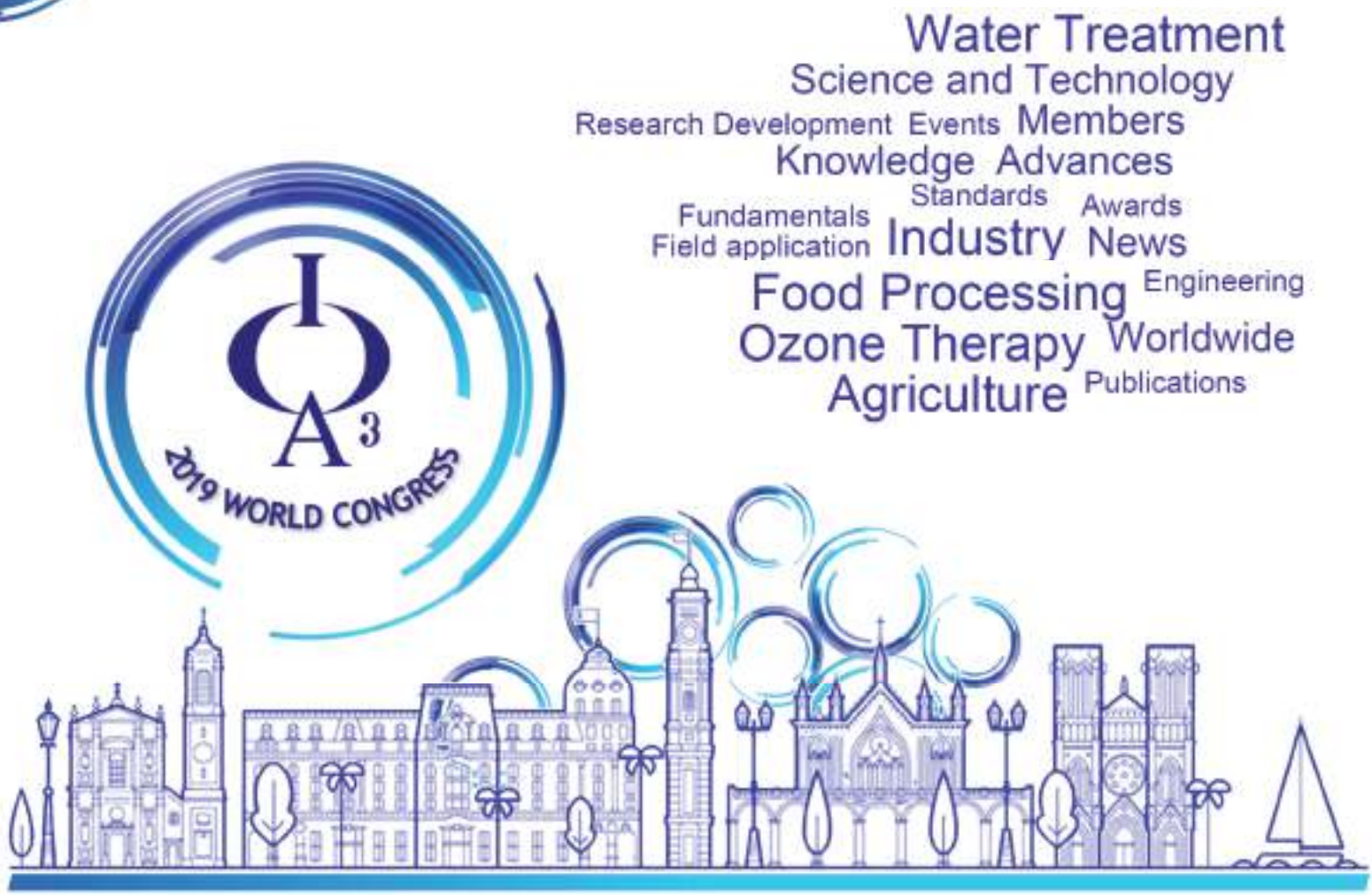
The International Ozone Association
is pleased to present the

24th World Congress & Exhibition

20 - 25 October 2019, Nice, France

Ozone and Advanced Oxidation
Leading-edge science and technologies

PROGRAMME
BOOK OF ABSTRACTS



WELCOME ADDRESS

Bernhard PAOLINI,
IOA President

Frédéric VIOLLEAU,
IOA-EA3G President

Following a long series of successful congresses organized every two years, it gives us great pleasure to welcome you to the IOA World Congress & Exhibition in Nice, at one of the most beautiful hotels on the Riviera, the Hyatt Regency Hotel, Nice Palais de la Méditerranée, located on la Promenade des Anglais.

With the ambition to repeat the success of past World Congresses held worldwide for more than 40 years, the International Ozone Association has designed this new congress with the aim of providing a very unique forum for all concerned with fundamental, engineering and applied aspects of oxidation techniques involving ozone and advanced oxidation systems:

- To interface with scientists, researchers, students, engineers, users, technical experts, representatives of leading organizations from various disciplines,
- To share the latest information on research topics, current issues, technologies under development, new applications, full-scale experiences and equipments and products,
- To consider and discuss directions able to deliver innovative, competitive and sustainable solutions which address current and next challenges.

Under the Chairmanship of Professor Michel Roustan, the Scientific Committee has produced an outstanding programme from the large number of abstracts submitted. This scientific programme will include numerous high quality scientific presentations, whether oral or posters. It will cover three major application fields: environmental and human health protection, industrial manufacture and conditioning and medical therapy.

The promising answer to the call for papers and exhibitors as well as the further support received through sponsorships and finally the attendance level already proved the "uniqueness" of this event. This uniqueness is not only about the congress organization, but still reflects the dynamism of international research and industry in developing and implementing processes and technologies based on ozone or related oxidants – this is the scope of the IOA Association. There is no doubt that this congress will meet our expectations, as delegate or organizer.

Enhancing an excellent technical and scientific programme, you will have many opportunities to discover the famous and beautiful Nice city and its area.

We would like to express our gratitude and thanks to all of you who contributed to make this event possible: authors, exhibitors, sponsors, Associations' members, chairpersons and the local organizing Regional Group of the IOA.

On behalf of the Board of Directors of the International Ozone Association,

We wish you, delegate, exhibitor, guest, accompanying person a very enjoyable and fruitful Congress.

THE ORGANIZER

IOA

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.

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

IOA-EA3G

The EA3G group of IOA manages IOA membership in Europe, Africa, Asia and Australasia.

Among usual activities, it is over years the local organizer of all IOA Congresses held under the Presidency of one of its member.

It initiated and carried out the organization of the Congress.

FOR ANY FURTHER CONTACT

INTERNATIONAL OZONE ASSOCIATION

IOA-EA_3G Secretariat

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Fax: +33 (0)549 454 060

Phone: +33 (0)549 454 454

E-mail: ioa@esip.univ-poitiers.fr

COMMITTEES

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- Bernhard PAOLINI, Switzerland | IOA President

Organizing committee

- Frédéric VIOLLEAU, France | IOA-EA$_3$G President
- Sylvie BAIG, France | IOA Past President, IOA-EA$_3$G Past President
- Alain LASALMONIE, France | IOA-EA$_3$G Secretary-Treasurer

Scientific committee

Chair

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Chair

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- Dr. Shahzad BHATTI | Sir Ganga Ram Hospital, Pakistan
- Dr. Aziz G.H. AZIZ | German Specialist ozone Therapy Clinic, UAE
- Prof. Olga LEÓN FERNÁNDEZ | Havana University, Cuba
- Dr. Michael SCHREIBER | German Medical Association of Ozone Application in Prevention & Therapy, Germany
- Dr. Alberto ALEXANDRE | EUNI European Neurosurgical Institute, Italy
- Dr. Umair RASHID | Lahore General Hospital, Pakistan
- Dr. Stefan TIRON | Romanian Asociation, Romania

SPECIAL ACKNOWLEDGEMENTS AND CONTRIBUTIONS

The success in the organization of this congress results from the strong involvement of many individuals and from the generous contributions of sponsors and exhibitors.

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

- **SUEZ OZONIA** | **General** Sponsor, Exhibition
- **Xylem** | Sponsoring, Exhibition

- **AirSep Corporation** | Exhibition
- **BMT Messtechnik GmbH / OSTI** | Exhibition
- **De Nora Water Technologies** | Exhibition
- **Dr. J. Hänsler GmbH - OZONOSAN** | Exhibition
- **Ecole d'Ingénieurs de PURPAN - Plateforme TOAsT** | Exhibition
- **Institut Polytechnique UniLaSalle / LASALLEO3** | Exhibition
- **Statiflo** | Exhibition
- **Teledyne API** | Exhibition
- **ZED Ziegler Electronic Device GmbH** | Exhibition

- **SUEZ | Technical tour**
- **VEOLIA | Technical tour**

General sponsor

GENERAL INFORMATION

Language

English will be the official language.

Congress Venue

Congress venue will be: Hyatt Regency Nice Palais de la Mediterranée, 13 Promenade des Anglais, 06000 NICE – France - https://www.hyatt.com/

Registration categories

There are 14 categories of registration and associated as follows:

Full registration

- IOA Member - Full registration
- Non-member - Full registration
- IOA Member - Student registration*
- Non-member - Student registration*

Covers scientific sessions, electronic proceedings, abstracts book, exhibits, welcome reception, lunches, refreshments, internet access. One-year IOA membership is included in the non-member full registration.

IOA Membership provides significant discount on registration fees and entitles other numerous benefits.
To discover them and start your IOA subscription, please visit www.ioa-ea3g.org/membership

One-day registration

- IOA Member – 1-day registration
- Non-member – 1-day registration

Additional registration is required for

• Technical tour T1** WWTP Valbonne-Bouillides, Sophia Antipolis	Thursday 24 October. Included bus transfer and lunch. Minimum number of 30 registrations is required per visit.
• Technical tour T2** DWP La Verne, La Môle	Friday 25 October. Included lunch and entrance fees for the public visit of the aquarium. Minimum number of 30 registrations is required per visit.
• Congress dinner "Le Grand Balcon"	Wednesday 23 October. Number of registrations is limited to 280.
• Accompanying person registration	Covers welcome reception and lunches from 21 to 23 October
• Cultural tour C1*** Visit of Old Nice and tasting of Socca	Monday 21 October afternoon. Minimum of 30 registrations is required per visit. Covers bus transfer, guide and entrance fees.
• Cultural tour C2*** Eze Village & Exotic garden, Fragonard perfume factory, Villa Ephrussi	Tuesday 22 October. Minimum of 25 registrations is required per visit. Covers bus transfer, guide, entrance fees and lunch.
• Electronic proceedings for members or non-members	Additional copies available can be purchased during and after the Congress at discounted rate for IOA member.

*Copy of valid student ID is required / **Passport copy has to be provided before the technical tours - On site visit authorization conditioned by the strict application of security rules into force / ***Opened to accompanying persons and delegates

Author registration

At least one author of each selected paper and/or poster must register and attend the Congress.

Cancellation policy

Notification of cancellation must be received by the Congress Secretariat in writing. A 50% refund will be provided if notified by September 1st. No refund will be provided after September 1st.

Each cultural or technical tour can be cancelled if the number of registrations required is not met. Full refund will then be provided.

Liability and insurance

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

Disclaimer

The organisers may at any time, with or without giving notice, in their absolute discretion and without giving any reason, cancel or postpone the Congress, change its venue or programme and withdraw any invitation to attend. In any case, neither the organisers 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 Congress 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).

Registration desk

It will be opened during the Congress as follows:

- Sunday, October 20 17:00 - 18:30
- Monday, October 21 7:00 - 17:00
- Tuesday, October 22 8:30 - 17:00
- Wednesday, October 23 8:30 - 16:15

Badges

The wearing of badges is compulsory inside the Congress Centre. They are necessary to access all scientific sessions, exhibits, social events and other Congress services and functions.

Breaks

Each morning and afternoon complimentary coffee and drinks will be available in the exhibition area at the scheduled break time. Each day, lunch will be offered at Exhibition room “Salon AZUR”.

Meeting point

The meeting point for all tours is at the registration desk.

Wifi

A Wifi connexion will be available for each delegate.

Nice

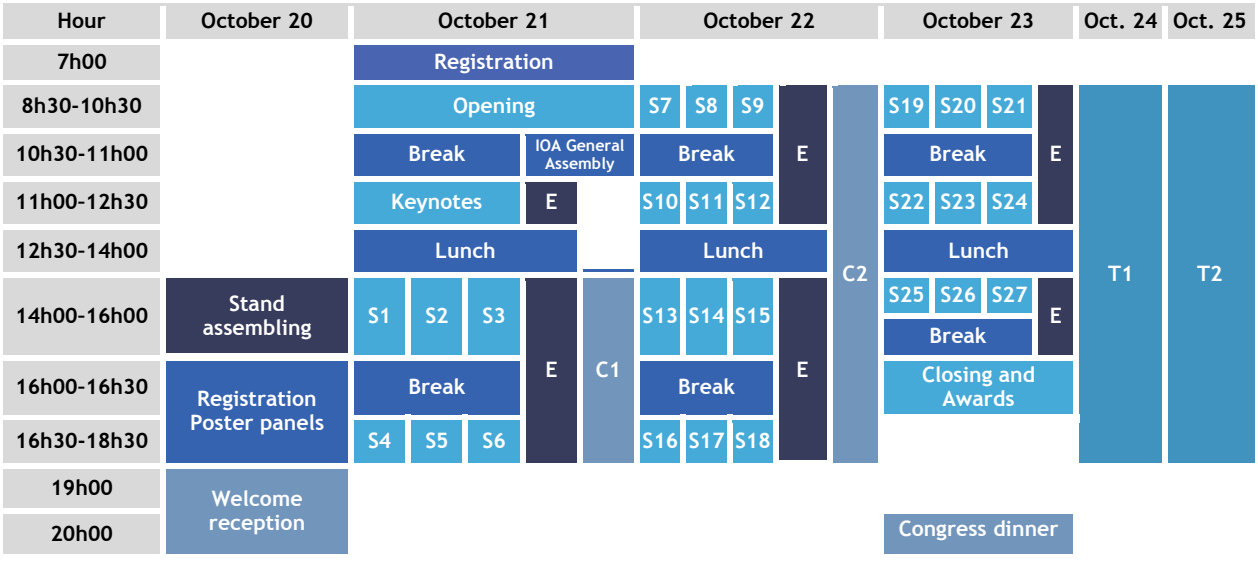
Nice, the fifth largest city in France, acts as a magnet attracting people from all over the world, for a multitude of reasons. Nice is at the same time an elegant and popular city, lively, cheerful, proud of its past and its independence. The city will surprise you by its personality, dynamism and its passion for art and culture. Not only renowned for its grace, Nice has become a hub for research in industry, science and advanced technology since the creation of such centers as Acropolis and Sophia Antipolis.

GENERAL PROGRAMME

This event features 5 full days. Here's a snapshot of what it offers:

- Attendance by top specialists and researchers from public and private organizations, all working on technologies based on ozone and advanced oxidation systems and all interested in environmental and human health protection, industrial manufacture and conditioning, medical therapy
- 3-day Technical and Scientific Programme with more than 120 scientific presentations arranged in 27 sessions in 3 parallel tracks. All topics of current or future interest are covered.
- A large Exhibition, of technologies, products and services,
- 2-day exclusive plant tours to the ozone installations - WWTP Valbonne-Bouillides, Sophia Antipolis and DWP La Verne, La Môle
- And social and cultural events for the enjoyment of the delegates and their guests: welcome reception, celebratory Congress Dinner, Awards Ceremony, 2 tours to discover the prestigious places Old Nice and tasting of Socca, Eze Village & Exotic garden, Fragonard perfume factory, Villa Ephrussi
- Special IOA meetings, particularly the IOA General Assembly (Monday 21 October)
- All in the France's world-famous environment and hospitality.

Schedule of the congress program



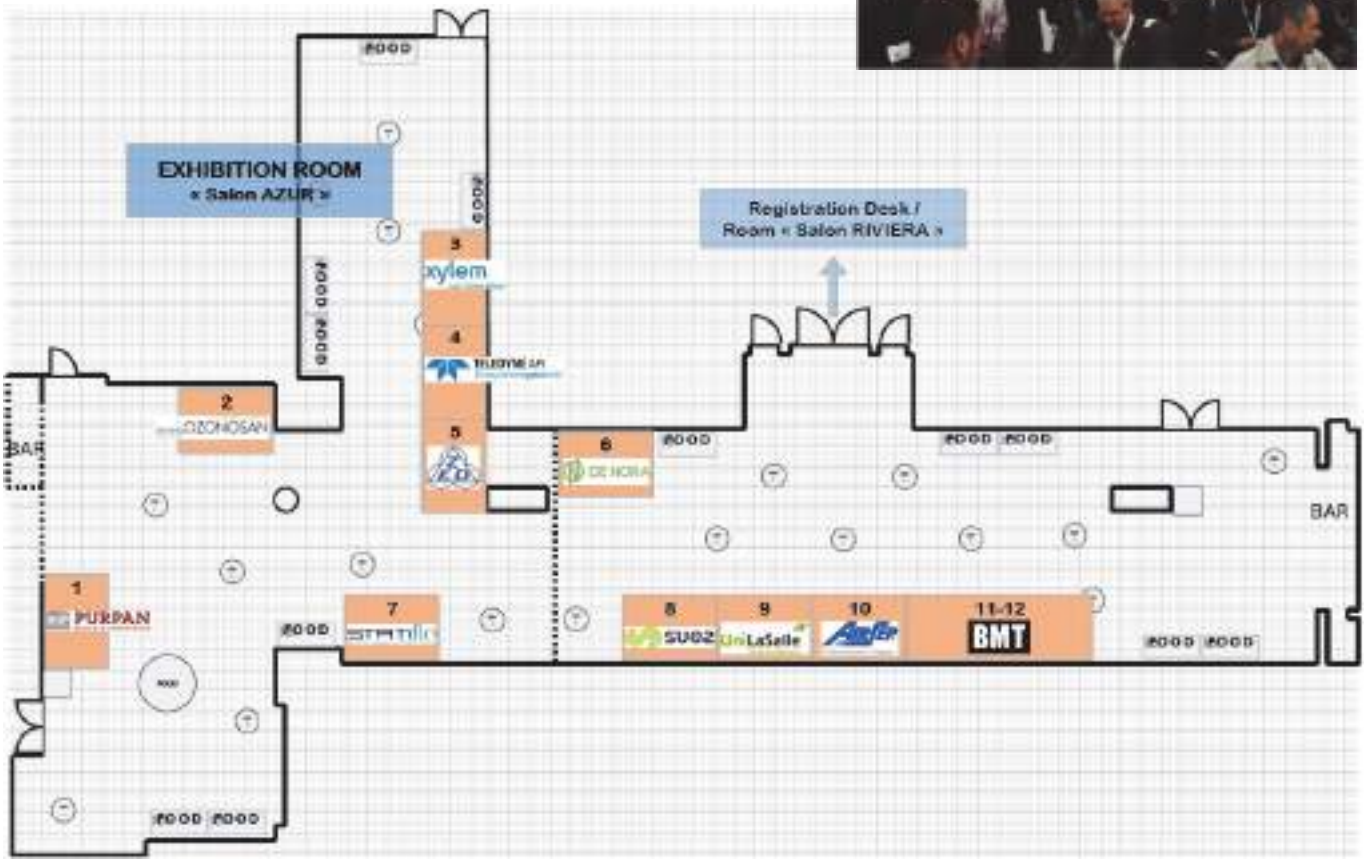
With S: Scientific Session; E: Exhibition; C: Cultural tour; T: Technical tour

S1 Ozone in the water cycle
S2 Design and engineering
S3 Ozone generation and measurement
S4 *Workshop - Young Ozone People*
S5 *Workshop - CFD Modelling*
S6 *Workshop* - Feed gas for ozone generators
S7 Applications in drinking water
S8 Fundamentals - Part 1
S9 Ozone in Medicine - Part 1
S10 Poster introductions - Part 1
S11 Poster introductions - Part 2
S12 Ozone in Medicine - Part 2
S13 Ozone in Agrifood - Part 1
S14 Fundamentals - Part 2
S15 Ozone in Medicine - Part 3
S16 Ozone in Agrifood - Part 2
S17 *Workshop Ozone plant design: Key questions*
S18 Ozone in Medicine - Part 4
S19 New challenges in wastewaters - Part 1
S20 Fundamentals - Part 3
S21 Ozone in Medicine - Part 5
S22 New challenges in wastewaters - Part 2
S23 Applications in Industrial Processes - Part 1
S24 Ozone in Medicine - Part 6
S25 New challenges in wastewaters - Part 3
S26 Applications in Industrial Processes - Part 2
S27 *Workshop - IOA Highlights on innovation*

EXHIBITION

Monday 21 October to Wednesday 23 October

Leading companies and institutions supplying equipment for ozone application display new and standard products. Enough time will be available to go in the exhibition space and see the exhibits.



