. Of the well-known ozone-reactive moieties, aliphatic amines are commonly found as structural moieties in micropollutants. They can be key moieties where transformation reactions occur because of their high reactivity towards ozone. However, current information on the corresponding ozone reactions is limited to tertiary amines. This study aims to broaden the understanding of the reactions on primary and secondary amines. Ethylamine, diethylamine, and triethylamine were chosen as simple model compounds and their transformation products were determined after ozonation. All amines mainly underwent oxygen transfer pathways. However, unlike triethylamine, ethyl- and diethylamine led to a more oxidized final product, nitroethane, with high yields. The significant formation of nitroethane observed in this study requires further efforts to understand the occurrence, fate, and effects of nitroalkanes in the aquatic environment.

5.2. Profilomic, large scale screening of emerging pollutants and far beyond

D. HALTER, M. SARTER, F. ROUHOLAHNEJAD (France)

Comprehensive analytical methods are needed to have a thorough picture of the micropollutant content of our water resources. Profilomic has developed fully automated analytical approach based on solid-phase extraction and liquid chromatography coupled to high resolution mass spectrometry (SPE-UHPLC-HRMS). The data can be processed to perform targeted and non-targeted analyses. Two examples of applications of this methodology are discussed in this paper: The first application discussed here involves identifying the compounds in a wastewater sample responsible for an endocrine disrupting effect observed in an animal model. The second example is related to targeted analysis to screen for micropollutants in samples taken before and after processing of wastewater in a treatment plant.

5.3. Comparison of different advanced oxidation processes used to the decomposition of organic pollutants in real thermal wastewater

Á. FAZEKAS, G. VERÉB, S. KERTÉSZ, S. BESZÉDES, C. HODÚR, Z. LÁSZLÓ (Hungary)

Thermal water often contains high amount of inorganic and/or organic contaminants, therefore its purification is required before the final disposal. Although phenolic and humic substances can be successfully eliminated from salty thermal wastewater by ozone treatment, the high radical scavenger ion content prevents the effective COD or TOC elimination from saline water. In the present study the purification of a real thermal wastewater (with high hardly oxidizable organic content and high carbonate concentration) was investigated comparing different AOPs, such as ozonation, Fenton reaction, and photo-Fenton reactions with different light sources. It was found, that ozone treatment was almost ineffective in COD and TOC elimination, but photo-Fenton reactions have given promising results. Investigating the effect of ferrous ion and hydrogen-peroxide concentration, the 1:25 molar ratio was found to be the most effective. Investigating the effects of different light sources, it was revealed that both the purification efficiency, and the COD or TOC elimination related “quantum yield” increased with the energy of photons due to their increased hydroxyl radical producing effect during the Fenton reactions.

5.4. On the mechanism and phytotoxicity evolution during solar photolytic enhanced ozonation of tritosulfuron in water

R. SOLÍS, J. RIVAS, O. GIMENO, F. BELTRÁN (Spain)

Tritosulfuron (TRITO) oxidation by means of the combination of ozone and solar simulated radiation (300-800 nm) has been examined as a technology to improve the oxidation rate of this ozone recalcitrant herbicide ($k_{O3,TRITO}=9.4\cdot10^{-2}$ $M^{-1}s^{-1}$). A complete degradation was achieved after 30 min of photolytic ozonation, while single ozonation reached a 90% removal in 2h. Mineralization was highly improved when radiation and ozone were integrated. After 2h of ozone+radiation and ozonation application, 80 and 20% TOC conversions were reached, respectively. Accurate mass LC-MS-ESI(-)-QTOF was used to identify oxidation intermediates. Mass to charge ratio (m/z) 236.0401 outstands from the rest as the main byproduct from all the observed intermediates. In general, photolytic ozonation demonstrated to be more efficient in the removal of the generated Transformation products (TPs) as can be extracted from their peaks areas. TRITO displayed a moderate toxicity towards lettuce germination assay (50% of initial inhibition), which was completely removed with the application of photolytic ozonation during 2h. After single ozonation application, a 10% inhibition still remains.

5.5. Mechanisms of reaction of ozone and ozone-UV with 2,5-dichlorophenol

J. C. ALEXANDER, C. GARCIA-MARTINEZ, C. R. RAMIREZ-CORTINA, I. HERNANDEZ-PEREZ (Mexico)

This investigation is focused on studying the different reaction mechanisms of ozone and ozone-UV with 2,5-dichlorophenol (DCP) in distilled water and wastewater. The chloride ion concentrations of 2,5-DCP within the first five minutes was faster in the wastewater solutions (S2) than in the distilled water solutions (S1). The chloride ions concentration measured in the 2,5-DCP solutions of S1:O_3, S1:O_3-UV, S2:O_3 and S2:O_3-UV were 14 %, 18%, 28% and 37% respectively. The use of photolytic process favors free radical hydroxylation of 2,5-DCP, over the ozone addition process. This is deduced from the low concentration of intermediates detected when the oxidation of 2,5-DCP was carried out with ozone-UV oxidation. The oxidative by-products identified after 60 minutes of ozonation and ozone-UV radiation were 2,5-dichlorohydroquinone, 3,6-dichlorocatechol, 4-chlororesorcionol, phenol, hydroquinone, catechol, 4-chlorocatechol, 3-chlorophenol, acetic acid, pentanoic acid, propanoic acid and glycolic acid.

5.6. Simultaneous dosing of ozone and hydrogen peroxide for advanced oxidation treatment of municipal wastewater effluents

A. CRUZ-ALCALDE, S. ESPLUGAS, C. SANS (Spain)

The combination of ozone and hydrogen peroxide, known as peroxone, is one the potential good candidates for an efficient treatment to abate micropollutants in municipal wastewater effluents. The combination of both oxidants produces large amounts of hydroxyl radical which unselectively may degrade the more refractory micropollutants presented in the water matrix. In this work, by using a two-stage model based on the hydroxyl radical exposure versus the transferred ozone dose (TOD) (•OH-exposure/TOD ratio), three different wastewater effluents from two WWTPs were tested using Acetamiprid as model ozone-resistant micropollutant. According to the experimental results, both effluent properties and employed oxidant ratios significantly affected the treatment performance. In addition, carbonates and bicarbonates typically present in wastewater effluents played an important role in the degradation of micropollutants.

5.7. Protection mechanism of rubbers from ozone attack

F. CATALDO (Italy)

Ozone is a pollutant at the ground level derived from the anthropogenic activities such as combustion and VOCs release in the environment. The ozone concentration at the ground level passed from <10 ppb in pre-industrial era to 50 ppb of the present time. Ozone concentration at ground level is growing at a rate of 1% per year. Rubber articles and tires are degraded by the ozone attack. The increasing ozone concentration in air requires adequate protection of rubber goods to avoid premature ageing and failure. At present, the best antiozonant molecules used in the industrial practice are N,N’-substituted p-phenylenediamines (PPDs). In this review, the reaction of ozone with diene rubber double bonds are examined together with the macroscopic effects produced by ozone in the rubber articles. Since the protection of rubber from ozone is ensured by the addition of PPDs, in this review the early stages of ozone reaction with PPDs are discussed in detail using both theoretical and experimental results. The stoichiometry O_3/PPD was determined experimentally. It was found that each single PPD molecule is able to scavenge at least 4 ozone molecules.

5.8. Assessment of ozone and solar-light based AOPs in the removal of NOM and DBPs formation potential
A. REY, E.-M. RODRÍGUEZ, R. SOLÍS, F. BELTRÁN (Spain)

The degradation of chlorination-DBPs precursors in surface water was studied by means of different ozonation and solar AOPs (i.e. ozonation, photolytic ozonation, TiO_2 photocatalysis and TiO_2 photocatalytic ozonation). The efficiency of the treatments was assessed in terms of the evolution of DOC, A_{254}, $SUVA_{254}$, TPC, short-chain organic acids and also the fractionation of raw and remaining NOM and their corresponding DBPFP. DBPs analysed after subsequent chlorination were THMs, HAAs and AOX. The combined treatment of solar photocatalytic ozonation using TiO_2 promotes a fast mineralization of NOM leading to the lowest DBPFP. Main precursors of THMs and HAAs were hydrophobic compounds whereas total AOX formation was favoured by the hydrophilic fractions of NOM.

5.9. Electrochemical generation of ozone over nickel, niobium doped tin oxide electrode
M. VENKATA SIVAIAH, A. DEVADAS, H. GHEE ANG (Singapore)

Nickel, Niobium doped Tin Oxide (NNTO) electrodes were fabricated and employed as anodes in proton exchange membrane assisted electrochemical cell for generation of ozone. A customized flow cell using 0.1 M H_2SO_4 as anolyte and catholyte was investigated to study the performance of NNTO electrode with varying dopant concentrations for ozone formation. Electrochemical characterization of NNTO electrode was performed in a three electrode cell to ascribe its ability for oxygen, ozone generation. The results revealed that NNTO electrode functions as a electrocatalyst for ozone generation and its high activity was observed on 6, 1 % doping of Nb, Ni respectively in place of 'Sn' in Tin Oxide.

5.10. Heterogeneous catalytic ozonation of diclofenac using $Fe_3O4/SiO_2/Co_3O_4$
L. W. LU, C. N. CHANG, Y. P. PENG (Taiwan)

Heterogeneous catalytic ozonation is a novel type of AOPs to promote the capacity of oxidation. The Cobalt oxide catalyst can catalyze ozone to generate free radicals and then achieve mineralization of dissolved organics effectively in water. Cobalt oxide (Co_3O_4) could be supported on magnetic Fe_3O_4/SiO_2 for recovery. The presence of Co_3O_4 catalyst during ozonation at pH 5 results in the production of hydroxyl radicals, which acts as strong oxidants. Catalyst which is covered by surface hydroxyl groups will be protonated or deprotonated when pH of solution is below or above pH_{pzc}. Methylene Blue and Diclofenac had the optimal condition of pH at 5 due to pH of solution more closed to pH_{pzc} can reach the activity of catalysts to generate more hydroxyl radicals which the surface hydroxyl groups of catalysts will be generated and revealed in solution to be $^{\bullet}OH$ which is more powerful oxidant. Dosage of from 1.0 increased to 2.0 g/L, the TOC removal had not enhancement apparently. The enhanced generation of H_2O_2 in the catalytic ozonation has evidence for the development of DCF degradation. The TOC was insignificant decreased after 30 minutes in COP of pH5 and pH11. In SOP of pH5, the maximum yield of H_2O_2 that was generated 2.28 at 60 minutes and it was the lowest of all reaction.

5.11. Degradation of two antihypertensives by hydroxyl and sulfate radicals
M. C. STARLING, P. PATTERSON, A. LE PERSON, C. COSTA DE AMORIM, J. CRIQUET (Brazil, France)

Losartan Potassium (LP) and Furosemide (FRSM) are consumed mainly by hypertensive patients. Their consumption is predicted to increase in the next years, and thus will they discharge onto surface waters. Therefore, it is important to establish effective treatment technologies for the removal of these compounds in water treatment plants, thus preventing their occurrence in drinking water.
In the present work, quantum yields (Φ254nm) for LP (0.016) and FRSM (0.024) were determined. The addition of hydrogen peroxide or persulfate in the irradiation process largely increases the degradation of losartan potassium while the degradation of furosemide is only slightly higher in presence of reactants. TOC degradation was reduced, indicating accumulation of degradation products.