AirSep Corporation - www.airsepcpd.com

AirSep Corporation offers innovative, economical, non-cryogenic oxygen supply solutions as an alternative to cylinder or liquid supplies. Producing an unlimited supply of oxygen on-location, an AirSep Oxygen Generator eliminates regular oxygen deliveries.

AirSep offers the widest selection of systems including, standard oxygen generators, self-contained oxygen generators, packaged systems and VPSA oxygen plants. AirSep's products maximize ozone generator performance and can be used in a wide range of applications such as water and wastewater treatment.

BMT Messtechnik GmbH / OSTI - www.bmt-berlin.de

For 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.

De Nora Water Technologies - www.denora.com

De Nora is an Italian multinational leader in sustainable technologies that offers energy saving products and water treatment solutions. Globally, De Nora is the major provider of electrodes for electrochemical processes in the Chlorine & Caustic, Electronics & Surface Finishing and Renewable Energy Storage and is among the leaders in technologies and processes for the filtration and disinfection of water. It serves clients in 119 countries worldwide with 19 offices, 12 manufacturing facilities, and three research & development centers in Italy, the USA and Japan. The Group intellectual property portfolio currently contains 350 patent families with more than 3,000 territorial extensions and about 90 trademarks all over the world.

Dr. J. HANSLER GmbH – OZONOSAN - www.ozonosan.de

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.

Ecole d'Ingénieurs de PURPAN - Plateforme TOAsT - www.linkedin.com/company/plateforme-tfffc

Ecole d'Ingénieurs de PURPAN is engineering school in life sciences. Its Research, Development and Consulting activity is focus on service to industrial and socio-economic partners. In this context, PURPAN has developed a research platform for the development of alternative solutions to chemical products using Oxidative Technologies for Agriculture and Agro-Food (TOAST platform). This platform is equipped with storage rooms, culture chambers and an experimental room to evaluate the performance of oxidative technologies (O_3, UV, O_3/UV, EW ...) for the preservation and disinfection of foodstuffs, the disinfection of agro-food processes, the protection of plants, the modification of the technological qualities of agricultural raw materials, the realization of a green chemistry reaction ....

The TOAST platform team from the PURPAN is at your disposal for your research and development projects!

Institut Polytechnique UniLaSalle / LASALLEO3 - www.unilasalle.fr

UNILASALLE is a graduate school training engineers in the fields of agriculture, agri-food, food-health, environment and geosciences. Today the 2,800 students are trained on three different campus (i.e. Beauvais, Rennes and Rouen). In terms of research, UNILASALLE supports agricultural and agro-industrial sectors, and more broadly the fields of Life Sciences, Earth and Environment. The Transformation & Agro-Resources research unit (EA7519) is developing a scientific program focusing on the transformation and valorization of the whole plant in a sustainable development perspective. The work is based on an integrated scientific approach covering the entire transformation chain of agro-resources from the study of the mechanisms of their construction to the study of their properties and functionalities at the end of their use either for food (PETALES team) and/or for non-food purposes (VAM2IN team). As part of the development of its R&D and transfer activities, the research unit EA7519 manages the LASALLEO3 which is an R&D platform dedicated to the applications of ozone in the domains of the agro-industry, the food-processing industry and of the green chemistry. This unique platform will valorize the scientific and technological expertise of UNILASALLE and of his multiple industrial partners. This 900 m^2 facility includes different pilot plants fully instrumented to generate various type of ozonation reactions (i.e. gas/liquid, gas/solid and gas/gas) enabling:

- The decontamination and/or the stabilization of the various biological products;
- The remediation of agricultural and agro-industrial effluents;
- The development of green chemistry and advanced chemistry applied to bio-sourced fractions;
- The valorization of bio-waste and by-products from agriculture.

Statiflo - www.statiflo.com

Statiflo is a world leader in the development and application of static mixers, gas dispersion systems, flow conditioners and associated technologies. Statiflo have extensive experience in the application of ozone gas dispersion systems as well as the areas of advanced oxidation. Providing custom designed Ozone contacting systems which continually meet or exceed our guaranteed 95% mass transfer efficiency. This experience also extends to the other applications in the water industry, supplying products to a worldwide water treatment and industrial market. To support the products, Statiflo have branch offices in the USA, Germany and Canada as well as distributor offices world-wide.

Please visit our stand to discuss your application with our experienced engineers. We would like to see you.

SUEZ OZONIA - www.suezwatertechnologies.com

SUEZ Water Technologies & Solutions solves the toughest water, wastewater and process challenges wherever they occur.

SUEZ's Ozonia® product line is a recognized leader in ozone technology performance, quality and reliability with over 40 years of experience. From laboratory testing, to pilot testing, through design and engineering, Ozonia® ozone solutions enable you to solve your challenges.

Teledyne API - www.teledyne-api.com

Teledyne API (TAPI) is a global leader in the design and manufacture of precision industrial gas and air quality monitoring instrumenta%on located in San Diego, California, USA. Our instruments are used worldwide in industrial process applica%ons, ambient air quality monitoring systems (AQMS), and con%nuous emissions monitoring systems (CEMS). Our instruments comply with many interna%onal regulatory agency approvals for the measurement of criteria pollutants, including the U.S. Environmental Protection Agency (EPA) and European Union (EU). Our industrial gas por/olio includes ozone analyzers, generators, sensors and turnkey ozone delivery systems for gas or solution based applications. Through consistent delivery of high quality instrumentation and superior customer service, we have become a global leader in the markets we serve.

Xylem - www.xylem.com

Xylem is a leading water technology company committed to "solving water" by creating innovative and smart technology solutions to meet the world's water, wastewater and energy needs.

In a world of ever-growing challenges, Xylem delivers innovative water technology solutions throughout the cycle of water.

Our technological strength across the life cycle of water is second-to-none. From collection and distribution to reuse and return to nature, our highly efficient water technologies, industrial pumps and application solutions not only use less energy and reduce life-cycle costs, but also promote sustainability.

ZED Ziegler Electronic Devices GmbH - www.z-e-d.com

ZED GmbH was founded in 2001 using experience gathered since 1996.

We focus on development, production and sales of reliable and efficient electronic driver systems designed to meet the special requirements within the curing, purification and disinfection industry.

Standard accessories, classical and highly innovative solutions complement each other.

Next generation accessories for UV and VUV systems: digital UV sensors, ozone generators, digital controlled electronic ballasts, control units for lamp operation and monitoring, excimer systems.

SOCIAL AND CULTURAL EVENTS

Welcome reception

On Sunday 20 October from 19:00

Room: Terrasse Madison

Congress dinner

On Wednesday 23 October from 20:00

Located in the old parts of Nice, Le Grand Balcon will offer you a gourmet discovery you will truly enjoy!

Who could possible resist a dining room decorated by Jacques Michalis? Red dominates here, along with noble materials, offering a cosy and subdued atmosphere.

As for the cuisine here, fusion food is the key word for a passionate and experienced Chef Rossi who wants his recipes to be original and creative. Each dish, each flavours, each scent is underlined for a true explosion in your mouth. All is subtle and refined. True bliss for your taste buds, a pleasure for your eyes...

The Grand Balcon combines mediterranean gatronomy with innovation and inventiveness!

Restaurant: Le Grand Balcon

Address:10 rue St Francois de Paule / Phone: [+33] (0)493 626 074 / www.le-grand-balcon-restaurant-nice.com

How to get to the restaurant?

By walk from the Promenade des Anglais / By Public transport, Tram T1: Stop Opéra - Vieille Ville

Awards Ceremony

Wednesday 23 October from 16:15

At every IOA event, several awards are presented to recognise special contributions.

- To encourage young researchers, the Scientific Committee will select and award several prizes to the best papers presented by Doctorate Students.
- The European African Asian Australasian Group of the International Ozone Association will award the Willy Masschelein Prize for the best PhD thesis that has been issued within the past 4 years (2016 up to 31st March 2019).
- The Harvey M. Rosen Memorial Award was established in 1989 to recognise the “best paper” published in Ozone Science & Engineering [OS&E] during the two-year period between World Congresses. Dr. Harvey M. Rosen was a prime mover behind the establishment of the International Ozone Association and of OS&E, the Journal of the Association. Recipients of the Rosen Award are determined by consensus polling of the members of the Editorial Board of OS&E.
- The International Board of Directors bestows Honorary Membership in recognition of outstanding contributions towards furthering the ideals & objectives of the Association.
- Morton J. Klein Medal of Excellence, an award of excellence recognises contributions of the highest order to the International Ozone Association in commemoration of the clear vision, diplomatic proficiency, and unparalleled leadership which characterised the life of Morton J. Klein.

CULTURAL TOURS

The organizing Committee designed sightseeing tours especially for Congress participants, spouses and partners. Special registration is required. All tours will include tourist English guide, entrance tickets, transport by bus (if need be) with pick up and return at Hyatt Hotel. Information on time for departure will be available at the registration desk.

Cultural tour C1 – VISIT OF OLD NICE AND TASTING OF SOCCA

Monday 21 October Afternoon – Half day tour

Discover "Vieux Nice" by walk

Discover the heart of the old town, its lively atmosphere and customs, the small St Francis Square with its fish market and fountain, the other piazzas with their 17th and 18th Baroque churches, the small cafes where the Niçois like to meet, the winding alleys lined with quaint shops, tall houses with ochre facades…

Tasting of Socca: The famous local speciality made with chick pea flour.

Included: Tasting of socca, 1 drink.

Cultural tour C2 – EZE VILLAGE & EXOTIC GARDEN, FRAGONARD PERFUME FACTORY, VILLA EPHRUSSI

Tuesday 22 October, Full day

Eze: Narrow and steep little streets, stone buildings with turrets, dry stone facades behind which numerous crafts-men work olive-wood, leather or silk according to ancestral techniques… Time seems to have given up the idea of crossing the ramparts of this fortress. The planet Square: With it's Italian style fountain constructed in 1930. The Riquier Mansion: This was the residence of the Lords of Eze during 14th-15th centuries. White Penitent's Chapel: During the 14th century, this was the meeting place of the non-religious white Penitents brotherhood, who took care of lepers and poor people. The Poterne: A double fortified gateway dating fromthe 14th century. It is the only access to the old village.

Exotic Gardens: A garden in the sky, perched at 249 m above sea level, the Jardin d'Eze is the ideal place to soak up the atmosphere of the French Riviera. Linger at one of the peaceful viewpoints overlooking one of the world's most beautiful panoramas, or discover Eze's history and traditions s you stroll through the gardens. Ornamental pools, water vaporisers add a unique, fresh note to this garden over the Mediterranean, where the earth goddesses by sculptor Jean-Philippe Richard live harmoniously among the exotic plants.

The Laboratory Factory: Suspended above the sea, on the Moyenne Corniche between Nice and Monaco, stands the perfume, soap and cosmetics factory equipped with the most modern laboratories and workshops. Discover the trade secrets of perfumes and cosmetics.

Villa Ephrussi: An exceptional site on narrowest part of Saint-Jean-Cap-Ferrat peninsula, overlooking the bays of Villefranche and Beaulieu-sur-Mer. The Villa: the large patio, the richly decorated rooms and the private apartments. The porcelain collection: a priceless collection of Sèvres and Vincennes royal porcelain. The film: a documentary which tells the story of the magical Villa and its collections (in French and English). The famous gardens perched above the sea: 9 heavenly gardens adorned with patios, fountains, ponds, flowerbeds and shady paths.

Included: transportation, entrance at the exotic garden & perfume factory, lunch and entrance Villa Ephrussi.

TECHNICAL TOURS

Upon proposals of IOA corporate members and by kind permission of the operator companies, two visits have been arranged for the Congress delegates. They will close the Congress on 24 and 25 October full day. Set out from Nice to explore the French Riviera. The tours will depart from and return to the Congress venue. Special registration will be required. The fee will include bus transfer and lunch.

Visitors will have to provide copy of ID card or passport one month prior to visit. 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.

Technical tour T1 – WWTP Valbonne -Bouillides, Sophia Antipolis

Thursday 24 October - Full day tour

In November 2009, the "Syndicat Intercommuncal" for the extension and management of the Sophia Antipolis plant, advised by BG Ingénieurs Conseils, entrusted the plant's extension to the "SUEZ/EITP" group.

Commissioned on 24 January 2012, its treatment capacity increased from 26,000 population equivalent (PE) to 50,000 pe to conserve the Bouillide, the plant's treated water receiving water body. This river flows into the Brague and has a saver low water level. Water lost in this flow feeds the Antibes water table which serves as the town's water supply.

In order to meet regulatory requirements aiming at improving the quality of treated water and thereby protecting the receiving body and water resource, the "Syndicat" and BG Ingénieurs Conseils chose:

- Advanced nitrogen treatment, for a more effective treatment quality than before, with significant and definitive removal of the nitrogen contained in water (eutrophication factor in the river);
- Disinfection using ozone rather than final chlorination in order to remove micropollutants too.

With this process, the Bouillides plant has become the first plant in France to treat micropollutants and to meet the requirements of the European Water Framework Directive (WFD) which imposes the reduction in the release into the natural environment of 41 priority substances. This is therefore fully in line with a sustainable development approach and the protection of water resources.

Technical tour T2 – DWP La Verne, La Môle

Friday 25 October - Full day tour

Water resources are unequally distributed in the Gulf of Saint-Tropez. To ensure the water supply of their population and be stronger together in the face of drought, the municipalities of the Gulf have regrouped in the Syndicat Intercommunal de Distribution d'Eau de la Corniche des Maures (SIDECM).

The Verne drinking water treatment plant has a treatment capacity of 3,000 m^3/h. It is likely to receive a mixture of raw water of 2 distinct origins: the water of the Verdon routed by the Society of the Canal of Provence or the water of the dam of the Verne.

The treatment process consists of the following steps:
Remineralization / Coagulation – Flocculation / Lamellar settling / pH correction / Inter-remineralization /Inter-ozonation / Dual media filtration / Post ozonation / Injection of sodium bisulfite / Lime injection for pH adjustment / Chlorination / Storage before distribution.

The sludge generated by the filter wash water and by the pretreatment undergo on-site treatment to greatly reduce their volume and facilitate their truck transport to the ultimate treatment site. The main stages of sludge treatment are: Sludge flocculation / Thickening / Centrifugal dehydration / Solar drying.

SCIENTIFIC AND TECHNICAL PROGRAMME

The Scientific Programme includes:

More than 140 presentations

- Keynote lectures
- Long oral presentations
- Short oral presentation for poster introduction and Poster exhibition
- Workshops on highly relevant topics

Organized in 27 sessions arranged in three parallel tracks.

S1 Ozone in the water cycle

S2 Design and engineering

S3 Ozone generation and measurement

S4 *Workshop - Young Ozone People*

S5 *Workshop* - CFD Modelling

S6 *Workshop* - Feed gas for ozone generators

S7 Applications in drinking water

S8 Fundamentals – Part 1

S9 Ozone in Medicine – Part 1

S10 Poster introductions – Part 1

S11 Poster introductions – Part 2

S12 Ozone in Medicine – Part 2

S13 Ozone in Agrifood – Part 1

S14 Fundamentals – Part 2

S15 Ozone in Medicine – Part 3

S16 Ozone in Agrifood – Part 2

S17 *Workshop Ozone plant design: Key questions*

S18 Ozone in Medicine – Part 4

S19 New challenges in wastewaters - Part 1

S20 Fundamentals – Part 3

S21 Ozone in Medicine – Part 5

S22 New challenges in wastewaters - Part 2

S23 Applications in Industrial Processes – Part 1

S24 Ozone in Medicine – Part 6

S25 New challenges in wastewaters - Part 3

S26 Applications in Industrial Processes – Part 2

S27 *Workshop - IOA Highlights on Innovation*

Monday, 21 October

Plenary session. Opening

Hour		
09:00		**Opening Addresses**, *Bernhard PAOLINI, IOA President and Frédéric VIOLLEAU, IOA-EA$_3$G President* **Congress introduction**, *Michel ROUSTAN, Renate VIEBAHN, Co-chairs of the Scientific Committee* **Exhibition opening**
10:30		**IOA General Assembly**
10:30		**Break**
11:00	KN	**00.1. Ozone and Nice, a nice story!** *M. Roustan (France)*
11:30	KN	**00.2. Forty years of advances in ozone technology. A review of Ozone Science & Engineering** *B. Loeb (USA)*
12:00	KN	**00.3. Outlook - Acting in a regulated market** B. Paolini *(Switzerland)*
12:30		**Lunch**

Session 1. Ozone in the water cycle | Chair: S. Jasim

Hour	Presentation		ID
14:00	LP	**01.1. Ozonation at Super Rimiez drinking water plant of Nice** *T. Jaeck (France)*	
14:40	LP	**01.2. Advanced treatment trains for indirect potable reuse** *A. Aaharoni, H. Cikurel, A. Ried, M. Fassbender, J. Gebhardt, H. Raanan Kiperwas (Israel, Germany)*	148
15:00	LP	**01.3. Electro-Pulse Oxidation Process (EPOP) – An alternative AOP as pre-treatment for Soil-Aquifer Treatment of secondary effluents for Indirect Potable Reuse** *O. Gafri, R. Abekasis, H. Cikurel, H. Raanan-Kiperwas, A. Izhar, A. Aharoni, O. Eliyahu (Israel)*	174
15:20	LP	**01.4. Closing the water cycle applying suspended ion exchange and ozonation for pharmaceutical control** *B. Martijn, J. Malley, G. Zoutberg, J. Kruithof (The Netherlands)*	205
15:40	LP	**01.5. Ozone Solutions For Micropollutants Treatment at all Positions in the Water Cycle: Drinking Water to Wastewater** *L. De Franceschi, K. Wasiak, M. Reid, C. Huynh (Switzerland, USA)*	215
16:00		**Break**	

Session 2. Design and engineering | Chair: M. Roustan

Hour	Presentation		ID
14:00	LP	**02.1. How advanced modelling (CFD) can enhance ozone system design** *J. Anton, A. Ried (Germany)*	168
14:20	LP	**02.2. Emerging operational challenges to ozone applications - high turndown, high doses, stable ozone residuals** *S. S. Pathapati, D. W. Smith, A. L. Mazzei (USA, Canada)*	108
14:40	LP	**02.3. Diffusion of Gas with Bubble Column in fully Turbulent Flow** *P.A. Liechti, R. Hausler (Switzerland, Canada)*	155
15:00	LP	**02.4. Ozonation and ozone based advanced oxidation in combinations with hydrodynamic cavitation – impacts on by-products formation in post-chlorinated drinking water** *M. Čehovin, A. Žgajnar Gotvajn (Slovenia)*	142
15:20	LP	**02.5. Ozone mass transfer in spray column** *A. Canado, M. Pages, M. Tournois, M. Roustan, W. Remus-Borel, N. Dietrich, G. Hebrard, F. Violleau (France)*	87
15:40		**Round table. Instantaneous Ozone Demand** *IOA Ozone Engineering Group*	
16:00		**Break**	

Session 3. Ozone generation and measurement | Chair: F. Martin

Hour	Presentation		ID
14:00	LP	**03.2. Efficient ozone generation using excimer – a competitive study between excimer and low-pressure mercury vapor lamp technology** *K. Ziegler, S. Krahnert, F. Becker (Germany)*	112
14:20	LP	**03.3. Photo Chemical Ozone Generation with Xenon Excimer Lamps- A Paradigm Shift for Ozone generation** *N. Brueggemann, M. Salvermoser, R. Fietzek, R. Fiekens (Germany)*	152
14:40	LP	**03.4. Innovative analytical method to measure ozone in gas phase** *L. Vitola Pasetto, M.H. Manero, R. Richard, J.S. Pic, V. Simon, F. Violleau (France)*	126
15:00	LP	**03.5. Corrosion resistance of stainless steel in dry ozone gas environment** *T. Yoshimi, E. Ishimaru, M. Abe, T. Nishimura (Japan)*	105
15:20	LP	**03.6. Implementation of a fluorescence (FDOM) online measurement at an ozonation plant used for micropollutant elimination – operational aspects and comparison to UVA_{254}** *M. Stapf, J. Schütz, V. Thiyagarajan, U. Miehe (Germany)*	147
15 :40		**Discussion**	
16:00	**Break**		

Session 4. Workshop - Young Ozone People

Hour			ID
16:30	WS	*Leader: M. Pages*	

Session 5. Workshop - CFD Modelling

Hour	Presentation		ID
16:30	WS	*Leader: A. Cockx and J. Morchain*	

Session 6. Workshop - Feed gas for ozone generators

Hour	Presentation		ID
16:30	WS	*Leader: P. A. Liechti*	

Tuesday, 22 October

Session 7. Applications in drinking water | Chair: F. Violleau

Hour	Presentation		ID
08:30	KN	**07.1. Climate Change, Water Quality Challenges, is the water Industry Ready?** *S. Jasim (Canada)*	
09:10	LP	**07.2. Removal of micro-pollutants by combining ozone and activated carbon filtration at a full scale drinking water production plant** *E. Chauveheid (Belgium)*	88
09:30	LP	**07.3. Worlds First Sequential Advanced Oxidation Process for Drinking Water Treatment put to the Test – Lessons learned from the first Year of operation** *J. Scheideler, T. Knol, A. Ried (Germany, The Netherlands)*	133
09:50	LP	**07.4. The Two-Stage Ozonation - Adsorption technology of Ground Water from Trichloroethylene and Tetrachloroethylene** *I.S. Tkachenko, S.N. Tkachenko, N.A. Mamleeva (Russia)*	140
10:10	LP	**07.5. Improving GAC based pump-and-treat remediation of chloroethenes by adding ozonation** *A. Kokkoli, N. Agerholm, H. R. Andersen, K. M. S. Kaarsholm (Denmark)*	195
10:30		**Break**	

Session 8. Fundamentals – Part 1 | Chair: J.S. Pic

Hour	Presentation		ID
08:30	LP	**08.1. Ethylbenzene decomposition by ozone in a three-phases system** *J. Dueñas Moreno, T. Poznyak, J. L. Rodríguez (Mexico)*	82
08:50	LP	**08.2. Phenol degradation in H_2O_2/ pulsed UV process** *A.I. Kulebyakina, A.D. Volosatova, Y.A. Goldshteyn, S.G. Shashkovskiy (Russia)*	83
09:10	LP	**08.3. Application of activated carbon/persulfate for acetominophen removal from water** *M. Qutob, S. Doğan (Turkey)*	111
09:30	LP	**08.4. Developing the next generation of UV-based advanced oxidation process using a dual wavelength approach: UV_{254nm}-H_2O_2 and Vacuum UV_{185nm}-H_2O** *N.K. George, B.A. Wols, D. Santoro, L. Furatian, J. Ferwerda, W. Gernjak (The Netherlands, Canada, Spain)*	176
09:50	LP	**08.5. Passing the smell test – with ozone AOP** *S. Dominguez, L. Dinkloh, S. Besser, A. Ried, H. Stapel (USA, Germany)*	177
10:10	SP	**08.6. Novel magnetic photocatalyst [UETiO$_2$ (Fe)] for photocatalytic ozonation processes** *J. López, A. Rey, P. M. Álvarez, F. Beltrán (Spain)*	109
10:15	SP	**08.7. Solar photocatalytic ozonation of nom with TiO_2, WO_3 and WO_3-TiO_2 catalysts for drinking water treatment** *A. Rey, A. M. Udaondo, F. J. Beltrán (Spain)*	130
10:30		**Break**	

Session 9. Ozone in Medicine – Part 1 / Introduction. Clinical trials in topical ozone application | Chair: R. Viebahn, S. Batthi

Hour	Presentation		ID
08:30	LP	**09.1. Ozone in Medicine: the low-dose ozone concept and the role of glutathione** *R. Viebahn, O. S. Leon Fernandez (Germany, Cuba)*	217
08:50	LP	**09.2. Evaluation of the role of topical ozone therapy in management of moderate and severe burn injuries** *M. Masoud, H. Shalaby, K. Eltobgy, M. Degheidy, M. Mawsouf, E. Abdelzaher (Egypt)*	121
09:20	LP	**09.3. Effectiveness of ozone therapy in the prevention of purulent infections after the operation of sigma-anal anastomosis** *S. Navruzov, A. Khakimov (Uzbekistan)*	93
09:40	LP	**09.4. Treatment of peri anal fistulas with ozone therapy** *S. Bhatti (Pakistan)*	221
10:00	LP	**09.5. Ozonated Sunflower Oil in Full-thickness Burns** *M. S. Melo, H. C. Carvalho, A. B. Fernandes, C. J. de Lima, L. P. Alves, L. H. M. S. Melo, M. A. C. Salgado, R. A. Zângaro, (Brazil)*	136
10:20		**Poster exhibition**	
10:20	SP	**09.6. Mild ozonisation activates antioxidant cell response by the Keap1/Nrf2 dependent pathway** *V. Covi, M. Malatesta, G. Tabaracci (Italy)*	86
10:25	SP	**09.7. Analysis of Blood Ozonation by Dispersive Raman Spectroscopy** *H. C. Carvalho, A. B. Fernandes, C. J. de Lima, L. P. Alves, L. H. M. S. Melo, M. S. Melo, R. A. Zângaro, L. Silveira Jr. (Brazil)*	137
10:30	SP	**09.8. Evaluation of Ozonated Red Blood Cells Elasticity** *H. C. Carvalho, A. B. Fernandes, C. J. de Lima, R. A. Zângaro, Y. S. S. Silva, A. Fontes, D. S. Moura, R. E. de Araujo (Brazil)*	138
10:30		**Break**	

Session 10. Poster introductions – Part 1 | Chair: A. Ried

Hour	Presentation		ID
11:00	SP	**10.1. Modification of dough rheological properties, storage proteins characteristics and change in the glutathione reductase activity in soft wheat flour after grains gaseous ozone treatment** *M. Heuls, M. Pages, J. Of, S. Rannee, A.M. Busuttil, F. Violleau (France)*	80
11:05	SP	**10.2. Impact of dissolved ozone and free chlorine for the viral decontamination of ready-to-eat salads at laboratory scale** *J. Loutreul, A. Gombert, S. Gauthier, S. Baig, T. Aussenac, B. Picoche, N. Boudaud (France)*	199
11:10	SP	**10.3. Preozonation for aerobic stabilization of biosolids generated in a dairy products industry** *C.R. Ramírez-Cortina, A. Colín-Sánchez, M. de la Soledad Alonso-Gutiérrez, G. Ibáñez-Cervantes (México)*	171
11:15	SP	**10.4. Degradation of organic compounds during ozonation in the presence of zero-valent iron** *A. Cruz-Alcalde, N. López-Vinent, L. Sánchez-Fontanet, S. Esplugas, C. Sans (Spain)*	128
11:20	SP	**10.5. Degradation of cimetidine by hybrid titanium dioxide photocatalytic system with process component combination and dissolved oxygen** *H. Lee, H.J. Bang, S.J. Kim, H. Kim, S.C. Jung (Korea)*	154
11:25	SP	**10.6. Effect of NOM on the efficacy of different ozone and solar-light based AOPs for the reduction of DBPs formation potential** *A. Rey, A. M. Udaondo, E. M. Rodríguez, F. J. Beltrán (Spain)*	132
11:30	SP	**10.7. Vibrational spectroscopy as a tool for fast and on-line monitoring of ozone concentration in water inside a reactor** *S. Treguier, S. Cuq, V. Lemetter, A. Canado, M. Pages, F. Violleau (France)*	89
11:35	SP	**10.8. A new process of disinfection and deodorization of helmet by ozonation** *B. Lerzy, C. Staut, F. Girard, T. Aussenac (France)*	124
11:40	SP	**10.9. Solar photo-fenton for olive mill wastewater treatment** *E. Domingues, R. Martins (Portugal)*	
11:45		**Poster Exhibition**	
12:30		**Lunch**	

Session 11. Poster introductions – Part 2 | Chair: E. Chauveheid

Hour	Presentation		ID
11:00	LP	**11.1. Advanced Oxidation Process treatment for 1,4-Dioxane and VOC removal at LADWP's North Hollywood Central and Tujunga Facilities** *M. Maxwell, C. Cotton, B. Kuhnel, K. Wells, A. Medina, N. Blute (USA)*	
11:20	SP	**11.2. Cefuroxime removal from water with ozone photolysis** *O. Monago, A. M. Chavez, F. J. Beltrán (Spain)*	115
11:25	SP	**11.3. Degradation of microcystin-LR by vacuum UV/ O_3** *F. Alafifi, S. Jasim, M. Mohseni (Canada)*	188
11:30	SP	**11.4. Removal of Microcystin-LR in drinking water using ozone and ozone-based AOP** *J. Saththasivam, G. Ponnusamy, S. Jasim (Qatar)*	103
11:35	SP	**11.5. Mineralization of Primidone in an urban secondary wastewater effluent with TiO_2 photocatalytic ozonation and a UVA LED photoreactor** *M. Figueredo, E. M. Rodríguez, F. J. Beltrán (Spain)*	113
11:40	SP	**11.6. Catalyst selection for industrial textile wastewater treatment** *L. Bilińska, K. Blus, M. Gmurek, S. Ledakowicz (Poland)*	107
11:45	SP	**11.7. Carbon nanotube electrochemical filtration for estrogenic activity removal** *G. Cunha, B. Souza, J. P. Bassin, D. Bila, C. Vecitis, M. Dezotti (Brazil, USA)*	198
11:50	SP	**11.8. Photocatalytic Absorption and COD Degradation of Dewatering Wastewater from a Gas Refinery Storage Tank by using MWCNTs/TiO2 Nano-composite** *M. Akrami, F. Farzaneh (Iran)*	226
11:55		**Poster Exhibition**	
12:30		**Lunch**	

Session 12. Ozone in Medicine – Part 2 / Inflammatory Diseases | Chair: S. Bhatti, A.G.H. Aziz

Hour	Presentation		ID
11:00	LP	**12.1 Potentiation of medical ozone beneficial effects after a second cycle of ozone exposition is mediated by innate immune memory in rheumatoid arthritis patients** *O. S. León Fernández, R. Viebahn-Häensler, G. Takon Oru, E. García Fernández, J. C. Polo Vega, B. Tamargo Santos, G. López Cabreja, I. Serrano Espinosa (Cuba, Germany)*	96
11:20	LP	**12.2 Intraarticular injection of IL-1/ozone in osteoarthritis of the knee: a randomized, placebo-controlled study** *Z. Fahmy (Germany)*	218
11:40	LP	**12.3 Ozone therapy against inflammation and degeneration** *V. Simonetti (Italy)*	153
12:00	SP	**12.5. Ozonucleolysis is more effective in cervical than lumber disc lesions - 45000 cases** *U. Rashid (Pakistan)*	164
12:05		**Discussion**	
12:30		**Lunch**	

Session 13. Ozone in Agrifood – Part 1 | Chair: J.P. Duguet

Hour	Presentation		ID
14:00	LP	**13.1. *In vivo* fungicide properties of ozone dissolved into water against the fungus responsible of apple scab, *venturia inaequalis*** *M. Pages, D. Kleiber, S. Maldes, F. Violleau (France)*	85
14:20	LP	**13.2. Fludioxonil, difenoconaozole and sedaxane, pesticides degradation of loaded wheat seeds: comparison of different oxidative technologies** *M. Heuls, M. Pages, J. Of, S. Rannee, A.M. Busuttil, F. Violleau (France)*	78
14:40	LP	**13.3. Effect of ozone on the rheological properties of flours and dough of french soft wheat** *P. Gozé, R. Larbi, T. Aussenac (France)*	125
15:00	LP	**13.4. Ozonation of sunflower oils: properties, purification and application** *J. Vinet, S. Moureu, R. Pierron, A. Calmon, F. Violleau (France)*	97
15:20	LP	**13.5. Ozonisation of meat processing environments acts on microbiota that survives after cleaning: a promising disinfection synergism** *C. Botta, I. Ferrocino, M.C. Cavallero, S. Riva, C. Carboni, L. Cocolin, K. Rantsiou (Italy)*	157
15:40	LP	**13.6. Ozone treatment: a solution to improve sanitary and physiological quality of grapevine** *A. Romeo-Olivan, M. Pages, C. Breton, F. Violleau, A. Jacques (France)*	79
16:00		**Break**	

Session 14. Fundamentals – Part 2 | Chair: S. Esplugas

Hour	Presentation		ID
14:00	LP	**14.1. Catalytic ozonation for micropollutants removal: laboratory and pilot studies** *R. Mahmudov, I. Pajolli, F.J. Chassaing, V. Yargeau (USA, France, Canada)*	90
14:20	LP	**14.2. Synergetic Micropulluants Removal by Hybrid Oxidation Separation Technology (HOST): Fabrication of Ceria-Functionalized Ceramic Membrane, Performance Evaluation and Mechanistic Study** *W. J. Lee, T.-T. Lim (Singapore)*	118
14:40	LP	**14.3. Degradation of phenol in water using ozonation and catalytic ozone** *R. Kidak, G. Badru Olabimpe (Turkey)*	101
15:00	LP	**14.4. Modelling of clopyralid removal by solar photocatalytic ozonation coupled process** *Z. Rajah, M. Guiza, F. J. Rivas Toledo, A. Ouederni (Tunisia, Spain)*	110

15:20	LP	**14.5. Removal of ibuprofen and gemfibrozil using ozone and ozone/hydrogen peroxide advanced oxidation** *H. Farzaneh, K. Loganathan, J. Saththasivam, G. McKay (Qatar)*	114
15:40	LP	**14.6. Treatment of ciprofloxacin by ozone/persulfate oxidation** *S. B. Kpange, S. Doğan, S. Pirgalıoğlu (Turkey)*	119
16:00		**Break**	

Session 15. Ozone in Medicine – Part 3 / Pain | Chair: O. León Fernández, M. Schreiber

Hour	Presentation		ID
14:00	LP	**15.1. Minimally Invasive OxygenOzone Therapy for Lumbar Disk Herniation. Improving the results.** *A. Alexandre (Italy)*	219
14:30	LP	**15.2. Comparison of disc herniated patients receiving ozonucleolysis with & without physical therapy** *Noor-ul-Huda, U. Rashid, M. Farooq (Pakistan)*	163
14:50	LP	**15.3. Herniated discs unchanged over the time: size reduced after oxygen-ozone therapy** *M. Bonetti, A. Zambello (Italy)*	172
15:10	LP	**15.4. Effect of adding ozone sauna to local injections in low back pain treatment** *T. T. Tanbouli, M. Al-Qanni (Egypt)*	106
15:30		**Discussion**	
16:00		**Break**	

Session 16. Ozone in Agrifood – Part 2 | Chair: S. Brosillon

Hour	Presentation		ID
16:30	LP	**16.1. The effect of the combination of gaseous ozone and different storage temperatures on the quality of yellow-flesh kiwifruit CV. 'Soreli'.** *C. Carboni, V. Goffi, R. Forniti, R. Botondi (Italy)*	158
16:50	LP	**16.2. Effects of continuous low ozone exposition on ariane apples in cold storage conditions with modified atmosphere** *V. Lemetter, M. Pages, D. Kleiber, J. Joulie, S. Maldes, F. Violleau (France)*	94
17:10	LP	**16.3. Researches on active and passive monitoring aeromicroflora in milk processing units and the results obtained following use the GF3XO-15 ozone generator** *I.E. Popa, G. Puchianu, D.V. Enache (Romania)*	186
17:30	LP	**16.4. Short-term ozone treatments during postharvest manegement influence grape volatile composition** *S. Río Segade, M. Vilanova, M. Pollon, S. Giacos, C. Carboni, L. Rolle (Italy, Spain)*	159
17:50	LP	**16.5. Effectiveness of ozonated water treatment on microbial control and storage quality of different Citrus fruit species** *M.C. Strano, F.V. Romeo, P. Foti, M. Allegra, C. Carboni (Italy)*	160
18:10	LP	**16.6. Effect of two different application methods of ozone on *geobacillus stearothermophilus* spores** *E. Sarron, D. Marier, S. Gauthier, S. Baig, B. Picoche, P. Sajet, P. Gadonna-Widehem (France)*	207

Session 17. Workshop Ozone plant design: Key questions

Hour	Presentation		ID
16:30	WS	*Leader: S. Baig*	

Session 18. Ozone in Medicine – Part 4 / Case reports, preclinical trials | Chair: A. Alexandre, U. Rashid