5.12. Ozone in nuclear physics detectors at accelerators
V. KRAMARENKO, I. TKACHENKO, S. TKACHENKO (Russia)

Safety aspects and the role of ozone are considered in this paper during the operation of nuclear physical detectors of charged particles in the ATLAS installation on the Large Hadron Collider. The ozone arisesin the gas drift detectors which detect charged particles under the influence of shock ionization. Ozone is rather stable connection hazardous to health of the person maximum permitted concentration (MPC)=0,1 mg/m^3 and causing corrosion of drift detectors of the ATLAS installation. Generation and accumulation of ozone are measurement at the detectors prototypeand real ATLAS installation during operation of the Large Hadron Collider. The decomposition of ozone was carried out by a filter GTT designed on Faculty of Chemistry Moscow State University and manufactured by firm of TIMIS.

5.13. Comparative study of conventional and advanced disinfection processes applied to urban wastewaters
P. VALERO, R. MOSTEO, J. L. OVELLEIRO, M. P. ORMAD (Spain)

More and more, water resources are increasingly coming under stress, leading to water scarcity and quality deterioration. In this context, a wider reuse of treated wastewater appears as an alternative solution to the use of drinking or pre-drinking water for some applications. Thus, wastewater reuse can help lower the pressure on freshwater resources, reducing and preventing pollution of surface water, as well as the overexploitation of aquifers. The high microbial load of faecal origin, which is in urban wastewaters, can reduce to some extent through the different processes of a conventional wastewater treatment plant (WWTP), especially during the biological treatment process. However, treated wastewaters still contain relatively high concentrations of indicator bacteria, such as *Escherichia coli* and *Enterococcus* sp., pointing out the possible presence of pathogenic microorganisms. The main objective of this research work is the study of several AOPs, which might be suitable as alternatives or complements to the conventional disinfection treatments. The research is focused on the removal of bacterial indicators of faecal pollution (*Escherichia coli*, *Enterococcus* sp. and *Staphylococcus aureus*) present in WWTP effluents, with the aim of achieving reclaimed water susceptible of being reused. As a conclusion, the chlorination and the ozonation show a high disinfectant power in WWTP effluents, although the possible generation of organochlorinated compounds during the chlorination might be a problem for their reuse. The ozonation avoids the issue of excessive trihalomethanes formation without losing inactivation efficiency and with an operational cost comparable to chlorination, being its main disadvantage the need of more complex infrastructures with a considerable investment cost. The photo-electro-Fenton treatments are an efficient alternative, with relatively long exposure times and operational costs higher than ozonation but without the need of very complex equipment. Finally, the TiO_2 photocatalysis not only shows slow inactivation rates in WWTP effluents and high operational costs, mainly related to TiO_2 cost, but also has to address the issue of the nanoparticles presence and their removal from the water through nanofiltration, thus reducing the impact on the receiving environment.

5.14. Researches on active and passive monitoring of the aeromicroflora in bakery units and the results obtained from the use of the GF 3XO - AW8 ozone generator
I. E. POPA, G. PUCHIANU, D. V.,ENACHE, V. NECULA (Romania)

For monitor the microaeropholore in the backyard processing premises, we took sampling using active monitoring procedures (by taking determined amounts of air), which have become an essential tool for environmental monitoring, in units operating in the food industry .
The microbiological examinations performed were: detection of the total number of aerobic bacteria (TNG) / m^3 of air and the number of yeasts and molds / m^3 of air.
To perform the active monitoring, we took out defined amounts of air passed through a sampling device directly onto a solid culture medium. The sampling was carried out in two distinct time periods: one in which no microbiological air decontamination equipment was used and the other used ozone generating equipment of the GF3XO1000 class. Generators produce large amounts of ozone, and can also work in the presence of humans.
After sampling during the two time periods incubation of the plates at different temperatures was performed according to the target organism and then the microbiological air load was determined by estimating the number of microorganisms expressed as cfu / m^3.
Following the experiment, we have found that ozone generating equipment of the GF3XO1000 class, makes a significant improvement in microclimate conditions, the effect being the considerable reduction of the risk of microbiological contamination on the different stages of processing the bakery products with pathogenic microorganisms and alterations present in the air.

5.15. Aldehyde abatement based on ozonation in homogenous gas phase
L. VITOLA PASETTO, F. VIOLLEAU, R. RICHARD, J.-S. PIC, V. SIMON, M.-H. MANERO (France)

Carbonyl compounds – especially aldehydes – are common air pollutants due to a large variety of emission sources, such as exhaust gases from motor vehicles and chemical plants including food industry, wastewater, incineration and fertilizer plants. In order to reduce the negative impact caused by these odorous compounds, several techniques can be applied, such as reactive absorption (wet scrubber in presence of oxidant agent)3, adsorption on activated carbon4, biological treatment (biofilter)5 and thermal or catalytic oxidation6. In this study, feasibility of odor treatment based on ozonation in homogenous gas phase has been evaluated as a new alternative to heterogeneous treatments and to situations when thermal oxidation cannot be implemented (due to low pollutant concentrations or high energy demand). Selecting butanal as reference compound of odorous aldehydes, we have studied the removal efficiency by ozone in warm conditions (50 to 100°C). An experimental design based on Doehlert matrix was employed to optimize and to investigate the influence of the process parameters on the butanal conversion rate. Four operating conditions were studied residence time at the reactor (2 to 20 s); inlet molar ratio between ozone and butanal (1 to 30); relative humidity (between 0 to 80%) and reaction temperature (50 to 100 °C). Satisfactory conversion rates superior to 90% were achieved when the operating conditions were kept at the optimal values.