Hour	Presentation		ID
16:30	LP	**18.1. Ozone Therapy and Its Usefulness in a Wide Variety of Ailments: A Systems Medicine Approach** *L. Re (Italy)*	
16:50	LP	**18.2. Medical ozone an important part of COPD-therapy** *R. Thiele (Austria)*	151
17:10	LP	**18.4. Effect of ozonation over the therapeutic properties of different vegetable oils with low ozonation degree** *F. Antunez, P. Guerra-Blanco, T. Poznyak, I. Chairez, J. Dueñas Moreno (Mexico)*	141
17:30	SP	**18.5. Life quality study in relation to alternative infusion solution: conventional versus glucosate** *M. Martinelli, F. Giovannangeli (Italy)*	161
17:35		**ROUND TABLE Discussion with all Speakers** | Chair: S. Tiron, R. Viebahn	

Wednesday, 23 October

Session 19. New challenges in wastewaters – Part 1 | Chair: D. Smith

Hour	Presentation		ID
08:30	KN	**19.1. TReating Urban Micropollutants and Pharmaceuticals in wastewaters: new solution involving synergetic biological and chemical oxidation using ozone** *B. Domenjoud, A. Gonzalez Ospina, A. Kiss, A. Bergé, E. Vulliet, M. Marce, S. Esplugas, S. Bony, A. Devaux, A. Wigh, S. Baig (France, Spain)*	206
09:10	LP	**19.2. Micropollutant removal – full-scale reality for the largest sewage treatment plant in Switzerland** *L. Dinkloh, T. Puehmeier, A. Ried, H. Stapel, S. Bressmer, C. Abegglen (Germany, Switzerland)*	178
09:30	LP	**19.3. Degradation of pharmaceuticals in waste water treatment plant effluent by ozonation and ozone based advanced oxidation** *B. Delfos, B. Martijn, H. Bruning, J. Kruithof (The Netherlands)*	204
09:50	LP	**19.4. Coupling ozonation and nanofiltration for removal of pharmaceuticals pollutants in wastewater for sustainable reuse** *Z. A. Yacouba, J. Mendret, F. Zaviska, G. Lesage, S. Brosillon (France)*	122
10:10	LP	**19.5. Transformations of protein-like and humic/fulvic-like fractions during post-treatment of wastewater effluent by ozonation** *A. Ignatev, T. Tuhkanen (Finland)*	144
10:30		**Break**	

Session 20. Fundamentals – Part 3 | Chair: C. Schulz

Hour	Presentation		ID
08:30	LP	**20.1. Ozonation using hollow fiber contactor technology for the elimination of pharmaceuticals: state of the art** *A. Schmitt, S. Brosillon, J. Mendret (France)*	123
08:50	LP	**20.2. Impact of Ozone and Biological Filtration on NDMA Formation (WRF 4491 and 4669)** *B. Kuhnel, A. Evans, C. Russell, P. Huck, S. Peldszus, W. Mitch, R. Hozalski (USA, Canada)*	143
09:10	LP	**20.3. Estrone degradation using non-thermal plasma and ozone: kinetics of degradation products** *C. Tizaoui (UK)*	189
09:30	LP	**20.4. Accelerated oxidation of iopamidol by ozone/peroxymonosulfate (O_3/PMS) process: Kinetics, mechanism and simultaneous reduction on iodinated disinfection by-products formation potential** *H. Dong, Y. Mao, L. Zhang, Z. Qiang (China)*	216

09:50	LP	**20.5. A novel kinetic ozonation model for prediction of bromate formation, bromate mitigation and trace organic contaminant removal** *W. Audenaert, G. Bellandi, R. Mack Pearce, I. Takács, P. Buehlmann, S. Hogard, G. Salazar-Benites, U. Rehman, I. Nopens, C. Wilson, C. Bott (Belgium, USA, France)*	192
10:10	LP	**20.6. How to predict bromate formation during ozonation** *S. Baig, M. Roustan (France)*	
10:30		**Break**	

Session 21. Ozone in Medicine. Workshop: Ozone in Inflammatory Conditions

Hour	Presentation		ID
08:30	LP	**21.1 The effect of ozone on colonic epithelial cells** *H. Himuro, H. Matsumura, T. Abe (Japan)*	117
08:50	LP	**21.2 Ozone workshop: Ozone as a complimentary therapy in medicine in the fields of chronic inflammatory disease** *M. Schreiber (Germany)*	116
09:40	LP	**21.3 Possible errors in pain treatment with ozone** *S. Tiron (Romania)*	179
10:00	LP	**21.4 Trigeminal nevralgia treated with ozone** *S. Tiron, V. Simonetti, M. Marcvart, L. Rajnoveanu (Romania, Itlay)*	180
10:30		**Break**	

Session 22. New challenges in wastewaters – Part 2 | Chair: S. Baig

Hour	Presentation		ID
11:00	LP	**22.1. Successful Treatment of Micropollutants and Recalcitrant COD from Wastewater using the Nyex™ Combined Adsorption and Electrochemical Regeneration (AOP) Process** *M. A. Khan, M. Massaros, D. Zulfiqar, E. Carson (UK)*	167
11:20	LP	**22.2. Strategies for enhanced ozone-resistant micropollutants abatement in wastewater and alternatives for process monitoring** *A. Cruz-Alcalde, S. Esplugas, C. Sans (Spain)*	127
11:40	LP	**22.3. Removal of microcontaminants from water in presence of microplastics** *T.G. de Aragão Belé, T.M. Bragadin de Castro, J. Cristale, R. Falcão Dantas (Brazil)*	193
12:00		**Discussion**	
12:30		**Lunch**	

Session 23. Applications in Industrial Processes – Part 1 | Chair: C. Tizaoui

Hour	Presentation		ID
11:00	LP	**23.1. Color stripping of the reactive dyed fabric by conventional and ozone assisted process-a comparative study** *A. Powar, A. Perwuelz, N. Behary, L. Hoang, T. Aussenac (France, Romania, China)*	91
11:20	LP	**23.2. On the mechanism of wood pulp oxidation during ozone bleaching** *D. Lachenal, F. Pouyet, J. Perrin, E. Montet (France)*	173
11:40	LP	**23.3. Comparison of bleaching treatments of linen fabrics for clothing and furniture applications: conventional versus ozone** *A. B. Rhouma, A. Perwuelz, N. Behary, X. Legrand, L. Hoang, T. Aussenac (France)*	92
12:00	LP	**23.4. Evaluation of excess sludge reduction using ozone ultra-fine bubble** *K. Hashimoto, T. Marushima, S. Nakai, W. Nishijima, H. Motoshige (Japan)*	84
12:20		**Discussion**	
12:30		**Lunch**	

Session 24. Ozone in Medicine. Workshop: Ozone in Dentistry

Hour	Presentation		ID
11:00	WS	**24.1 Ozone in dentistry: the systemical ozone therapy and the lokal use of ozonated water and ozonated olive oil in dentistry and dental surgery** *W. Schueler (Germany)*	166
11:45	WS	**24.2 Integration of ozone with photon-induced photo-acoustic streaming (PIPS) for enhanced outcomes in endodontic therapy** *P. Mollica (USA)*	222
12:30		**Lunch**	

Session 25. New challenges in wastewaters – Part 3 | Chair: M. Dezotti

Hour	Presentation		ID
14:00	LP	**25.1. Performic Acid: An alternative chemical disinfectant for Reuse application, evaluation of its bactericidal efficacy, impacts on the natural environment and facilities: feedback after 18 months of use as tertiary treatment of urban waste water** *P. Aubeuf-Prieur, M. Hesampour (France)*	135
14:20	LP	**25.2. Impacts of water matrix on the efficiency of micropollutants elimination from urine by ozonation** *J.S. Pic, H. Deng, C. Guigui (France)*	120
14:40	LP	**25.3. Catalytic ozonation for municipal wastewater disinfection and micropollutants removal** *J. A. Malvestiti, A. Cruz-Alcalde, N. López-Vinent, R. F. Dantas, C. Sans (Brazil, Spain)*	95
15:00		**Break**	

Session 26. Applications in Industrial Processes – Part 2 | Chair: L. De Franceschi

Hour	Presentation		ID
14:00	LP	**26.1. Development and industrial cases of oxidation and ozonation in flow chemistry** *J. Vinet, G. Gotti, M. Pages-Homs, F. Violleau, J.C. Monbaliu, G. Gauron (France, Belgium)*	197
14:20	LP	**26.2. Comparison of UV/Fenton, UV/H_2O_2, UV/Oxone and Ozone in degrading the naphthenic acids in oil sands process water** *H. Demir-Duz, S. Ashagre Messele, M.G. Álvarez, S. Contreras, M. Gamal El-Din (Canada, Spain)*	191
14:40	LP	**26.3. Ozone and H_2O_2 in wastewater treatment of a bio-refinery** *C. Carboni (Italy)*	156
15:00		**Break**	

Session 27. Workshop – IOA Highlights on Innovation

Hour	Presentation		ID
14:00	WS	*Leader: C. Tizaoui*	
15:00		**Break**	

Plenary session

15:30	**Award Ceremony** **Synthesis and Conclusions** **Announcements**
17h00	**Adjourn**

KEY NOTES SPEAKERS

Mr. Barry L. Loeb is the Editor-in-Chief (since 1999) of Ozone: Science & Engineering, the technical journal of the International Ozone Association (IOA) and Ozone News, the news magazine of the IOA. He has a BS and MS in Chemical Engineering (1971) from the University of Cincinnati and has more than 50 years' experience with ozone, including the production of industrial chemicals.
He was Vice President of the Emery division of Henkel Corporation (USA) and President of Praxair-Trailigaz Ozone Company which supplied ozone systems for drinking water and wastewater treatment. He is a member of the Executive Committee of the IOA.

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 George Warren Fuller Award (2016), 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 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

Monday, 21 October

Plenary session. Opening

Opening Addresses, *Bernard PAOLINI, IOA President and Frédéric VIOLLEAU, IOA-EA3G President*
Congress introduction, *Michel ROUSTAN, Renate VIEBAHN, Co-chairs of the Scientific Committee*
Exhibition opening

00.1. Ozone and Nice, a nice story!
M. Roustan (France)

00.2. Forty years of advances in ozone technology. A review of Ozone Science & Engineering
B. Loeb (USA)

The first issue of Ozone: Science & Engineering (OS&E) was published in early 1979 with Dr. L. J. Bollyky as the Editor-in-Chief. This was a milestone for the International Ozone Association enabling professional recognition of the advances in ozone technology.
Since this first issue, 41 volumes of Ozone: Science & Engineering have been published containing 222 individual issues, 1616 technical articles and nearly 20,000 pages. Dr. Rip Rice became Editor-in-Chief in 1985 and continued this position until 1998. Barry Loeb has been the Editor since. Under the leadership of these gentlemen, OS&E expanded from about 70 pages per issue four times per year to 100 pages, then to six issues per year, at about 100 pages. In 2001 the dimensions of the journal were increased to accommodate even more manuscripts.
In 1989, the Harvey M. Rosen Memorial Award was established to recognize the "best paper" published in Ozone: Science & Engineering during the two-year period between World Congresses. The selection of this award is determined by the Editorial Board of Ozone: Science & Engineering. To date, seventeen papers have received this prestigious award.
OS&E has followed and reported development of ozone technologies via peer reviewed articles from ozone researchers, manufacturers and consultants. This paper reviews the development of ozone technologies as reported by OS&E and summarizes how the technologies have evolved to meet environmental and other needs. This paper also reviews the Food-Energy-Water Nexus and explores possible roles for ozone in addressing the Nexus.

00.3. Outlook - Acting in a regulated market
B. Paolini (Switzerland)

Session 1. Ozone in the water cycle

01.1. Ozonation at Super Rimiez drinking water plant of Nice
T. Jaeck (France)

01.2. Advanced treatment trains for indirect potable reuse
A. Aaharoni, H. Cikurel, A. Ried, M. Fassbender, J. Gebhardt, H. Raanan Kiperwas (Israel, Germany)

An innovative hybrid process based on biofiltration, ozonation and short SAT (sSAT), with ~22 days retention time, was previously demonstrated in an 6-7 m^3/h pilot to be successful in removing emerging trace organic compounds (TOrCs), organic matter and control Mn^{2+} dissolution in reclaimed water in the aquifer, meeting local drinking water criteria for the chemical constituents monitored during that pilot. To improve the performance of the original system with respect to biodegradability of the organic matter (expressed as UVA), TOrCs concentration, and the removal of dissolved organic matter, as well as the overall consumption of chemicals and energy (ozone dose), a new pilot system was constructed. The new-ozonation pretreatment system consisted of a 2m bed depth biofilter and was operated at 7-8 m^3/h, doubling the empty bed contact time (EBCT from 4.5 min. to 9 min). Coagulation conditions remained the same, hydrogen peroxide concentrations were 25% lower than in the old system, and energy consumption (O_3:DOC ratio) ranged between 0.75-0.9 as opposed to 1.1-1.2 in the old system (25-30% energy saving).The new system also applied recirculation of 22-27% of the ozonated stream back to the biofilter to improve biodegradability, which was taken into account when calculating the ration of O_3:DOC. The new system included, as post treatment to ozonation, two parallel systems: A fully engineered system consisting of ozonation-bioactive carbon filter-ultrafiltration system (O_3-BAC-UF) and an engineered-natural system (ozonation-sSAT). The performances of both systems were compared for chemical parameters, TOrCs, disinfection by products (DBPs) and microbiology. The ozonation-sSAT track reached the IPR (indirect Potable reuse) regulations, including the 2 months Hydraulic Retention Time (HRT) in the soil, producing water with no micropollutants, DBP and microorganisms. For the O_3-BAC-UF train the results indicate that it still requires optimization before reaching the IPR regulations. Particularly with respect to biodegradability, the removal of organic matter, microorganisms, TOrCs and DBPs. For that purpose, a popular multi-barrier approach (O_3 -BAC-GAC-UF-UVA/H_2O_2), but preceded by the tertiary bio-treatment explained in this paper is suggested.

01.3. Electro-Pulse Oxidation Process (EPOP) – An alternative AOP as pre-treatment for Soil-Aquifer Treatment of secondary effluents for Indirect Potable Reuse

O. Gafri, R. Abekasis, H. Cikurel, H. Raanan-Kiperwas, A. Izhar, A. Aharoni, O. Eliyahu (Israel)

Advanced oxidation processes (AOPs) aim to produce, besides oxidation products like ozone UV, and peroxides, mainly hydroxyl radicals ($OH^{\cdot}$) radicals which quickly and effectively react with organic constituents in water forming reaction products much biodegradable then their parent compounds. WADIS Electrical Pulse Oxidation Process (EPOP) is a process in which high voltage electrical pulses are being discharged through multiple hollow electrodes with oxygen (O_2) carrier gas, at high frequency, creating plasma and forming directly with the water (OH*) and other strong oxidants. In the current work, the EPOP (10-30 LPM O_2, 22-29 kV, 500-1000 Hz) was used to treat secondary effluents at the Shafdan WWTP in parallel to an Ozonation process (ozone/DOC 0.7-0.9) in order to evaluate the process capabilities to reduce micro pollutant at minimum Disinfection by-products (DBP). Both processes were pretreated by coagulation/flocculation-hydrogen peroxide addition for enhanced biofiltration. Both processes used a biofiltration contact time of 9 min. and only in case of ozonation a 20-25% of the ozonated stream was recirculated back to the biofilter. No contact tank was used in the EPOP system (direct flow though), as opposed to a 5 minutes contact time in the ozonation process. The decomposition of several Trace Organics (TrOC) were analyzed and compared. Field measurements of filtered UVA_{254}, DOC, NH_4, NO_2, NO_3, and (DBPs) like NDMA, bromate and microbiology have been measured. The results show, especially for hardly biodegradable X-ray contrast media, higher removal compared to ozonation with almost no DBPs formation and complete microbial disinfection. The electrical energy use (as kWh/m^3) is still relatively high compared to ozonation and will be improved in future work.

01.4. Closing the water cycle applying suspended ion exchange and ozonation for pharmaceutical control

B. Martijn, J. Malley, G. Zoutberg, J. Kruithof (The Netherlands)

Hoogheemraadschap Hollands Noorderkwartier (HHNK) and PWN Water Supply Company North-Holland (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. When an ozone residual was present high concentrations of bromate were observed. Pretreatment by suspended ion exchange decreased the ozone demand significantly but did not have a strong impact on micropollutant degradation and bromate formation. 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 impact on bioassay response will be investigated.

01.5. Ozone Solutions For Micropollutants Treatment at all Positions in the Water Cycle: Drinking Water to Wastewater

L. De Franceschi, K. Wasiak, M. Reid, C. Huynh (Switzerland, USA)

Concentrations of trace contaminants in all positions in the water cycle continue to increase as the proliferation of pharmaceuticals, cosmetics, and personal care products increases. The adverse "cocktail" effect of the combination of a wide variety of these contaminants of emerging concern (CEC), or micropollutants, on the environment and human health have been proven through many studies around the world.

Session 2. Design and engineering

02.1. How advanced modelling (CFD) can enhance ozone system design

J. Anton, A. Ried (Germany)

Todays the rising focus on energy efficiency is even resulting in energy neutral WWTPs and demanding energy efficiency optimization beyond the ozone generation equipment. In addition to the improved and increased efficiency of the actual ozone technology, the ozone contact system also offers a high potential to improve energy consumption of the entire process. Depending on the specific design of the ozone contacting unit the utilization of ozone in the field can vary from insufficient processes with 50% mass transfer up to excellent mass transfer reaching 98% or higher. It is evident, that it makes sense to exploit the potential of the overall system, when optimizing the energy efficiency of ozonation processes.
A CFD model was developed and calibrated with data from existing plants. The model can support the optimization of existing plant conditions or new system designs by varying parameters e.g. geometry of tank, number of chambers, arrangement of diffusors, gas flow per diffusor, bubble size and Ozone gas concentration. Thus, the tool supports the overall design of an ozone contact system.

02.2. Emerging operational challenges to ozone applications - high turndown, high doses, stable ozone residuals

S. S. Pathapati, D. W. Smith, A. L. Mazzei (USA, Canada)

The operational limits of existing, proven ozone dissolution and contacting technologies are being tested by rapidly evolving applications of ozone. Recent water reuse applications have required higher than typical ozone doses– ranging from 7 mg/L all the way to 30 mg/L in the bulk flow. In addition, many plants require contactors to operate at turndowns as high as 13:1. These turndown ratios are requiring a contacting method that can treat influent water across a wide velocity range, from as low as 0.23 m/s to greater than 2.4 m/s. SCADA-controlled systems where the stability of ozone residual reading directly affects ramp up of ozone generation equipment present a different challenge – where and how to measure ozone residual so that the operator is getting an accurate snapshot of mixing and mass transfer. Ozone dissolution and contacting systems are required to adapt to these new bounds and continually meet or exceed stringent mass transfer efficiency (MTE) targets while providing a stable dissolved ozone residual as close as possible to the downstream target location. Sidestream Venturi Injection (SVI) combined with pipeline contacting is an efficient ozone contacting method due to the advantages of rapid mixing and mass transfer in a small foot-print, with minimal maintenance requirement and increased turndown capability. This presentation focuses on recent applications which required multiphase computational fluid dynamic (CFD) model-based adaptive design of Pipeline Flash Reactors TM (PFR) to meet mass transfer efficiency (MTE) and ozone residual targets, with minimal head loss across all design flow rates. Design of a cross-plane sampling mechanism for accurate ozone residual sampling is also discussed.

02.3. 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) and chronic toxicity of wastewater.
However control and mitigation of the formation of disinfection by-products such as Bromates and more poisonous micro-pollutants can be a drawback to this technology, if not designed correctly.
Together with Ozone Generation its Diffusion into water and wastewater is the heart of this technol-ogy.
Optimization of Ozone Diffusion Technology towards better efficiency and optimization is of the essence.
This essay is a trial to address and investigate the effect of Turbulence Intensity TI on the behavior of a Bubble Column BC which is generated and homogeneously dispersed into a Fully Turbulent Water Flow FTWF and on the overall Reaction Kinetics of Ozone with the Reactants dispersed in a wastewater/water.
Our focus is directed towards the case of Wastewater.

- We begin with an introduction
- We continue with a comprehensive description of a FTWF
- Next, we present a qualitative and quantitative description of Diffusion in a FTWF, the so-called Eddy Diffusion
- Then we present a short physical description of a BC generated inside a FTWF and address its stability under the influence of the strong TI of the Completely Turbulent Flow CTF where this BC is installed.
- Another item is the qualification of the Turbulence in the voids in between the Bubbles inside the BC.
- Then we will propose a qualitative and quantitative description of the Diffusion Path of Ozone from the inside of the Ozone Gas Bubble into the Bulk of the inter-bubble liquid where the reac-tions with Ozone take place, assuming that the carrier gas of Ozone is inert and practically non soluble in wastewater.
- Finally, we will, present results with a program developed for a such a situation based on a typi-cal case.
- As suggested by Prof. Michel Roustan and Dr. Sylvie Baig on occasion of the IOA Conference in Lausanne in 2108, we will verify this case with the Damköhler Number DaII linking the Chemi-cal Reaction Rate with the Diffusive Mass Transfer Rate.

02.4. Ozonation and ozone based advanced oxidation in combinations with hydrodynamic cavitation – impacts on by-products formation in post-chlorinated drinking water

M. Čehovin, A. Žgajnar Gotvajn (Slovenia)

In the everlasting quest of increased process, economic and energetic efficiencies of ozonation and ozone based advanced oxidation processes (AOPs), various treatment technologies have been assessed over the past decades, hydrodynamic cavitation included. When post-chlorination, most commonly for disinfection, is applied to such water, it can in some cases result in increased formation of the, trihalomethanes (THMs), halogenated acetic acids (HAAs) and adsorbable organic halogens (AOXs). These are causing great concern in water treatment due to their toxic effects on organisms. Related to human health, adverse carcinogenic and reproductive outcomes are among the most studied and scientifically proven ones. Applying ozone or ozone based AOPs on water and wastewater containing natural and synthetic organic matter influences formation of oxidation and disinfection by-products with chlorine, depending on the oxidants dosages, water pre-treatment and other applied/combined technologies, concentration and characteristics of organic matter. Prediction of the outcome is, due to variety of influencing parameters, sample constitutions and experimental conditions, still rather impossible. Therefore, this paper is emphasizing the need of extensive laboratory and pilot testing in as realistic conditions as possible in order to obtain realistic insight to formation of oxidation and disinfection by-products.

02.5. Ozone mass transfer in spray column

A. Canado, M. Pages, M. Tournois, M. Roustan, W. Remus-Borel, N. Dietrich, G. Hebrard, F. Violleau (France)

Thanks to its high oxidizing and biocide potential, ozone is a good candidate to substitute chemical phytosanitary products in agriculture especially for its low remanence. Unfortunately, when water containing dissolved ozone is pulverized, the dissolved concentration of ozone decreases dramatically along the spraying distance. This study aims to identify if the ozone loss during spraying is due to a mass transfer phenomenon. Identification is done by realizing absorption of dioxygen and comparing profiles concentrations with the ozone ones. We confirm that the decrease of dissolved ozone in the liquid is caused by mass transfer, and most of the transfer occurs few centimetres after crossing the nozzle. A model has been made from mass balances and mass transfer correlations to predict the profile concentration in the fully developed spray only (when liquid film is already atomized in droplets).

Round table. Instantaneous Ozone Demand

IOA Ozone Engineering Group

Session 3. Ozone generation and measurement

03.1. Efficient ozone generation using excimer – a competitive study between excimer and low-pressure mercury vapor lamp technology

K. Ziegler, S. Krahnert, F. Becker (Germany)

Dielectric barrier discharge excimer lamp technology based on Xe_2^* promises fast and efficient ozone generation without mercury-containing components. This paper compares established systems based on low-pressure VUV lamps and novel excimer systems in terms of ozone production per hour, efficiency and time course of VUV radiation. The results show clearly the benefits of excimer systems. Additionally, the "ZED Ozone Generator – ZO3gen" is presented – a simple and efficient solution for an economical ozone generation.

03.2. Photo Chemical Ozone Generation with Xenon Excimer Lamps- A Paradigm Shift for Ozone generation

N. Brueggemann, M. Salvermoser, R. Fietzek, R. Fiekens (Germany)

In the laboratory, narrow band VUV (vacuum ultraviolet) radiation from Xenon Excimer lamps with wavelength around 172 nm is ideally suited for ozone generation [1]. Up to now, for industrial applications, VUV excimer lamps were limited by low wall plug efficiencies, short lifetimes

and high cost. What would happen if one could overcome these disadvantages? Efficient ozone generation at high ozone concentrations and high gas pressures without nitrogen oxide formation are some of the features of the photochemical ozone generation.

03.3. Innovative analytical method to measure ozone in gas phase
L. Vitola Pasetto, M.H. Manero, R. Richard, J.S. Pic, V. Simon, F. Violleau (France)

Ozone in air has been mainly quantified from ultraviolet absorbance (at the wavelength of 254 nm), chemiluminescence (from electronically excited NO_2 produced *via* NO-O_3 reaction) and wet chemical techniques, such as iodimetric and indigo colorimetric methods [1,2]. However, some of these techniques are subject to analytical interference, as it the case of humidity disturbance for UV absorbance [3] and sulfur compounds for the iodimetric method [4].

03.4. Corrosion resistance of stainless steel in dry ozone gas environment
T. Yoshimi, E. Ishimaru, M. Abe, T. Nishimura (Japan)

Stainless steel is a material that can be used in ozone gas with its high oxidizing property, but there is hardly any research on the corrosion resistance1) and the change of the surface film of stainless steel exposed to dry ozone gas. In this study, corrosion resistance and the surface film of stainless steel exposed to dry ozone gas were investigated with common stainless steels UNS S30400 and UNS S31603, and duplex stainless steel UNS S821222) used as an alternative to UNS S30400.

03.5. Implementation of a fluorescence (FDOM) online measurement at an ozonation plant used for micropollutant elimination – operational aspects and comparison to UVA_{254}
M. Stapf, J. Schütz, V. Thiyagarajan, U. Miehe (Germany)

Micropollutant removal in wastewater is an emerging area of ozone application. The relative reduction of UVA_{254nm} (ΔUVA_{254nm}) is an established surrogate parameter for micropollutant elimination and can be used for monitoring of the ozonation process control as well as for the adaption of the ozone dose to a varying water quality. As an alternative to UVA_{254nm}, usage of fluorescence has also been in discussion, however, most of the experiments were conducted at lab-scale so there is a lack of experience using fluorescence online sensors under real conditions. To overcome this knowledge gap, relative reduction of fluorescence (ΔfDOM) caused by ozonation was investigated at a pilot scale plant at a German municipal WWTP and compared to the well-known ΔUVA_{254nm} surrogate. The preliminary results show a clear potential for the operation of a fluorescence (fDOM) online measurement at an ozonation plant used for OMP elimination. The reduction of fDOM shows a good correlation with the OMP elimination but is more sensitive to a variation of the ozone dose and is also less affected by fouling compared to a $UVA254_{nm}$ online measurement when using a single online sensor to monitor the influent and effluent of the ozonation alternatingly.

Session 4. Workshop - Young Ozone People

YOP session is privileged meeting beetwen young people (phD students, engineers, young researchers, …) to exchange around our ozone experiments. This year, the session will be split in two parts: a technical part with a former young people interview and a technical round table related to our daily ozone experiment issues (regulations, process, experimental design, others). The second part of the session will be devoted to how we could structure the Young Ozone Peoples network outside congresses. The goal: create an active community so all ideas are welcome!

Session 5. Workshop - CFD Modelling

Introduction to Two-Phase Flow CFD
Hydrodynamics and mixing aspects (turbulence modeling, retention time distribution)
Gas-Liquid transfer (two-phase flow modeling, bubble size, ozone transfer)
Kinetics aspects (slow/fast reaction, coupling with hydrodynamics / mass transfer, water quality)
Cases studies (ozonation tower, venturi, deep U tube, etc...)
Perspectives

Session 6. Workshop - Feed gas for ozone generators

Brief introduction on ozone generation by electrical discharge
Usual composition normale of feed gas
Feed gas pollutants
Systems for feed gas generation

Tuesday, 22 October

Session 7. Applications in drinking water

07.1. Climate Change, Water Quality Challenges, is the water Industry Ready?
S. Jasim (Canada)

Keynote lecture

07.2. Removal of micro-pollutants by combining ozone and activated carbon filtration at a full scale drinking water production plant

E. Chauveheid (Belgium)

Organic micro-pollutants were followed during several years at a conventional surface water treatment plant producing drinking water, where ozone and granular activated carbon filtration are applied in the process. Most organic micro-pollutants followed were completely oxidized at a pre-ozonation step where both molecular ozone and the hydroxyl radical were active oxidizing species. Some of these organic substances were resistant to these pre-ozonation conditions, such as benzotriazoles and gabapentine, and combining the ozone oxidation with successive granular carbon adsorption improved their removal. The most reluctant micro-pollutants to this drinking water production process were highly polar metabolites of pesticides. Nevertheless, the applied multi-barrier treatment could reduce significantly their concentration in finished water. Finally, pre-ozonation appeared quite effective to reduce the concentration of many polar organic substances in water. This advanced oxidation process used for decades in the drinking water industry behaves similarly to a final ozonation step applied today to treated wastewater effluents.

07.3. Worlds First Sequential Advanced Oxidation Process for Drinking Water Treatment put to the Test – Lessons learned from the first Year of operation

J. Scheideler, T. Knol, A. Ried (Germany, The Netherlands)

In 2007 Dunea Duin & Water initiated a pilot study to investigate the effect of Advanced Oxidation Processes on their treatment process with regards to the removal of micro pollutants and the impact on down stream treatment processes focusing on the core of their treatment scheme an artificial groundwater recharge using sand dunes at the sea side of The Hague. The pilot study led to the conclusion that the direct combination of ozone based advanced oxidation and UV based advanced oxidation will provide the highest removal of micro pollutants with the lowest oxidation by product formation and use of electrical energy. Based on the pilot plant a full scale treatment system was designed to treat 2,200 m^3/h of drinking water using ozone and UV AOP directly attached to each other.
The full scale system was commissioned and full scale tested between 2017 and 2018 resulting in a full acceptance of the system by the owner and start of a research project investigating the impact and integration of the full scale AOP system into the overall treatment scheme. Through the combination of advanced treatment steps the owner experiences significant savings on consumables compared to single treatment step solutions. The paper will highlight the operators experience with this first of its kind installation and results for the removal of emerging contaminants but also by products that are potentially formed when AOPs are applied to drinking water with higher DOC levels.

07.4. The Two-Stage Ozonation - Adsorption technology of Ground Water from Trichloroethylene and Tetrachloroethylene

I.S. Tkachenko, S.N. Tkachenko, N.A. Mamleeva (Russia)

The optimum parameters for ozonation and sorption stages of ground water purification from TCE and PCE are elucidated using laboratory and pilot-plant scales. Prolonged test of this technology for purification of ground demonstrated that the higher achievable efficiency of destruction with ozone is 94% for TCE and 38% for PCE. Ozonation-sorption treatment of ground water allows one to achieve TCE and PCE removal efficiency of 96-97% and 92-94% correspondingly. The most efficient carbon sorbent is microporous carbon fiber AUT-M. Using this sorbent, TCE and PCE concentrations in treated water decrease below MPC level (5¤g/l) adopted in Russia. It is concluded that the combination of ozonation with sorption of residual contaminants by carbon sorbents is a promising way for purification of waters containing chlorinated contaminants.

07.5. Improving GAC based pump-and-treat remediation of chloroethenes by adding ozonation

A. Kokkoli, N. Agerholm, H. R. Andersen, K. M. S. Kaarsholm (Denmark)

Chloroethenes are a frequent occurring groundwater contaminant especially in old industrial areas, and are of concern for potable water production. Pump-and-treat applying granular activated carbon (GAC) are frequently applied at point sources to limit spreading of chlorethenes into aquifer. Perchloroethene (PCE) and trichloroethene (TCE) sorb well to GAC but their biodegradation products dichlororethene (DCE) and vinylchloride (VC) sorb poorly. However, DCE and especially VC react fast with ozone, where PCE and TCE react very slowly. These properties were utilised by adding ozone treatment prior to GAC filtration. In laboratory experiments, contaminated groundwater was ozonated and it was found that VC and trans-DCE could be removed > 90% with less than 0.21 mg ozone/L. To remove 90% of cis-DCE and 1,1-DCE, 1.0 mg ozone/L had to be added, while TCE, as more resistant, had to be treated with 3.2 mg ozone/L for 90% reduction. Thus applying an ozone dose at approximately 1.8 mg/L could remove VC and DCE and partly TCE, and thereby extended the lifetime of the GAC filter approximately 7 times.

Session 8. Fundamentals – Part 1

08.1. Ethylbenzene decomposition by ozone in a three-phases system

J. Dueñas Moreno, T. Poznyak, J. L. Rodríguez (Mexico)

In the present study was realized the decomposition of the ethylbenzene (ETB), as one represents of the volatile compounds, in a three-phase system by conventional ozonation. The ozonation starts in the liquid phase (water with the dissolved ETB). Then, by the stripping effect with oxygen flow this compound emigrates to solid phase (sand), where adsorbed and also decomposed. Finally, in the gaseous phase finishes it's almost complete decomposition (91%) in 20 min. As observed, the solid phase (sand) serves as a good absorber, where the more part (93%) of the ETB decomposed, while in water only 29% of the initial contaminant decomposed, because there was, the competition between both processes ozonation and stripping. In the proposed combined scheme optimizes the use of ozone to treat three phases simultaneously with minimize the residual ozone. The identified intermediates and final products of the ETB decomposition are less toxic (oxalic acid and formic acid).

08.2. Phenol degradation in H_2O_2/ pulsed UV process

A.I. Kulebyakina, A.D. Volosatova, Y.A. Goldshteyn, S.G. Shashkovskiy (Russia)

In this study, the effect of pulsed ultraviolet continuous spectrum radiation on phenol degradation in H2O2/UV process in completely mixed reactor conditions was investigated. As light source a 200 W xenon flashlamp was used. The experiments were conducted with phenol solution concentration in range from 5 to 200 mg/l and oxygen peroxide concentration in range from 20 to 7500 mg/l. The phenol degradation level 99.99% was obtained. The cost of phenol reduction from 200 mg/l to 0.02 mg/l using pulsed xenon lamps in our tests was 13 Euro/m3.

08.3. Application of activated carbon/persulfate for acetominophen removal from water

M. Qutob, S. Doğan (Turkey)

Conventional treatment methods are found inadequate to deal with emerging contaminants in wastewaters. Advanced water treatment alternatives are therefore need to be considered to deal with such recalcitrant compounds. In this study, Persulfate(PS)/Powdered Activated Carbon(PAC) system has been examined for its efficiency to remove the selected pharmaceutical, acetaminophen (ACT), from aqueous solutions. 0.165 mM aqueous acetaminophen was exposed to three different pH (3, 7 and 10), PS (1.65, 3.30 and 16.5 mM) dose and PAC dose (1.65, 3.30 and 8.25mM) conditions. The fastest and complete removal of acetaminophen was achieved after 7 minutes at pH 3 at ACT(1):PS(10):PAC(50) (k=0.509min-1) and ACT(1):PS(100):PAC(20) (k=0.506min-1) molar ratios and after 3 and 10 minutes at pH 7 ACT(1):PS(10):PAC(50) (k=1.610min-1) and ACT(1):PS(100):PAC(20) (k=0.481min-1) molar ratios, respectively. It was found that increasing PAC dose increased the surface area for acetaminophen adsorption therefore, its oxidation rate enhanced. In addition, PS dose elevation resulted with more consumption (doubled from 0.35 to 0.70mM after ACT(1):PS(100):PAC(20) application) and therefore, faster removal rate was observed. Elimination of acetaminophen under alkaline conditions was inefficient as complete removal couldn't be reached after 90 minutes. It was concluded as both acetaminophen (pKa=9.5) and the surface of the PAC (pHzpc=8.6) became negatively charged at pH 10 and because of the repulsion, adsorption rate lowered. The major by-product of acetaminophen was observed by HPLC and might be a Quinone derivative, on the other hand GC/MS analysis showed aliphatic byproducts which were Acetaldoxime and 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl.

08.4. Developing the next generation of UV-based advanced oxidation process using a dual wavelength approach: UV_{254nm}-H_2O_2 and Vacuum UV_{185nm}-H_2O

N.K. George, B.A. Wols, D. Santoro, L. Furatian, J. Ferwerda, W. Gernjak (The Netherlands, Canada, Spain)

Low-pressure mercury (LP-Hg) lamps emit both UV_{254nm} and Vacuum UV_{185nm} (VUV_{185nm}) allowing to combine generation of hydroxyl radicals ($^{\cdot}OH$) via photolysis of H_2O_2 by UV254nm and H_2O by VUV_{185nm} simultaneously in a single advanced oxidation processes (AOP). Experiments were conducted with a collimated beam (CB) setup proved that addition of the VUV_{185nm}-H_2O AOP to the conventional UV_{254nm}-H_2O_2 AOP improved the observed reaction rate constant (k') of carbamazepine (CBZ) degradation in a 1cm optical path-length cell up to 5 times. Mixing was proved to be important even at small optical path-length due to the high molar absorption coefficient of H2O at VUV185nm ($\varepsilon_{H2O,185}$). However, at environmentally relevant concentrations certain anions, particularly chloride (Cl^-), was determined to be the major absorber of VUV_{185nm} rather than H_2O [1]. [1] also experimentally proved the negative and positive effect of Cl^- on the VUV_{185nm}-H_2O AOP in the presence of Suwanne River natural organic matter (SR-NOM) and tert-Butanol (t-BuOH) was present as the dissolved organic carbon (DOC) respectively. However, Cl^- was found to no impact on the combined UV_{254nm}-H_2O_2 + VUV_{185nm}-H_2O AOP, with t-BuOH as DOC in this study suggesting the importance of the background matrix on the applicability of the process.