Process development

5.16. Hard COD Removal in Textile Dye Effluent with a 2 Stage Treatment Applying Ozone Followed by Peroxone
B. HEINIGER, L. DE FRANCESCHI (Switzerland)

In several semi-batch tests it was demonstrated that a process starting with ozonation for the fast and direct electrophilic reactions, followed by peroxone-AOP (ozone/peroxide) for the removal recalcitrant COD was most efficient. To compare, the effluent from a textile dye industry in asia was also tested with ozone alone. The COD levels of the 2 main matrices was between 400 and 800 mg/L. COD removal rates of 44% were achieved with ozone and up to 55 % with ozone/peroxide. Beside the substantial COD reduction an almost complete discoloration was achieved in all tests including ozonation at original pH and peroxone at controlled pH.

5.17. Cyanide recovery from thiocyanate by ozonation of mining effluent
B. HEINIGER, L. DE FRANCESCHI, A. MURILLO (Switzerland)

The cyanidation processes for the extraction of gold or silver frequently involves the processing of sulfur, containing solids that react with cyanide, to form thiocyanate, which is an undesired reaction[1]. Usually, ozone is used as an alternative gas for oxidation in water treatment and cyanide removal[2]. Considering the number of gold and silver mining projects, cyanide recovery might be economically interesting but more attention is being focused on the reuse of cyanide by recovering cyanide from thiocyanate.
Tests performed by Ozonia showed that using synthetic test-water (thiocyanate in water), nearly 100% of thiocyanate was converted into cyanide (CN^-) at a stoichiometric rate of approximately 1:1.

$$SCN^- + O_3 + H2O \leftrightarrow CN^- + 2\ H^+ + SO_4^{2-}$$

The feasibility of the conversion of the contained thiocyanate into cyanide was studied in four ozone semi batches at different pH in real mining effluents containing a high concentration of COD of approximately 4 g/L and 2.3 g/L of SCN^-. Due to side reactions, the optimal absorbed ozone / converted thiocyanate is 1.5 units at the suitable pH. This study highlights a new application in the ozone water treatment and mining process field: cyanide recovery or cyanide recycling involved in gold mining leaching processes.
An economical study based on annual industrial SCN^- production of 600-650 T SCN^- / year was completed. The study showed that using Ozone for Cyanide recovery could save $700-800k per year.

Process Engineering

5.18. Effects of pre-ozonation on ultrafiltration of oil-in-water emulsions using different hydrophilic and hydrophobic membranes
G. VERÉB, J. VÉGH, S. KERTÉSZ, S. BESZÉDES, C. HODÚR, Z. LÁSZLÓ (Hungary)

Emulsified oily contaminants of wastewaters cannot be eliminated effectively by conventional treatments, but they pose significant risk both to the environment and to human health, therefore their efficient elimination is strongly required. Membrane filtration is a promising technique for the effective purification of oil-in-water emulsions, however usually the accumulation of hydrophobic contaminants on the membrane surface quickly leads to significant water flux reduction, which is a limiting factor of the economic utilization. In the present study short ozonation was investigated as a suitable pre-treatment to achieve lower flux reduction during the efficient separation of micro or even nano-scaled crude oil droplets by ultrafiltration. Results confirmed that pre-ozonation modified the surface charge (Zeta-potential) of the oil droplets which resulted reduced accumulation of the contaminants on the membrane surface and higher fluxes in case of all the investigated ultrafilter membranes (such as polyethersulfone - PES, Polyvinylidene fluoride – PVDF and Polytetrafluoroethylene – PTFE). Filtration experiments were carried out using ultrapure- and model groundwater matrices for a deeper discussion of available advantages, and it was concluded that in case of low ionic concentration the PES membrane provided the highest flux, however in case of realistic water matrix (model groundwater) the utilization of acetone conditioned PTFE ultrafilter membrane (combined with pre-ozonation) was much more beneficial. In overall, pre-ozonation decreased the total resistance in all cases, however, the reversibility of the measured filtration resistance and flux reduction was strongly dependent from both the matrix and the membrane surface material.

5.19. Thermal Vent Ozone Destructor Technology using Heat Recovery Process Improves Resistance to Hard Process and Operating Conditions
C. HUYNH, W. UTTINGER, E. AUBIN, H. FELLMANN (Switzerland)

Vent gases from processes where ozone has been used invariably contain residual amounts of un-reacted ozone. In most countries it is illegal to discharge even low concentrations of ozone. Before this gas can be released to the atmosphere, it is necessary to destroy the remaining ozone.
There are various methods available to treat vent gas but two types of methods are used in commercial scale ozone systems. Thermal Vent Ozone Destruct (VOD) products raise the temperature of the vent -gas to a level where the half-life of the ozone is reduced to milliseconds and can be destroyed efficiently and very reliable. Catalytic VOD products use a catalyst to accelerate the ozone molecule decay rate on the surface of the catalyst by converting the ozone to oxygen.

5.20. Catalytic protection against ozone of drift detectors of the atlas installation of the large hadron collider
S. TKACHENKO, V. KRAMARENKO, I. TKACHENKO, E. GOLOSMAN, V. LUNIN (Russia)

The modes and operating time in time (resource tests) of the ozone decomposition catalyst Goptalum the GTT brand and coal for the purpose of optimization of destructors – filters of ozone and the number of filling of catalytic materials are investigated. Ways of neutralization of influence of ozone on drift detectors are offered.

Session 6. Process development

6.1. A practical approach for the control of micropollutants removal during wastewater ozonation using kinetic and water quality parameters
A. CRUZ-ALCALDE, S. ESPLUGAS, C. SANS (Spain)

Ozonation is one of the most efficient treatment to abate micropollutants in municipal wastewater effluents. The transferred ozone dose needed to remove the more refractary micropollutants is still an issue mainly because the big influence of the physicochemical parameters of the water in this ozone dose. In this work, by using a two stage model based on the •OH-exposure/TOD ratio, six different wastewater effluents from five WWTPs were tested using Acetamiprid as model ozone-resistant micro pollutant. A good relation between the UV absorbance and the •OH-exposure/TOD ratio was obtained. This allows to have a good strategy for predicting the TOD needed to abate micropollutants.

6.2. Ozonation performance for micropollutants removal from source-separated urine
H. DENG, C. GUIGUI, J.-S. PIC (France)

Ozonation process was applied to reduce unwanted organic contaminants from urine effluents after a series of pre-treatment units (biological treatment–ultrafiltration (UF)-struvite precipitation). Prior to precipitation, a mixture of 7 target pharmaceuticals compounds (PhACs) (ofloxacin OFL, sulfamethoxazole SMX, propranolol PRO, carbamazepine CBZ, 2-hydroxyibuprofen 2OH-IBP, diclofenac DIF and ibuprofen IBP) was spiked into UF permeates. Considering the high load of caffeine (CAF) in the urine sample, no CAF was spiked into UF permeates. Ozonation behavior of urine effluents after pre-treatment was evaluated in a semi-batch reactor where ozone gas was continuously injected into the reactor at 50 mg NL^{-1} and 30 NL h^{-1}. The removal efficiency was evaluated in terms of non-purgeable dissolved organic carbon (NPOC), dissolved inorganic carbon (DIC), chemical oxygen demand (COD), pH, ion species and PhACs residual. These results obtained here showed that the targeted PhACs could be effectively eliminated by ozonation with 482 mg cumulated consumed ozone dose corresponding to 2.81 mg cumulated transferred ozone per mg $NPOC_0$. The high content of organic (NPOC) and inorganic matter ($N\text{-}NH_4^+$) in the effluent matrix could influence the apparent ratio between consumed O_3 and micropollutants carbon removed. It should be pointed that, the ozonation step for micropollutants elimination should be carefully conducted since the monitoring of global parameters (NPOC, COD, O_3 demand…) is not precise enough for the very low micropollutants concentration observed in urine effluents.

6.3. Successful landfill leachate wastewater treatment using the sequence of ozonation, adsorption on charcoal and photo-ozonolysis
F. CATALDO (Italy)

Landfill leachate derived from the landfilling practice of the municipal wastes is a problem affecting all countries and continents. Even after the shutdown of a landfill site, the leachate production continues for decades. In this work a solution for the landfill leachate treatment has been proposed based on three fundamental steps: the pre-ozonolysis of the leachate, the passage of the ozonized leachate through a fixed bed of activated carbon and the final step consisting in a photo-ozonolysis stage involving in the simultaneous action of ozone and UV light. A distinction between the chemical structure and chemical behaviour of young and old leachate was evidenced by thermal analysis of the soluble organic matter (SOM) obtained from these substrates. Furthermore, a distinction between young and old leachate was also evidenced in terms of their different reactivity toward ozone as illustrated by the COD abatement and by FTIR spectroscopy on pristine and ozonized SOM. A modular pilot plant for the treatment of different leachate types was presented and proposed.

6.4. UV/H_2O_2 before biological treatment in drinking water: effects on the removal of micropollutants and biodegradability
R. WÜNSCH, D. CAYON, F. EUGSTER, J. PLATTNER, J. GEBHARDT, R. WÜLSER, U. VON GUNTEN, T. WINTGENS (Switzerland, Germany)

To avoid anthropogenic trace organic compounds (TrOCs) to enter the drinking water, UV/H_2O_2 can be used as an advanced oxidation process (AOP) for their removal during drinking water production. Produced •OH radicals also react with natural organic matter (NOM), leading to increased bio-availability, hence resulting in a higher removal of NOM in a subsequent biological filtration. In this study, two pre-filtered river waters (Rhine and Wiese) were treated on a continuously operated pilot plant. The UV dose was varied from 0-11000 J/m^2 and H_2O_2 was dosed between 0-15 mg/L. Abatement of 1H-benzotriazole, carbamazepine, diclofenac, and iopromide were studied. The AOP was found to be more effective producing •OH radicals in Wiese water due to lower carbonate/bicarbonate scavenging. TrOCs could be abated below the limit of quantification in both water sources when deploying an AOP.

6.5. Ozone, O_3 Plus AOP: an Optimized Treatment Line for COD & TOC Removal: Wanhua
L. FAN, L. DE FRANCESCHI, S. FOUCHER, B. HEINIGER, C. JI, M. WANG, K. WASIAK, J. YU (PR. China, Switzerland)

Industrials often have to meet challenging effluent discharge requirements. The project presented in this paper analyses the treatment of a Reverse Osmosis concentrate from a chemical industry park in the city of Yantai, Eastern China. The main treatment target is COD and TOC removal. This paper shows how a cost-effective treatment line has been designed through laboratory- and pilot-scale trials, and process design optimization.