08.5. Passing the smell test – with ozone AOP

S. Dominguez, L. Dinkloh, S. Besser, A. Ried, H. Stapel (USA, Germany)

Anderson Regional Joint Water System (ARJWS), located at 998 Hunters Trail, Anderson 29625, South Carolina (USA) is a partnership of rural and municipal water districts devoted to providing a high-quality, clean, safe, reliable, economical flow of treated water to its wholesale customers in Anderson and Pickens counties.
After its source water Lake Hartwell started experiencing harmful algae blooms (HABs) in 2013, the water utility began receiving hundreds of complaints each week regarding musty-smelling and bad-tasting water.
Ozone AOP was determined to be the most viable overall option because it provided operational flexibility and an additional AOP barrier when needed.

08.6. Novel magnetic photocatalyst [UETiO_2 (Fe)] for photocatalytic ozonation processes

J. López, A. Rey, P. M. Álvarez, F. Beltrán (Spain)

A novel magnetically separable composite, UETiO_2(Fe), was synthesized and its photocatalytic activity tested in ozonation processes. UETiO_2(Fe) samples were prepared by a facile method mixing $FeCl_2{\cdot}4H_2O$, an organic acid and TiO_2 P25 in aqueous solution and room temperature. After the synthesis, the solid obtained was repeatedly washed with water to eliminate traces of free organic acid. The product was characterized by XRD, SQUID, FT-IR, Surface Area, X-ray fluorescence and scanning electron microscopy (SEM). The catalyst shows a homogeneous structure of TiO_2 P25 and magnetite. The photocatalytic activity of catalyst was tested using metoprolol as probe which showed a good photocatalytic property though it did not exceed the activity of TiO_2 P25. However, the better magnetic separation and reusability make viable the synthesis and use of the new catalyst. The initial concentration of MTP was 50 mgL^{-1} and was completely degraded in 90 min of reaction with the combination UV-vis, Ozone and Catalyst. Mineralization reached was 90% after 3 hours.

08.7. Solar photocatalytic ozonation of nom with TiO_2, WO_3 and WO_3-TiO_2 catalysts for drinking water treatment

A. Rey, A. M. Udaondo, F. J. Beltrán (Spain)

The performance of three different catalysts (commercial TiO_2 P25, commercial WO_3, and an own-made WO_3-TiO_2 composite containing 4 wt.% WO_3 on TiO_2 P25) in the removal of NOM by solar photocatalytic ozonation in order to reduce the precursors of chlorine disinfection by-products was studied. For TiO_2 and WO_3-TiO_2 catalysts, a synergistic effect between ozone and irradiated photocatalysts was produced leading to a higher efficiency in the photocatalytic ozonation process compared to ozonation, solar ozonation or photocatalysis, which is noticed not only in the NOM mineralization but also in the disinfection by-products formation after water chlorination. At the conditions used, even with

a higher capacity of absorbing visible light of the WO_3-TiO_2 composite, the commercial TiO_2 P25 catalyst demonstrated the best performance due to its high activity and its larger irradiated exposed area according to its lower hydrodynamic particle size.

Session 9. Ozone in Medicine – Part 1 / Introduction. Clinical trials in topical ozone application

09.1. Ozone in Medicine: the low-dose ozone concept and the role of glutathione

R. Viebahn, O. S. Leon Fernandez (Germany, Cuba)

Chronic inflammations or diseases associated with chronic inflammatory conditions are the indications for systemic ozone applications in the form of the low-dose ozone concept as a complementary medical method.
Chronic inflammatory processes are always accompanied by high oxidative stress, reactive oxygen species, such as radical and non-radical oxidants, a suppressed antioxidant capacity and immunologic disbalance, each of which in turn promotes and maintains the inflammatory process.
At low concentrations and doses, systemically applied ozone acts as a bioregulator in a range of 10 to 40 µg/ml (autohemotherapy MAH or rectal insufflation RI) whereas the „antibiotic“ (germ killing) effect is restricted to the short time topical treatment for wound cleansing etc. by using ozone concentrations: 100 ≥ c ≥ 50 µg/ml, which are contraindicated in the systemic treatment methods MAH and RI.

09.2. Evaluation of the role of topical ozone therapy in management of moderate and severe burn injuries

M. Masoud, H. Shalaby, K. Eltobgy, M. Degheidy, M. Mawsouf, E. Abdelzaher (Egypt)

Background: Burn injuries are one of the major health problems all over the world. The problem of infection in burn wounds is considered a major problem and the main cause of death in many burned patients. Ozone has been used with good results in the treatment of patients with diabetic foot infected wounds, because of its germicidal properties and its influence on the processes of oxygen metabolism, and other bio-cytological effects promoting wound healing. Hence we conducted this study to evaluate the effectiveness of topical ozone therapy as a procedure in the management of moderate and severe burn wounds in adult patients.
Patients and Methods: Study was conducted as a prospective, randomized, controlled, trial carried on 100 patients with Burnt surface area ranging from 15% to 25% of total body surface area (TBSA) from the Burn Unit of Alexandria Main University Hospital. Patients were allocated to conventional (group A) and ozone (group B) treatment groups. Clinical assessment of burn wounds and laboratory work-up were done every week till 3rd week and on completion of treatment.
Results: The healing time of the ozone treated wounds was significantly lower than that of the control wounds as the duration of stay in hospital was significantly lower in ozone therapy group (mean=13.476±9.5 days)than in conventional therapy group (mean=31.26±8.5)days (P=0.0001).
There were high statistically significant differences between the two studied groups regarding need for grafting procedures, 52% of conventional therapy Group (A) versus only 22.0% of ozone therapy Group (B). Also, the percent of grafting was significantly higher in conventional therapy group (8.0±2.0%) than in ozone therapy group (4.5±1.0%). Also there were significant differences between the two groups with eradication of microbial infections in patients treated by ozone relative to whom treated by conventional method.
Conclusion: Topical application of ozone causes a highly significant reduction in the healing time of the recent burn injuries. Further prospective multicenter studies is advised to criticize the impact of topical ozone therapy for burnt patients with more stress on cytological and biological responses to clarify more about beneficial mechanisms and outcomes of medical ozone in management of burns.

09.3. Effectiveness of ozone therapy in the prevention of purulent infections after the operation of sigma-anal anastomosis

S. Navruzov, A. Khakimov (Uzbekistan)

In many diseases of the rectum and colon, such as colorectal cancer, ulcerative colitis, amebiasis and diffuse colon polyposis, Crohn's disease, megacolon, anorectal malformations, etc., it becomes necessary to perform abdominal-anal resection of the rectum with the bringing down of the proximal colon to the anal canal (operation " bringing down "). The aim of this study is ivestigating the effectiveness of ozone therapy in the prevention of purulent infections after the operation of "sigma-anal anastomosis".

09.4. Treatment of peri anal fistulas with ozone therapy

S. Bhatti (Pakistan)

The aim of this study is to assess the effect of ozone gas in the treatment of peri anal sinus.
Peri anal sinus is an entero cutaneous blind ending tract that develops after spontaneous or surgical drainage of an ano rectal abscess. It causes discharge, moisture, and a recurrent abscess in the perianal region. The main treatment for peri anal sinus is surgery. The aim of treatment is to eliminate the sinus, prevent recurrence, and minimize pain resulting from infection. Postoperative recurrence is a serious problem for these patients.
Ozone is a natural gas composed of three oxygen atoms. Medical ozone is composed of 3 % ozone and 97 % oxygen. It is a powerful disinfectant, inactivating a large number of pathogenic bacteria. It also offers recovery-enhancing effects by stimulating cell proliferation.

09.5. Ozonated sunflower oil in full-thickness burns

M. S. Melo, H. C. Carvalho, A. B. Fernandes, C. J. de Lima, L. P. Alves, L. H. M. S. Melo, M. A. C. Salgado, R. A. Zângaro, (Brazil)

Ozonated vegetable oils have been used topically for healing process in several biomedical applications, due to the stability of gas in oils as ozonides and may be linked to oxygen released, which activates skin-healing cells. Full-thickness burns have a complex healing process owing to full epidermis destruction and intense dermis damaged which can trigger several local and systemic reactions that cause severe complications for the patient, such as infections that frequently lead to septicemia and death. The aim of this work is to evaluate the histomorphological parameters in rats with skin full-thickness burns under the effects of ozonated sunflower oil. Thirty male Wistar rats were divided into two groups: NT group (no treatment, n=15) and OS group (treated with ozonated sunflower oil, n=15). The treatment with ozonated sunflower oil started 24 h after full-thickness burns were induced, and the oil was administrated topically at the burn daily for up

to 21 days. The animals of each group were sacrificed for histological analysis after 7 (n=10), 14 (n=10), and 21 (n=10) days after burn induction. After 21 days of treatment, the amount of fibroblasts was moderated in the OS group, while in the NT group had predominately blood vessels and inflammatory cells in the same period. Therefore, it is possible to infer that, at 21 days, the NT group was still ongoing inflammatory response, while in the OS group, collagen formation and maturation was the predominant event. These results demonstrated that ozonated sunflower oil promoted better tissue repair in full-thickness burns compared to the group that received no treatment.

09.6. Mild ozonisation activates antioxidant cell response by the Keap1/Nrf2 dependent pathway

V. Covi, M. Malatesta, G. Tabaracci (Italy)

Treatment with low-dose ozone is successfully exploited as an adjuvant therapy in the treatment of several disorders. Although the list of medical applications is increasing, molecular mechanisms underlying its beneficial effects are still partially known. Nrf2 is a master regulator of the genes that protect cells from the effects of endogenous and exogenous insults, such as xenobiotics and oxidative stress and plays a crucial role in modulating mitochondrial functional features under stress conditions to maintain cellular redox homeostasis. In particular, Nrf2 regulates the expression of genes under the control of antioxidant response element (ARE) enhancers.

09.7. Analysis of Blood Ozonation by Dispersive Raman Spectroscopy

H. C. Carvalho, A. B. Fernandes, C. J. de Lima, L. P. Alves, L. H. M. S. Melo, M. S. Melo, R. A. Zângaro, L. Silveira Jr. (Brazil)

Blood ozonation is a complex process that must have regard to the integrity of blood components. In this work an analysis by Raman spectroscopy of ozonated human blood in three blood:gas ratios were made. Our results showed that blood spectral changes related to biochemical oxygen status and dose-response to ozone process at 62 mg/L can be assigned to differences in hemoglobin (oxy/deoxy-hemoglobin) content and nitrogenated bases.

09.8. Evaluation of Ozonated Red Blood Cells Elasticity

H. C. Carvalho, A. B. Fernandes, C. J. de Lima, R. A. Zângaro, Y. S. S. Silva, A. Fontes, D. S. Moura, R. E. de Araujo (Brazil)

One of the modalities of ozone therapy is blood ozonation, a complex process that must have regard to the integrity of blood components. About 45% of the blood is consisted by red blood cells (RBCs). In this work, elasticity analyses of ozonated human blood were performed in four different blood:gas ratios samples (from 1:1 to 1:20). Then, an optical tweezers system was used to measure the elasticity of RBCs. No significant changes on the RBC elasticity were observed after the treatments when compared to control.

Session 10. Poster introductions – Part 1

10.1. Modification of dough rheological properties, storage proteins characteristics and change in the glutathione reductase activity in soft wheat flour after grains gaseous ozone treatment

M. Heuls, M. Pages, J. Of, S. Rannee, A.M. Busuttil, F. Violleau (France)

Nowadays, there is a clear interest in developing a process able to modify the physical and technological criteria in order to improve the quality of flour. The goal is to produce constant and modular flours, while avoiding flour mixtures and addition of additives. Ozone can lead to this required modulation by treatment of the grains before milling. This modulation could be due to chemical and biological modifications in the grain. In this work, the impacts of gaseous ozone treatment on wheat grains was evaluated by assessing the rheological properties of dough and the proteins characteristics (solubility and molecular weight distribution).
Flours from ozonated grains (variety Oregrain) are more persistent, less extensible and more elastic. The P/L ratio is generally higher than control. The baking force (W) is increased to optimal value of +30% compared to the control. The Doehlert experimental design shows that quality and rheological properties of a flour can be adjusted according to the ozone dose applied. About chemical changes, grains ozonation causes a significant reduction in the SDS solubility of the wheat proteins. The quantity of high molecular weights proteins is modified according to the ozone dose applied.

10.2. Impact of dissolved ozone and free chlorine for the viral decontamination of ready-to-eat salads at laboratory scale

J. Loutreul, A. Gombert, S. Gauthier, S. Baig, T. Aussenac, B. Picoche, N. Boudaud (France)

This study showed the interest of dissolved ozone for the viral decontamination of ready-to-eat salads, using MS2 phage as surrogate of pathogenic enteric viruses such as human noroviruses and hepatitis A virus. Virus removal induced by dissolved ozone (1 mg/L for 30 sec) during the washing step of artificially contaminated salads (iceberg lettuce and lamb's lettuce) were similar when replacing by the authorized processing aids in France (*i.e.* free chlorine, 60 mg/L for 30 sec). Removal of infectious MS2 phage was -1.9 Log_{10} and -2.1 Log_{10} using dissolved ozone or free chlorine during the washing step, respectively. It is important to emphasize that the virucidal effect of both oxidants during the washing step were limited when viral particles were adhered to vegetable matrices (below 0.7 log_{10} by comparison to the washing step without any oxidant). The viral decontamination of salads is due to the simultaneous action of i) mechanical dropout of viral particles adhered to food matrix and, ii) virus inactivation induced by the oxidant. On the contrary removal of MS2 phage in suspension in the washing water was significantly higher, indicating a reliable efficiency of both oxidants. These experimental data have enriched an application report dedicated to the future use of dissolved ozone as processing aids for microbial decontamination of salads in France.

10.3. Preozonation for aerobic stabilization of biosolids generated in a dairy products industry

C.R. Ramírez-Cortina, A. Colín-Sánchez, M. de la Soledad Alonso-Gutiérrez, G. Ibáñez-Cervantes (México)

Conventional dairy wastewater treatment plants are mainly based on activated sludge processes that involve the aerobic microbial metabolism of fats, lactose and proteins. In this study the effect of pre-ozonation for the aerobic stabilization of the biosolids generated in a wastewater treatment plant (WWTP) of a dairy products industry was studied, in which the best pH conditions for the ozonation, acidic, neutral and alkaline, to reduce the aerobic stabilization time and reduce the unpleasant odor of this type of biosolids. The best results were obtained at pH 5 and 7, favoring the direct reaction of molecular ozone to eliminate the unpleasant odor and reduced time stabilization.

10.4. Degradation of organic compounds during ozonation in the presence of zero-valent iron

A. Cruz-Alcalde, N. López-Vinent, L. Sánchez-Fontanet, S. Esplugas, C. Sans (Spain)

Ozone (O_3) application to water treatment is a mature technology, although there are some inherent limitations such as ozone selectivity and the low contribution of hydroxyl radical (•OH) to the process. The present work aimed to study the combination of ozone and zero-valent iron (ZVI) applied to organic pollutants degradation in aqueous matrices, with the intention of finding an alternative method for enhancing the hydroxyl radical contribution and thus improving the oxidation efficiency of ozonation. A positive effect with increasing ZVI doses was in general observed, which was mainly attributed to a catalytic effect triggered by ozone reactions with dissolved iron species released from the solid catalysts during the process. The medium pH conditions were found to highly affect this mechanism, as more acidic values favour iron corrosion and thus the leaching of Fe ions to the bulk solution. As a consequence, the process efficiency at environmentally relevant conditions (*i.e.*, pH values around 7.5) was observed to be markedly lower than that registered in experiments conducted at pH values of 5.5 or even 2.5. Therefore, a higher catalyst dosage would be required in practical applications if a significant improvement in the process efficiency with respect to single ozonation is wanted to be achieved. Results of this research are promising, although further work is still required to get more insights into this complex system, including the study of additional oxidation mechanisms and the influence of common components of realistic water matrices over the process performance.

10.5. Degradation of cimetidine by hybrid titanium dioxide photocatalytic system with process component combination and dissolved oxygen

H. Lee, H.J. Bang, S.J. Kim, H. Kim, S.C. Jung (Korea)

A new microwave/MDEL/DO/TiO2 photocatalyst hybrid system was used to decompose cimetidine, one of the PhACs. Increasing the microwave intensity and pH increased the rate of CMT degradation. The increase in the DO concentration in the aqueous reactant solution increases the rate of CMT degradation, but the rate of degradation decreases at concentrations above 40 ppm. The highest degradation efficiency was obtained when the pH and DO concentration of the aqueous solution were controlled and the CMT was decomposed using microwave/MDEL/TiO2 photocatalytic mixing system. The TiO2 photocatalytic mixing process for CMT degradation should be operated at the optimum DO concentration with the highest OH radical concentration.

10.6. Effect of NOM on the efficacy of different ozone and solar-light based AOPs for the reduction of DBPs formation potential

A. Rey, A. M. Udaondo, E. M. Rodríguez, F. J. Beltrán (Spain)

The influence of the water matrix (natural organic matter (NOM) content and fractions) on the efficacy of different ozone and solar-light based advanced oxidation processes (AOPs: ozonation, catalytic ozonation, photolytic ozonation, photocatalysis and photocatalytic ozonation) to remove the precursors of chlorine disinfection by-products was studied. Two types of water were selected with different dissolved organic carbon (DOC, 5.8 and 12.8 mg L-1) and NOM characteristics (80-70% hydrophobic fraction of different composition). At the conditions studied and regardless of the water matrix, compared to ozonation, catalytic ozonation with TiO_2, solar photolytic ozonation and photocatalysis, the application of solar photocatalytic ozonation using TiO2 led to the highest mineralization degree and the lowest disinfection by-products formation potential (DBPFP). Moreover, this combined treatment also turned NOM into more hydrophilic compounds in a greater extent. An important contribution of hydrophobic fraction of NOM to the formation of DBPs, mainly trihalomethanes (THMs) and haloacetic acids (HAAs) has been found, whereas the hydrophilic fraction highly contributed to the formation of unknown DBPs.