6.6. BIOTECH PROJECT: Hospital effluents treatment by oxidation with ozone and catalytic ozonation processes - elimination of biocides
F. PONTLEVOY, F. LASEK, N KARPEL VEL LEITNER, L. BLANCHIER, S. AYRAUD THEVENOT, O. CASTEL, C. PRINTEMPS-VACQUIER, P. PLAIRE, C. PAGOTTO, H. REISSER, T. TROTOUIN, S. CORMERY, N. DELLA-VALLE, S. BOUCHONNET, S. BOURCIER, E. NICOL, S. VUJOVIC, G. RAUWEL, M. DEBORDE (France)

The BIOTECH project (Biocides, Occurrence, Treatment and Hospital Effluents), funded by ONEMA and the Loire Bretagne Water Agency, was selected as part of the call for projects entitled "Innovation and changes in practices - Fight against the micropollutants of urban waters". As part of this research project, releases of biocides and their fate in the networks are evaluated. Solutions ranging from prevention to source treatment are also proposed to limit these releases. Of the biocides consumer sites, healthcare facilities are one of the largest emitters. After evaluating the main emitters, the objective of phase 2 of the project is to highlight a treatment pathway for the elimination of 3 main biocides which are: DIDAC (quaternary ammonium at a concentration of several mg / L), Chlorhexidine digluconate and bis (aminopropyl) laurylamine (BAPLA), found in low concentrations, a few µg / L or even tens of µg / L in the network.
A first step of the study is carried out in the laboratory on a solution reconstituted in tap water. Treatments in a semi-batch reactor in ozonation alone and in catalytic ozonation make it possible to highlight the effectiveness of these processes for the oxidation of these molecules. When optimizing the continuous ozonation and catalytic ozonation protocols in tap water, the biocides are quickly slaughtered:> 80% biocide removal before the first sampling at 2 min of contact time. The interest of the catalytic process is here on the consumption of ozone.
The second step consists in setting up a mobile catalytic ozonation unit, OCS®, for the treatment of the main discharge of the University Hospital as well as for the more specific treatment of wastewater from the general laundry of the University Hospital.
This conference will present the results obtained during the continuous test campaign on the CHU effluent and the rejection of the laundry. Very interesting results, on the abatement of the DIDAC, will make it possible to show the relevance of the use of the ozonation processes and more particularly of the catalytic ozonation OCS® for the elimination of biocides in these two complex matrices.

Session 7. Process engineering

7.1. Construction of a new treatment chain at the Saint-Sulpice drinking water treatment plant: ozonation and advanced oxydation pilot tests
C. MECHOUK, A. HAURET, L. PICCININI, F. KHAJEHNOURI (Switzerland)

The drinking water facility in Saint-Sulpice was built in 1971 and the treated water quality does not fully meet the current standards. In particular, the treatment chain is unable to target emerging threats such as micropollutants and microplastics. Pilot tests were carried out from 2014 to 2017 in order to choose the best treatment process for the new plant. The aim of the trials was to test different technologies such as activated carbon, high pressure membrane filtration and ozonation to evaluate their performances. Among the technologies assessed on site, an oxidation process with both ozone and a combination of ozone and hydrogen peroxide (Advanced Oxidation Process - AOP) was tested from August 2016 till March 2017. The results showed that the ozonation process could not be implemented because of a high bromide concentration in the Lake Geneva raw water. However, the AOP allowed to limit the bromate formation, while achieving high removal rates. The optimal ozone dose for Saint-Sulpice is 1 ppm with a molar ratio $[O_3]/[H_2O_2]$ of 0.5.

7.2. Foam fractionation and ozone in modern aquaculture systems: valuable tools for clear water production and farm management
J. ORELLANA, B. WECKER, U. WALLER (Germany)

Recirculating aquaculture systems (RAS) for farming finfish is a technology that offers the necessary bio-security and water quality control, as well as waste management. Modern closed recirculating systems can operate far away from the natural water source and a water consumption of less than 1% of the system volume per day. High-tech systems such as the oceanloop technology (neomar.de) allow the land-based production of fish species of high commercial interest and value, close to the consumer. This technology [10] represents the cutting edge of science and technology. The discharge of nutrients and organic matter can be well controlled. The technology is environmentally sound and supports the sustainability of aquatic food production.

7.3. Degradation of plant protection products from wastewater with advanced oxidation processes (AOP)
A. MOS-HUMMEL, K. NONNENMACHER (Germany)

The growing presence of pesticides in the water cycle causes many discussions due to negative effects on the ecosystem and human health. These includes herbicides, fungicides and insecticides which occurs particularly in larger concentrations in waste water. In many regions the problem with the cleaning of polluted water arise due to the fact that pesticides are difficult to decompose.[1] Among various water and wastewater treatment options, ozonation and ozone-based advanced oxidation processes, such as ozone/ultraviolet irradiation are likely key technologies for degrading and detoxifying these pollutants in water and wastewater. In this paper, ozone-based treatment of eight popularly used pesticides, namely carbendazim, glyphosate, imidacloprid, methiocarb, pirimicarb, pymetrozin, thiacloprid und tolclofos-methyl are presented.

7.4. Closing the water cycle applying suspended ion exchange and ozonation for pharmaceutical control
B. MARTIJN, D. FARLEY, G. ZOUTBERG, J. MALLEY, J. KRUITHOF (The Netherlands)

Hoogheemraadschap Hollands Noorderkwartier (HHNK) and PWN Water Supply Company (PWN) joined forces to investigate the upgrade of the quality of HHNK's waste water effluent. A combination of suspended ion exchange and ozonation was investigated for the degradation of pharmaceuticals. Batch experiments showed promising results for the degradation of six spiked micropollutants carbamazepine, diclofenac, caffeine, ibuprofen, iopromide and TCPP. Pretreatment by suspended ion exchange decreased the ozone demand significantly. When an ozone residual was present high concentrations of bromate were observed. Pilot plant experiments confirmed the degradations found in the batch experiments with untreated waste water effluent.
Both bench scale and pilot research will be continued and construction of a demonstration plant is under consideration. In addition to micropollutant degradation the focus will be on antibiotic resistance and bioassays.

7.5. UVA_{254nm} based ozone dosage control with one in –situ measurement sensor
V. THIYAGARAJAN, A. RIED, M. STAPF, J. SCHUETZ (Germany)

Micropollutant removal in wastewater is an emerging area of ozone application. The relative reduction of UVA_{254nm} (ΔUVA_{254nm}) is established as a surrogate parameter for micropollutant elimination and it is legislated in Switzerland as the preferred method for process control and monitoring micropollutant abatement. In order to evaluate the ΔUVA_{254nm} caused by ozonation, usually two UV online sensors are used, which leads to high initial costs and may lead to different. In this study, only one UV/VIS sensor is used to measure the UVA_{254nm} at the influent and effluent of the ozonation reactor at pilot plant site in Berlin, Germany. Programmable logic controller (PLC) based system is used to calculate the ΔUVA_{254nm} in the in and outflow. The resulting ΔUVA_{254nm} values are evaluated and compared with offline values and effect of drift is analysed. Besides, the DOC values were also collected the same sensor and compared with offline values.

Session 8. Process engineering (cont'd)

8.1. Micropollutants treatment at the vidy WWTP: feasibility of implementing ozonation with regard to by-products formation
C. MECHOUK, A. HAURET, L. PICCININI, F. KADRI, F. KHAJEHNOURI (Switzerland)

The Lausanne wastewater treatment plant (WWTP) will be completely rebuilt by 2022. In order to eliminate micropollutants, it was decided to implement an ozonation step followed by PAC injection and sand filtration. However, the ozone could react with certain compounds, such as bromide, to form toxic by-products. Industrial wastewaters, such as those of the city incinerator plant TRIDEL; are also treated at the WWTP. These wastewaters are more likely to contain compounds that could react with ozone to form dangerous by-products. The Swiss Water Association (VSA) has recently published guidelines [1] to verify the feasibility of implementing an ozonation treatment step at WWTPs. In particular, the VSA suggested analyzing bromide, chrome and nitrosamines. The oxidation of bromide and chrome could lead to the formation of bromate and chromate, which are classified as carcinogenic. Nitrosamines, and more specifically the ***N***-Nitrosodimethylamine (NDMA), are also considered as carcinogenic. The aim of this project was to analyze the three compounds mentioned in the VSA guidelines in order to verify the feasibility of implementing the ozonation treatment at the Lausanne WWTP. A nitrification pilot (BIOFOR®, Suez) was placed after the secondary treatment to achieve a water quality similar to the one that will feed the future ozonation process. The nitrified water was used to perform ozonation tests and, thus, assess the bromate formation. Moreover, 24 hours samplings were carried out at the WWTP entrance and after the pilot and chrome, bromide and NDMA analysis were performed. The results show that, depending on the bromide concentrations and the water quality, bromate formation is highly variable. NDMA and chrome are well eliminated by the biological treatment.

8.2. Micropollutant removal by ozonation at Sophia Antipolis wastewater facility: assessment of performances and reduction of toxicity

Y. PENRU, N. CREUSOT, J. COUTEAU, C. MIEGE, A. GUILLON, M. ESPERANZA, M. MASSON, A. ROUSSEL-GALLE, M. COQUERY, S. MARTIN RUEL, S. BAIG, J.M. CHOUBERT, S. AÏT-AÏSSA (France)

The discharge of treated effluent from municipal wastewater treatment plants (WWTPs) is one of the main routes followed by several micropollutants to enter the environment. The complementary approach based both chemical and effect-based analyses offers a new perspective to better characterize the presence of micropollutants, their potential impact on the receiving water body and process efficiency for their removal. The goal of the present work was to determine the performances of full-scale tertiary ozonation at Sophia-Antipolis WWTP on micropollutants removal through both chemical and effect-based analysis. For 20 micropollutants, selected as chemical indicators, we determined the specific ozone doses required to achieve 90% removal (from < 0.4 gO_3/gDOC for most reactive to 1.0 – 1.2 gO_3/gDOC for less reactive compounds). Nitrites were shown to influence the removal of intermediate and low reactive micropollutants. Residual endocrine disruptor (ED) activities were quantified in secondary effluent (ER, GR, PXR, PR and anti-MR). Ozonation was able to achieve ED activities removal by 30% to more 90% depending on the target activity and operation conditions. After ozonation, residual estrogenic activity was below the trigger value reducing potential impact of discharge effluent on receiving water body.

8.3. Micropollutant removal from WWTP effluent using the O_3-step filter

C. DE JONG, T. KIT LIU, A. VAN NIEUWENHUIJZEN, R. VAN DER AA, M. BECHGER, J. P. VAN DER HOEK (The Netherlands)

Inadequate treatment of wastewater effluent is one of the major point sources of pollution of organic micropollutants (OMPs) into aquatic environments. The 1-STEP® filter was originally developed with the aim to effectively remove nutrients from wastewater treatment plant effluent to ultra-low levels, combined with advanced removal of OMPs. Since reactivation of spent activated carbon is an energy intensive and expensive process, pre-ozonation has been proposed as a potential optimisation for OMPs removal and carbon life time in the 1-STEP® filter. In this study the treatment efficiency for selected OMPs, the effects of an ozonated feed water on GAC adsorption and on GAC bed life time, and the optimum ozone dosages for the design of a pre-ozonation step for the *ozone supported* 1-STEP® filter, the O3-STEP® filter, are studied. Batch adsorption experiments were conducted, of which the results show that pre-ozonation lead to higher elimination rates of the target compounds. The data obtained in the study was used to plot adsorption isotherms and to model breakthrough curves to investigate the effect of ozonation on GAC bed life. The breakthrough curves were modelled with COMSOL based on the linear driving force (LDF) model. With a dosage of 0.8gO_3/gDOC, breakthrough occurred significantly later, implying an improved GAC bed life time. Interestingly, dosages 0.2 and 0.4 gO_3/gDOC did not convincingly result in an improved breakthrough point, sometimes even occurring earlier than without ozonation. The results from this research justify the start of the next research phase, in which the pre-ozonation and activated carbon filtration for micropollutant removal will be combined with physical/chemical phosphate removal and biological nitrate removal in a pilot-scale O3-STEP® filter.