10.7. Vibrational spectroscopy as a tool for fast and on-line monitoring of ozone concentration in water inside a reactor

S. Treguier, S. Cuq, V. Lemetter, A. Canado, M. Pages, F. Violleau (France)

Food and water industries are highly sensitive to micro-organism contaminations. Nowadays, chlorine is the main treatment to provide clear water, but some alternative exists, such as UV treatment or ozone dissolved in water. Ozone is well-known for its efficiency as a disinfecting agent. Current methods for evaluating levels of dissolved ozone in water involve a two-step analysis. These methods are indirect, time-consuming and prone to errors related to manipulations.
Spectroscopy in the near infrared (NIR) and UV-visible (UV-Vis) regions combined with chemometrics methods are fast, repeatable and easy-to-use tools with many applications on water-based matrices. The work presented here details a method for on-line measurement of concentration of ozone dissolved in water by NIR and UV-Vis spectroscopy.
Spectra were acquired with two instruments at regular time intervals during and after the ozone dissolution process. Indigo analyses (measure the concentration of dissolve ozone in water) were realized during the same intervals and were used as reference values for data analysis. In both cases, spectra were mathematically preprocessed to remove noise and to correct the baseline. Calibration models were built from spectra and indigo values using the partial least squares (PLS) method. Concentration of dissolve ozone in water were then predicted with the models from an external set of spectra acquired during the ozone dissolution process.
PLS models allowed predictions ozone concentrations from an independent assay with a r^2 of 0.82 and a 95% confidence interval of 1.78mg.L-1 in a 2.8-8.7mg.L-1 range for UV-Vis, and with a r^2 of 0.82 and a 95% confidence interval of 3.86mg.L-1 in a 2.8-8.7mg.L-1 range for NIR.
While these results are promising, prediction robustness and accuracy could subsequently be improved by increasing the number of samples used to build the models.

10.8. A new process of disinfection and deodorization of helmet by ozonation

B. Lerzy, C. Staut, F. Girard, T. Aussenac (France)

The cleanliness and microbiological safety of helmets is an important issue for many and frequent users whether they are used in a professional setting and / or for leisure activities. Today, chemical-based spray disinfectant solutions are or can be used. Although the real effectiveness of these solutions is still to be demonstrated, the persistence of these chemicals compounds after treatment can be a real security problem for exposed users. The CleanCasc© process, developed as part of this study, proposes an alternative method of decontamination and deodorization of helmets using ozone gas. The results obtained during this feasibility study (i.e. commercial apparatus used) and synthesized in the framework of this presentation demonstrate that, depending on the different process parameters (ozone concentration, gas flow rate, etc.), the device used is perfectly capable to induce a reduction of more than 5 $\log_{10}$ (CFU/mL) of a standard strain of Staphylococcus aureus after 3 minutes of ozone gas application. Even though the CleanCasc© (Figure 1) process is being finalized before the start of its large-scale

commercialization phase, it can now be seen that the implementation of ozone gas during treatment makes it possible to respond already to requirements in terms of disinfection.

10.9. Solar photo-fenton for olive mill wastewater treatment

E. Domingues, R. Martins (Portugal)

The production of olive mill wastewater (OMW) is one of the most damaging environmental problems that countries from the Mediterranean area face today. One of the interesting technologies used today, among the so-called advanced oxidation processes - AOP, is Fenton and Fenton-like processes. The conventional Fenton process is still widely studied because of its ability to remove recalcitrant compounds, achieving in some cases concentrations bellow those legally established.
Synthetic Olive mill wastewater was treated with homogeneous photo-Fenton, using iron sulphate as the source of iron. The resulting effluent was submitted to depuration regarding iron removal through biofiltration and its possible reintegration in other oxidation cycles. This hypothesis would close the entire Fenton's process in a loop and, more importantly, sparing the environment of the iron sludge which constitutes the main drawback of Fenton's process. Biofiltration was carried out using Corbicula fluminea as host since it is considered an invasive species and its unnatural and abounding presence other than in Asia is also a source of environmental and economical problems. Thus, the proposed approach integrates wastewater treatment with pest control.

Session 11. Poster introductions – Part 2

11.1. Advanced Oxidation Process treatment for 1,4-Dioxane and VOC removal at LADWP's North Hollywood Central and Tujunga Facilities

M. Maxwell, C. Cotton, B. Kuhnel, K. Wells, A. Medina, N. Blute (USA)

The City of Los Angeles consists of an area of approximately 465 square miles with a population of around 4 million residents. The well fields in the San Fernando Basin (SFB) have historically provided local groundwater to the City of Los Angeles. Local groundwater provides approximately 11% of the City of Los Angeles water supply and the City has a goal of utilizing 50% of the water sources supply from the San Fernando Basin by 2035. The well fields in the San Fernando Basin are highly impaired with presence of VOCs including tetrachloroethene (PCE), trichloroethene (TCE) and 1,4-Dioxane. LADWP is currently constructing treatment for the first wellfield, the North Hollywood West treatment facility using a 'hybrid' consultant design and in-house construction. Two additional wellfields, North Hollywood Central and Tujunga, are proposed to be delivered using a progressive-design build approach.

11.2. Cefuroxime removal from water with ozone photolysis

O. Monago, A. M. Chavez, F. J. Beltrán (Spain)

Cefuroxime is a widely-use antibiotic in medicine found in different effluents. This work studies the removal of cefuroxime through different oxidation processes: photolysis (RAD), ozonation (O_3), solar photolytic ozonation (O_3/RAD) and solar-visible photolytic ozonation (O_3/RADvis). These processes were assayed both in ultrapure water (UPW) and a real Municipal Wastewater (MWW). Solar photolytic ozonation resulted the most effective AOP with 67% and 50% of total organic carbon (TOC) removal in UPW and MWW, respectively. Moreover, some carboxylic acids were detected as refractory intermediates in the ozonation processes (i.e. acetic, formic, pyruvic and oxalic). In MWW, a high concentration of oxalic acid was measured representing as TOC more than 55% of the whole short-chain organic acids detected. Higher transferred ozone doses (TOD) are needed in MWW (72 mg O_3 L^{-1}) than in UPW (50 mg O_3 L^{-1}) in order to remove a 50% of the organic matter.

11.3. Degradation of microcystin-LR by vacuum UV/ O_3

F. Alafifi, S. Jasim, M. Mohseni (Canada)

Microcystin-LR (MC-LR) is a toxin that is produced by cyanobacteria. It is one of the first microcystin toxins identified and the most common occurring in nature. The World Health Organization has proposed a maximum concentration of 1µg/L of MC-LR in drinking water. Ozone (O_3) based oxidation is considered very effective and commonly used for drinking water treatment. Also, ozone and ultraviolet (UV) based advanced oxidation process (AOP) has been proposed as an effective process, given the contribution of both ozone and hydroxyl radicals in the oxidation process. A potentially effective alternative to the above would be ozonation combined with vacuum UV (VUV), which relies on the photolysis of water by photons of less than 200 nm to generate OH radicals. While, the kinetics of MC-LR degradation with ozone and hydroxyl radicals is well documented in the literature, the degradation of MC-LR using integrated O_3 and VUV has not been investigated in the literature. The overall objective of this study is to determine the kinetics of degradation of MC-LR in water for the combined reaction of VUV and O_3 at different concentrations of dissolved organic carbon (DOC), in comparison with those of standalone O_3 or VUV under similar operating conditions.

11.4. Removal of Microcystin-LR in drinking water using ozone and ozone-based AOP

J. Saththasivam, G. Ponnusamy, S. Jasim (Qatar)

The presence of cyanotoxins in drinking water poses a great risk to public health if left untreated. Potent hepatotoxin such as MC-LR is one of the dangerous drinking water contaminants that could lead to severe liver disease. In this study, drinking water sample characteristics were slightly altered considering the worst-case scenario and spiked with MC-LR and subjected to ozonation and ozone-based advanced oxidation process. Ozone along with hydrogen peroxide was used in the AOP experiments. The experimental results obtained from these advanced oxidation technologies were also compared against the conventional chlorination treatment process. The results showed that the toxin concentrations in most of the simulated scenarios except for elevated DOC were well below the WHO prescribed limit of 1 µg/L at ozone dosage of 0.5 mg/L. This was compared against the drinking water at its normal water matrix and higher DOC of 0.71 mg/L, 39°C and 122 mg/L as $CaCO_3$ alkalinity. The experimental results indicated that variations in water temperature (between 27 and 39°C) and alkalinity have minimal effect on the MC-LR removal efficiency in both the treatment methods. As expected, the presence of organic carbon has a more adverse impact than the water temperature and alkalinity for toxin removal. It was also shown that both ozone and AOP showed better MC-LR removal efficiency than conventional chlorination as the latter requires longer contact time for effective degradation.

11.5. Mineralization of Primidone in an urban secondary wastewater effluent with TiO_2 photocatalytic ozonation and a UVA LED photoreactor

M. Figueredo, E. M. Rodríguez, F. J. Beltrán (Spain)

In the present work, primidone (PRM), an anticonvulsionant drug very often found in wastewater treatment plant effluents has been chosen as model compound to evaluate the efficiency of photocatalytic ozonation with UVA leds as radiation source. Secondary wastewater effluent doped with 0.1 mg L^{-1} of PRM was used as water matrix to perform the experiments. Experimental system consisted in an ozonation Pyrex reactor where the water was pumped to and recirculated from a tubular photoreactor equipped with 6 LED with a maximum wavelength emission at 365 nm. Irradiance of LEDs was measured by nitrite actinometry and resulted in $3.92x10^{-5}$ Einstein s^{-1}. Under the conditions tested, photolysis and photocatalysis processes did not eliminate the drug from water, but in presence of ozone, PRM was removed in less than 30 minutes. Depletion rate of TOC removal in the presence and absence of carbonates has been also studied. When inorganic carbon is removed from wastewater the efficacy of photocatalytic oxidation and ozonation processes increases drastically. The transferred ozone dose has been calculated with the result that photo-assisted processes improve the use of ozone.

11.6. Catalyst selection for industrial textile wastewater treatment

L. Bilińska, K. Blus, M. Gmurek, S. Ledakowicz (Poland)

Catalytic ozonation has appeared as one of the recent trends in textile wastewater treatment. The selection of catalyst type and the effectiveness of the process are the main issues that are extensively investigated. However, the discussion on the mechanism of the catalytic activity of catalysts seems to be open. Especially, when industrial textile wastewater is an object of the study the wastewater matrix, which can influence the treatment, is a topic of high concern. The necessity of effective color removal in short treatment time is a standard when an industrial implementation is planned. At the same time, efficient COD and toxic by-products removal are highly expected. Therefore these parameters were the outlines in this study. The main objective of the study was to investigate the catalytic activity of three types of catalytic materials in the ozone treatment of industrial textile wastewater.

11.7. Carbon nanotube electrochemical filtration for estrogenic activity removal

G. Cunha, B. Souza, J. P. Bassin, D. Bila, C. Vecitis, M. Dezotti (Brazil, USA)

This work analyzed the performance of an anodic carbon nanotube (CNT) electrochemical filter in degrading the 17ß-estradiol (E2) and 17α-ethinylestradiol (EE2) and investigate the estrogenic activity removal calculated in terms of E2 equivalent (EQ-E2). The performance of CNT electrochemical filter was evaluated at different total applied voltages (0 – 2.5 V) and in ultrapure water and urban wastewater, using 37 µM of E2 and EE2, a flow rate of 1.5 mL min^{-1} and using 10 mM of Na_2SO_4 as electrolyte. The CNT surface characterization was made by scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). The CNT electrochemical filter was successfully applied to degrade E2 and EE2 and removals higher than 95% were achieved applying 2.5 V for both water matrices. SEM and XPS results showed evidence of the polymer formation on the CNT surface after 300 min of reaction, which probably reduced the efficiency of the process under low applied voltages. Estrogenic activity was almost completely reduced and minimal EQ-E2 levels were observed when 2.5 V was applied. A residual EQ-E2 was observed, likely due to the presence of estrogens, which suggests the non-formation of estrogenic by-products. At 2.5 V total cell potential, the energy required to remove estrogenic activity was 0.014 ± 0.001 kWh m^{-3} for ultrapure water and 0.021 ± 0.001 kWh m^{-3} for post-secondary wastewater. Results suggest a CNT electrochemical filter may have potential to efficiently remove estrogenic activity and may be a feasible process for wastewater polishing treatment.

11.8. Photocatalytic Absorption and COD Degradation of Dewatering Wastewater from a Gas Refinery Storage Tank by using MWCNTs/TiO2 Nano-composite

M. Akrami, F. Farzaneh (Iran)

A photocatalyst is a semiconductor material that must be able to convert the light energy of the irradiation to the chemical energy of the electron–hole pairs. Therefore, a suitable bandgap energy together with chemical and physical stability, nontoxic nature, availability, and low cost are important requirements to be taken into account for selecting a solid photocatalyst. In this study, Multi-walled carbon nanotubes joint by titanium dioxide nanoparticles (MWCNTs/ TiO_2)synthesis by modified sol–gel method used as a catalyst, moreover, photocatalytic absorption and degradation of the dewatering wastewater from storage tanks of gas refinery in the fluidic bed reactor under ultra violet (UV) and visible light was scrutinized. FTIR, SEM and XRD analysis has been performed on this nano-composite. Furthermore, effect of individual and collaborative factors such as catalysis type, catalyst content, pH and time of photocatalytic reaction was investigated on the yield of reaction. As a result, nano-composite type B with 70% (w/w%) of MWCNT under UV and sun light irradiation showed maximum degradation of contaminant., The optimum condition of COD removal, occurred on room temperature, neutral pH value, 8 (g/l) content of catalyst and at the time interval of 6 hours under 57% of UV irradiation.

Session 12. Ozone in Medicine – Part 2 / Inflammatory Diseases

12.1 Potentiation of medical ozone beneficial effects after a second cycle of ozone exposition is mediated by innate immune memory in rheumatoid arthritis patients

O. S. León Fernández, R. Viebahn-Häensler, G. Takon Oru, E. García Fernández, J. C. Polo Vega, B. Tamargo Santos, G. López Cabreja, I. Serrano Espinosa (Cuba, Germany)

Methotrexate (MTX)+medical ozone combined therapy administered by rectal insufflation has demonstrated an increase of clinical efficacy and reduction of hepatotoxicity risk in rheumatoid arthritis (RA)patients. Although more than one ozone cycle is a routine procedure in clinical practice with efficacy and safety, no study about the clinical and redox characterization at the end of two or more cycles of ozone treatment in RA patients have been made. **Aim** The aim of this work has been to assess the ozone second cycle beneficial effects through clinical indicators and redox biomarkers and to evaluate whether innate immune memory could be associated to potentiation of clinical efficacy after ozone second cycle exposure. **Results.** Second ozone exposure promoted powerful clinical and redox responses with regard to the first cycle. An increased reduction of inflammation, disability, decrease of Anti-CCP levels (anticyclic citrullinated peptide) and

reestablishment of redox balance at the end of second ozone cycle was observed. Conclusions. RA patients treated with combined MTX+ozone therapy increased clinical and redox responses after second cycle of ozone exposure. This potentiation seems to be mediated by innate immune memory due to the close relationship between the targets involved in innate immune memory and those, regulated by medical ozone.

12.2 Intraarticular injection of IL-1/ozone in osteoarthritis of the knee: a randomized, placebo-controlled study

Z. Fahmy (Germany)

To evaluate the clinical response, safety, and tolerability of a single intraarticular injection of Interleukin/Ozone in patients with symptomatic osteoarthritis (OA) of the knee.
Patients with OA of the knee were enrolled in a placebo controlled study and randomized 2:1:2 to receive a single intraarticular injection of placebo, Ozone or IL-1 (interleukine-1) in their symptomatic knee. Patients were evaluated for 12 weeks post injection. End point was the change in the score from baseline to week 4. Safety assessments included the evaluation of adverse events (AEs). Laboratory tests, and vital signs.
Pharmacokinetic parameters were assessed in a subset of patients.

12.3 Ozone therapy against inflammation and degeneration

V. Simonetti (Italy)

Our health conditions mainly depend on our lifestyle and low-grade chronic silent inflammation (LGCSI)
The pathology manifests itself after the LGCSI increases in a stable and lasting way.
All chronic and degenerative pathologies, except congenital and infectious genetic disorders, develop into an acid cellular environment, derive their origin from a chronic inflammatory state and / or from a lack of tissue oxygen. Common basis for the various pathologies are: LGCSI and intestinal dysbiosis
Markers of inflammation TNFα, IL 1ß, IL 6, IL 8, PCR increase in all pathologies. Individual gene predisposition and influence of epigenetic factors would cause different clinical forms.
Ozone therapy reduces inflammation, spasticity, tissue acidity and oxidative stress; increases tissue oxygenation, cellular energy production and improves microcirculation, without any particular side effects.
We have demonstrated a favorable action of ozonetherapy, in immunomodulatory doses of 40-50 ϒ, in MS, dementia and tumors

12.4. Ozonucleolysis is more effective in cervical than lumber disc lesions – 45000 cases

U. Rashid (Pakistan)

Direct injection of Oxygen-Ozone in to the discs has proved to be the effective alternative for surgery in patients with disc herniation in many countries around the world. We report our experience with ozonucleolysis with patients effected by lower backache, sciatica and pain cervical region (Brachalgia) due to disc herniation including post operative recurrence or disc prolapse.

Session 13. Ozone in Agrifood – Part 1

13.1. *In vivo* fungicide properties of ozone dissolved into water against the fungus responsible of apple scab, *venturia inaequalis*

M. Pages, D. Kleiber, S. Maldes, F. Violleau (France)

Venturia inaequalis is the cause of the main apple disease which named apple scab. This fungus is mainly dispersed by spores. Their control is mainly managed by fungicide treatments but their use is currently controversial and some resistances appear. Ozone is a strong oxidant well-known for its disinfectant capacity and its low remanence. Anti-fungal effect of ozonated water against conidia of this pathogen have previously shown thanks to in vitro tests and experiments carried out on artificial leafs. However, after its arrival on vegetal material (leaf, flower or fruit), spore quickly germinates and interacts with the plant and the environment. That is why, before considering a transfer to the field, it is necessary to evaluate the anti-fungal effect of water loaded with ozone on young plants contaminated by V.inaequalis. Results show an effectiveness of ozone in controlled conditions: two ozone applications, repeated with 24 hours-apart, lead to significant decrease of fungus pressure.

13.2. Fludioxonil, difenoconaozole and sedaxane, pesticides degradation of loaded wheat seeds: comparison of different oxidative technologies

M. Heuls, M. Pages, J. Of, S. Rannee, A.M. Busuttil, F. Violleau (France)

The degradation efficiency of three pesticides on loaded wheat seeds by different oxidation techniques was followed. The three pesticides studied were fludioxonil, difenoconazole and sedaxane, all three presents in the Vibrance Gold® coating solution. Pesticides were extracted from wheat by ultrasonic bath and their concentrations were monitored by HPLC-UV. The effectiveness of ozone was first evaluated via a Doehlert experimental design and led to degradation rates of 90%, 95% and 80% respectively for fludioxonil, sedaxane and difenoconazole. Then, with a dose higher than the limit of the experimental design, 50 g of O_3 / kg, the percentages of degradation reach 97%, 92% and 93% for the three pesticides. Gaseous ozone can degrade the three wheat pesticides. Ozone and electrolyzed water coupling for solid state application is not effective to remove pesticides. However, coupling UV-C coupling with ozone is effective and allows higher degradation percentages than by using ozone or UV-C separately through the production of free radicals.

13.3. Effect of ozone on the rheological properties of flours and dough of french soft wheat

P. Gozé, R. Larbi, T. Aussenac (France)

Because ozone can promote oxidation and/or degradation of chemical constituents present in the treated material (i.e. proteins, lipids, starch) due to its strong oxidizing properties, we have studied the effect of ozone on the main rheological properties of flour and dough of soft wheat. The results obtained showed that gaseous ozone leads to profound changes in the rheological behaviour of the products generated (i.e. flour-water suspensions, dough after mixing and finished French bread-making products).The results obtained from the BIPEA bread-

making tests fully confirm all the conclusions drawn from the various indirect rheological evaluations. Thus, the breads obtained from the baking of ozonated grains are less developed with bread volumes are greatly reduced and a significant drop in their overall bread-making score.