8.4. Coupling ozone and activated carbon adsorption for organic micropollutants removal in advanced wastewater treatment

R. GUILLOSSOU, J. GASPERI, J. LE ROUX, R. MAILLER, S. BROSILLON, E. VULLIET, C. MORLAY, F. NAULEAU, V. ROCHER (France)

The removal of 28 organic micropollutants present in a real wastewater effluent was studied by ozonation coupled to activated carbon adsorption and compared to a sole adsorption. The influence of the specific dose of ozone (0.27, 0.48, 0.99 and 1.44 gO_3/gDOC) and the influence the of powdered activated carbon (PAC) dose (2, 5 and 10 mg/L) were first studied separately. The combination of two specific ozone doses (0.10 and 0.25 gO_3/gDOC) and one PAC dose (10 mg/L) was then tested and compared to adsorption alone. Micropollutant removal increased with both specific ozone dose and PAC dose. The two processes appear complementary: the micropollutants with a low reactivity toward ozone are well absorbed onto PAC, meanwhile the compounds with a high reactivity toward ozone exhibit low affinity with the PAC. Satisfactory performances (> 80 %), notably for 2 indicator substances (carbamazepine and diclofenac) considered in the Swiss legislation, are obtained for a specific ozone dose of 0.25 gO_3/gDOC and a PAC dose of 10 mg/L.

8.5. Where to go next to advance the design and operation of ozonation and advanced oxidation of secondary effluent and surface water

W. AUDENAERT, U. REHMAN, I. NOPENS, A. RIED (Belgium, Germany)

Ozonation and AOPs are increasingly applied to address the societal and regulatory pressure towards trace organic contaminant (TrOC) removal and the increasing need for (direct) potable reuse. These technologies are now increasingly used in integrated treatment trains treating water with relatively high and fluctuating DOC levels (e.g. surface water, secondary WWTP effluent). These trends are reflected in operational and design challenges such as minimisation of bromate and organic byproducts, guaranteed micropollutant removal and OpEx minimisation by smart control and design driven by smart sensoring. Different mathematical tools can bring the necessary advancement for oxidation technologies: simple spreadsheets, empirical models, kinetic models and (advanced) CFD models. This paper discusses their current usage and future potential by means of practical examples. Kinetic models and advanced CFD models will become important tools for the future due to their mechanistic and hence generic nature.

Session 9. Process engineering (cont'd)

9.1. Diffusion of Gas with Bubble Column in fully Turbulent Flow

P.-A. LIECHTI, R. HAUSLER (Switzerland, Canada)

Focus is more and more directed to the ozone technology for abatement of acute (disinfection), chronic and long-term toxicity of wastewater.
Together with ozone generation its diffusion into water and wastewater is the heart of this technology.
Optimization of ozone diffusion technology towards better efficiency and optimization is of the essence.
This essay is a first trial to address and investigate the effect of turbulence intensity on the behavior of a bubble column which is generated and homogeneously dispersed into a fully turbulent wastewater flow and on the overall reaction kinetics of ozone with the reactants dispersed in a wastewater.

9.2. How new generator technology can contribute to expanding ozone applications
E. AUBIN, L. RAMOINO, W. UTTINGER, H. FELLMANN, C. HUYNH (Switzerland)

Ozone is used with success in many processes. In order to make ozone technology more attractive and extend the range of applications where ozone can be competitive, an essential role is played by the ozone generator, i.e. the core of any ozone installation. The aspects of an ozone generator that significantly increase the competitiveness of ozone technology are: lower energy consumption, higher ozone production, wider turndown ratio, and easier integration in an ozone plant. This paper will present how some of these characteristics have been implemented in the new ozonia® M family of ozone generators and discuss how these improvements can help to increase the competitiveness of ozone against alternative technologies. Using a new power supply, process control improvements and optimized gas flow rates, the overall turn-down ratio of the ozone generation system has been improved to 20:1. The feed gas pressure inside the ozone generator can be automatically controlled to maintain the optimum process parameters for every operational point and operate at the optimal pressure for which the energy consumption is the lowest. New ozone generation technology is able to operate at higher pressure, and consequently, to supply ozonated gas to the contacting system at up to 2 bar-g with oxygen as feed gas. This increased pressure allows several optimizations of the surrounding systems and infrastructure, such as higher ozone transfer yield, higher water level above the diffusion system, reduced contact tank footprint and improved overall hydraulic plant profile. The new technology allows a reduction on both capital and operational expenditure, and provides improved reliability, stability and flexibility to the overall ozone plant. These ozone technology improvements contribute to expanding ozone applications and adapting to new market requirements.

9.3. Numerical simulation of the efficiency of full-scale ozone contactor
E. GHEFFARI, S. BAIG, D. PIERRAT (France)

This study shows how CFD modelling can be used in wastewater treatment industries, and more specifically to predict the efficiency of an ozone bubble column processing wastewater from micropollutants. We show how it is possible to estimate the performances of mass transfer and hydraulics for the whole operating range. The quality of the mass transfer mechanism is examined through the volume transfer coefficient between the continuous water phase and the dispersed gas bubbles, the dissolved oxygen concentration and the rate of dissolved gas. The hydraulic in the tank is analysed through its flow structure, vortex identification and local residence time.

Closing session and Award Ceremony

Conference Conclusions
Special Prize of the Programme Committee
IOA Harvey Rosen Award

FOR ANY FURTHER CONTACT

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