13.4. Ozonation of sunflower oils: properties, purification and application

J. Vinet, S. Moureu, R. Pierron, A. Calmon, F. Violleau (France)

Ozonated sunflower oils are well known for their antimicrobial properties. Different parameters can influence the ozonation of olefins (duration, solvent, gas flow rate, oil composition…). In order to respond the increasing demand in ozonized oils from the industry, it is necessary to find new way of synthesis, for example microreactor, and simplify the characterization of the mixture.
The aim of this study was to evaluate the influence on the addition of different media with sunflower oil to obtain different physical et and chemical properties. In that purpose two different protic media have been studied: water and nonanoic acid. The use of the first allows access to a mixture with good antifungal activity. The second is used to keep the mixture in a liquid state, an important point for the use of a microreactor.
"High oleic" sunflower oil (90% of oleic acid) and different proportions of the two media was ozonized with the same condition. Non-ozonated and ozonated mixture were characterized by determination of their peroxide index (PI), iodine index (II), and using infrared spectroscopy (Near-IR or Mid-IR) measurements to predict this previous data. The results show that it is possible to obtain a liquid mixture with the desired chemical properties (high PI, low II) and to develop a model to predict these values.

13.5. Ozonisation of meat processing environments acts on microbiota that survives after cleaning: a promising disinfection synergism

C. Botta, I. Ferrocino, M.C. Cavallero, S. Riva, C. Carboni, L. Cocolin, K. Rantsiou (Italy)

Ozonisation is considered an effective strategy to improve the sanitary and hygienic conditions of the abattoirs, since it can reduce airborne and wastewaters biotic contamination. However, the potential selective pressure exerted by this gas towards the resident microbiota of meat processing plants and its effective capability to decontaminate meat contact surfaces are still unclear.
The RNA-based surveillance coupled with culture methods in meat processing plants treated overnight with gaseous ozone, showed a significant reduction of the total viable bacteria present on their surfaces after the ozonisation at 20 and 40 ppm, but not at 4 ppm. After an initial increase of species number caused by cleaning and sanitizing treatments, the treatments with 20 and. 40 ppm of ozone determined a significant changes of the processing plants microbiota, with a decrease of Proteobacteria and, at genus level and a significant reduction of *Pseudomonas* and *Brochothrix* abundances and viable counts.
This study showed the effectiveness of gaseous ozone as adjunct sanitizing method for the meat processing plant surfaces, with the main aim to reduce the use chemical products, minimize cross-contamination and thus extend the meat shelf-life.

13.6. Ozone treatment: a solution to improve sanitary and physiological quality of grapevine

A. Romeo-Olivan, M. Pages, C. Breton, F. Violleau, A. Jacques (France)

Grapevine trunk diseases (GTDs) can cause severe symptoms and eventual death. GTDs can infect nursery plants at different propagation stages and symptoms may appear one year later. Grapevine cultivation is in need of a high volume of phytosanitary products. However, a reduction on pesticide use is a requirement for a sustainable viticulture. The goal of this study was to evaluate the efficiency of ozonated water against two different fungal species associated with GTDs (*P. minimum* and *P. chlamydospora*) *in vitro* and *in planta* conditions. The effect of ozone on the plant growth was also studied. We firstly assessed *in vitro* sporicidal properties of ozonated water (4,5g/m^3) by observing spore germination on plate. Secondly, we performed an *in planta* assay on cuttings of *Vitis vinifera L.* Cabernet-Sauvignon clone 15. Fungal development was assessed by q-PCR quantification of fungal genomes in woody tissues. Finally, to test the effect of ozonated water on plant growth, an irrigation assay was performed. The effect of ozone on bud break kinetics, and on leaf and roots development was evaluated. Our results showed that ozone suppresses spore germination *in vitro* in its totality. *In planta*, a reduction on fungal development is observed at 6 weeks post-inoculation. In addition, irrigation with ozonated water causes no negative effect on plant growth. The anti-fungal properties of ozonated water and the absence of phytotoxicity make ozone a promising alternative for controlling microbe infection in grapevine cultivation.

Session 14. Fundamentals – Part 2

14.1. Catalytic ozonation for micropollutants removal: laboratory and pilot studies

R. Mahmudov, I. Pajolli, F.J. Chassaing, V. Yargeau (USA, France, Canada)

Ozone treatment is effective in the oxidation of many organic compounds including micropollutants. Some micropollutants, however, have low reactivity toward ozone and high ozone doses are often needed to achieve efficient removal. Catalytic ozonation is an emerging technology that can be effective in improving micropollutants removal and wastewater disinfection and potentially lower the treatment cost. In the present study, catalytic ozonation with a series of proprietary metal oxide catalysts, such as Al_2O_3, CeO_2, and TiO2, were tested at laboratory scale. The most efficient catalyst in terms of wastewater disinfection and micropollutants removal was further tested at pilot scale at two wastewater treatment plants. Results of the laboratory studies with a model compound (succinic acid) showed that the alumina catalyst improved ozonation efficiency by enhancing ozone reactions leading to the formation of hydroxyl radicals. The use of alumina catalyst in the pilot trials significantly improved wastewater disinfection and micropollutants removal. Catalytic ozonation improved the inactivation of total coliform and fecal coliform compared to conventional ozonation at the same ozone dose.

14.2. Synergetic Micropulluants Removal by Hybrid Oxidation Separation Technology (HOST): Fabrication of Ceria-Functionalized Ceramic Membrane, Performance Evaluation and Mechanistic Study

W. J. Lee, T.-T. Lim (Singapore)

The degradation of micropollutants was investigated in a novel Hybrid Oxidation Separation Technology (HOST) system. In this study, ceria-functionalized ceramic membrane (CeCM) was fabricated via citrate sol-gel assisted wet impregnation method for isotropic impregnation of

nanosized-ceria which decorated the inner pore walls of the alumina substrate. The performance of the CeCM was evaluated in the HOST system operated with continuous dead-end filtration of micropollutants mixture containing bisphenol A (BPA), benzotriazole (BTA) and clofibric acid (CA), and pre-ozonated water for 1-h operation. Results indicated that the application of CeCM with a membrane contact time of 14 s had exhibited superior mineralization ability with 38% TOC removal. The robustness of the hybrid process towards different water matrix was also investigated with settled water sample from local water treatment plant, spiked with micropollutants, whereby only 2.3 g dissolved O_3/g TOC removed is required. The porous structure of the CeCM served as microreactor for catalytic ozone decomposition into reactive oxygen species (ROS) and thus, led to effective mircopollutants degradation. The major by-products of the micropollutants degradation were identified by LC-MS/MS and the mechanism of catalytic ozonation by CeCM was proposed based on the presence of protonated surface hydroxyl groups, ROS quantification and XPS analysis.

14.3. Degradation of phenol in water using ozonation and catalytic ozone

R. Kidak, G. Badru Olabimpe (Turkey)

Water and wastewater treatment have become the most concentrated areas of research and development when it comes to AOPs, but not forgetting groundwater treatment, soil remediation, municipal wastewater, sludge conditioning, volatile organic compound treatment and odor control. The toxicity of phenol, its stability in the environment, large production and usage in industries, makes it an important target for water treatment. Ozonation method for full mineralization or part conversion of target pollutants which in this case are phenolic compounds, is a very interesting technology widely used for the pretreatment of industrial wastewater in which ozone molecules break down toxic organic compounds into smaller and less harmful molecules. However, the main advantages of Ozonation is that it destroys toxic organic compounds without pollution transfer to another phase, but the formation of oxidation intermediates might make it potentially toxic.

14.4. Modelling of clopyralid removal by solar photocatalytic ozonation coupled process

Z. Rajah, M. Guiza, F. J. Rivas Toledo, A. Ouederni (Tunisia, Spain)

The oxidation of clopyralid by photocatalytic oxidation in aqueous solutions was studied. Activated carbon (OSAC) used as a catalyst was characterized by Scanning Electron Microscopy (SEM-EDX). Images showed the presence of irregular cavities and pores, which have different sizes and shapes with a great surface area 717 $m^2.g^{-1}$ of BET, X-ray photoelectron spectroscopy (XPS) verified the formation of chemical states (C, O) and a high pHpzc (10.5). Response surface methodology (RSM) has been investigated to identify the importance of each parameters and their interactions, the influence of three variables such as catalyst concentration (X1), initial concentration of ozone (X2) and pH (X3) on responses of rate kinetic. The results show that the combination of ozone and photocatalytic process exhibited a rapid oxidation rate and mineralization for the removal of pollutant in solution.

14.5. Removal of ibuprofen and gemfibrozil using ozone and ozone/hydrogen peroxide advanced oxidation

H. Farzaneh, K. Loganathan, J. Saththasivam, G. McKay (Qatar)

Reuse of treated sewage effluent has been more important these days to overcome water scarcity and sustain the environment but at the same time, its reuse can adversely affect the environment due to insufficient treatment. Pharmaceuticals has been known to be persistent to the conventional treatment processes thus advanced technologies are suggested to achieve higher removals. In this work the removal of ibuprofen (an analgesic) and gemfibrozil (a lipid regulator) has been studied using ozonation and ozone/H_2O_2 advanced oxidation processes. The removal of these compounds was tested in spiked treated sewage effluent and pure water in single component and in binary systems. The results showed complete removal of gemfibrozil by both ozonation and AOP tests from both pure water and treated sewage effluent within 5 minutes. Ibuprofen removal was found to be ~70% in pure water by ozonation after 5 mins oxidation time but after 60 mins it was completely removed. In treated sewage effluent 80% of ibuprofen was removed within 5 mins and no further removal was achieved after that. Treated sewage effluent contains other contaminants and scavengers which affect ozone decomposition rate due to higher oxidation demand. Ozone decay in pure water was relatively slow and after one hour the residual ozone was about 0.5 mg/L (ozone dosage= 1.5 mg/L) while in treated sewage effluent ozone residual after 5 mins was only 0.15 mg/L and was approaching zero after one hour. Bromate formation was found to be in a range between 0.027 to 0.039 mg/L where the lower values were obtained in the pure water and in the binary samples.

14.6. Treatment of ciprofloxacin by ozone/persulfate oxidation

S. B. Kpange, S. Doğan, S. Pirgalıoğlu (Turkey)

Presence of pharmaceutical compounds in treated wastewater effluents and freshwater resources possess adverse effects for both human health and the environment. Most of them are non-biodegradable and recalcitrant compounds which needs advanced water treatment for their elimination. In this study, a broad spectrum antibiotic ciprofloxacin have been investigated for its removal form water medium by ozone, ozone(O_3)/PS and zero valent iron/PS(Fe^0/PS) processes. Degradation of CIP by O_3/PS experiments followed pseudo first order kinetics and significant increase in the rate of removal of ciprofloxacin observed at 1/100/ozone runs (k'_{obs}=0.030min^{-1}) with respect to 1/10/ozone (k'_{obs}=0.023min^{-1}) and ozone (k'_{obs}=0.021min^{-1}) experiments at 24mg/L gaseous ozone concentration under acidic pH conditions. Fe^0/PS experiments resulted with 79, 86, 94, 95 and 99% CIP removal after 90 minutes at 1/10/20, 1/20/20 1/100/20, 1/500/20 and 1/1000/20 CIP/PS/Fe^0 molar ratios. The rate of ciprofloxacin removal increased with increasing PS dose and didn't affected by the increase in Fe^0 dose. However, consumption PS was enhanced when Fe^0 dose increased. Mineralization of ciprofloxacin was insignificant after O_3/PS and Fe^0/PS applications. Byproduct formation pathways were proposed for ozone, ozone/PS and Fe^0/PS processes. Byproducts containing benzene, alkane and pyridine functional groups as well as aliphatic structure were observed.

Session 15. Ozone in Medicine – Part 3 / Pain

15.1. Minimally Invasive OxygenOzone Therapy for Lumbar Disk Herniation. Improving the results.

A. Alexandre (Italy)

Oxygen-ozone therapy is a minimally invasive treatment for lumbar disk herniation. Now a day the biochemical characteristics of this gas mixture in clinical applications are well known, even if the specific mechanisms are to be understood.
We assessed the therapeutic outcome of oxygen-ozone therapy, and compared the outcome of administering medical ozone alone with the outcome of medical ozone followed by injection of vasoactive drugs and an anesthetic at the same session.

15.2. Comparison of disc herniated patients receiving ozonucleolysis with & without physical therapy

Noor-ul-Huda, U. Rashid, M. Farooq (Pakistan)

Background and repose: Lower backache is a common complain in the OPD causes of which are several- mechanical, autonomic, inflammatory. The conventional method of physical therapy has been somehow effective. However, reports about O2 and O3 have been increasing. In our setup when conservative approach is not effect then ozone therapy is recommended. Ozone is a strong oxidant gas with properties like, immune-modulating, anti-inflammatory, antiseptic and analgesic.
Objective: To find out the effectiveness of physical therapy along with ozone therapy in treating lower back pain, compared to outcomes of ozone alone.
Methods: A total of 93 patients with acute and chronic lower back pain received intra foraminal infiltration of ozone O2-O3 gas mixture under angiography machine with periradicular infiltration of steroids. Two groups were formed, first received ozone therapy with physical therapy and second group only received ozone therapy (without physical therapy). The 1st group received physical therapy session for trunk and lower extremity. The 2nd group is just for O2-O3 injection. Thereafter, neurologists/physicians unaware of the type of treatment assessed patients.
Results: This study provided better results in reduction of pain, improvement in functions and increasing range of movement in first group having both ozone and physical therapy treatment, 26.88% participants reported of no or very mild pain whereas the second group receiving only ozone 18.28% reported moderate pain.
Conclusion: Current study concluded that better results were seen in 50.5% of participants who had both, ozone therapy along with physical therapy. As physical therapy prevented the reoccurrence of disc herniation, by strengthening the muscles of trunk and maintaining the vertebral alignment. 49.5% participants of the 2nd group who only received ozone has slow recovery and relatively greater chances of reoccurrence. Therefore, this indicates that physical therapy is effective after ozone therapy for lower back pain. Until 15 years ago surgery was the treatment of choice but conservative measures are now preferred in the wake of unsatisfactory surgery outcomes (2). Among the techniques adopted to treat lower backach with herniated disc or non- discal spinal disease physical therapy with intraforminal injection of O3 has yielded encouraging results.
We compared the therapeutic effectiveness of these methods undertaking a randomized control study in 93 patients with acute and chronic lower back pain. 50.5% (47) patients ever treated with ozone therapy along with 3 weeks of physiotherapy and 49.5% (46) patients ever treated with ozone therapy only.
Nevertheless, current study concluded that physiotherapy is highly recommended for 2-3 weeks after ozone therapy.

15.3. Herniated discs unchanged over the time: size reduced after oxygen-ozone therapy

M. Bonetti, A. Zambello (Italy)

Spontaneous regression of disk herniation secondary to a dehydration process is a much debated topic in medicine. Authors often wonder whether it is really necessary to surgically remove the nucleus pulposus spilled when the "natural history" of 'herniated disc is, for many authors, the spontaneous disappearance. Unfortunately, if this does not happen, the chronicity of pain involves a progressive disability in patients with herniated discs, for which seems to be indicated as the only solution the surgical approach.
In recent years several studies have demonstrated the utility of oxygen-ozone therapy in the treatment of herniated discs with the result of herniated discs reduced in size.
In this study we present a retrospective evaluation of the results of a case series of patients, with the history of herniated discs of size neuroradiologically unchanged for over two years, treated in our Centre in the last fifteen years.
We treated 107 patients, 92 (85,9%) suffering for low back pain complicated or not by chronic sciatica, while 15 (14,1%) presented cervical disc herniation.
No drug therapy had enabled significant benefits, several neuroradiological documentation have been required as the result of several specialists consulted in two or more years, prior to the decision to undertake the oxygen-ozone therapy.
In our study we document as in cases of slipped discs "unchanged over time" the ozone therapy has been able to solve the problem, disrupting or significantly reducing the size of the prolapsed disc material into the spinal canal.

15.4. Effect of adding ozone sauna to local injections in low back pain treatment

T. T. Tanbouli, M. Al-Qanni (Egypt)

(A) Purpose: To evaluate the effect of adding ozone sauna with local O3 injection in low back treatment and comparing it to local O3 injection alone.
(B) Patients & Methods: This study was conducted on 70 patients suffering from chronic low back pain (> 6 month),(Age: 35-65 years.) , (L1/L2 to L5/S1), and Pain Assessment depends on Pain Scale before treatment and after 2, 4, 6, 8, 10, 12 sessions. Patients are divided randomly into 2 groups; group (A) is 20 patients 12 males and 8 females and group (B) is 50 patients 33 males and 17 females. Group (A): received local O_3 injection (7-12 mcg./ml.) for 12 sessions t twice weekly. Group (B): received local O3 injection as group (A) followed by OZONE SAUNA for 12 sessions twice weekly.
(D) Conclusion: Adding Ozone Sauna to local O3 injections in treating chronic low back pain resulted in fast improvement and better outcome (more patients) than using local O_3 injections alone.
(E) Discussion: (A) Previous studies were done proving that treating chronic low back pain by antibiotics for long periods gives good results. (B)Systemic effect of Ozone Sauna (its bactericidal effect) could be the reason standing behind the fast and sustained improvement of patients receiving it and local ozone injections (its anti-inflammatory effect) at the same time.

Session 16. Ozone in Agrifood – Part 2

16.1. The effects of gaseous ozone treatment and different storage temperatures on the quality of yellow-flesh kiwifruit cv. 'Soreli'

C. Carboni, V. Goffi, M. Petriccione, R. Botondi (Italy)

Post-harvest management and cultural techniques are the basis of high quality fruit production; there are different post-harvest methods suitable for storage fruits and vegetables. Among that, the use of ozone has been identified as a feasible post-harvest treatment due to its antimicrobial activity, eco-friendly property, cost-effectiveness, safety and ability to extend shelf-life.

Kiwifruit is a sub-tropical climacteric fruit with health benefits; 'Soreli' is a yellow fleshed kiwifruit, that nowadays it got attention for its sweeter flavoured and its high levels of bioactive compounds. Compared to 'Hayward' green fleshed kiwifruits, the yellow one is characterized by low temperature susceptibility. Therefore, the management of cold storage is a critical point for the storage-ability of kiwifruit. Indeed, low temperatures may cause low temperature disorders.
In this study, yellow fleshed kiwifruits were stored at 2 °C and 4 °C with normal atmosphere (CK) or with continuous atmosphere enriched with O_3 (300 ppb), for 60 days of storage condition.
It was found that the gaseous ozone post-harvest treatment matched with 2 °C and 4°C showed effectiveness on the microbial grown and on preserving the nutritional quality. Whereas, the colour traits were affected by the temperature; fruits stored at 4 °C were more affected than stored at 2 °C.
A proper concentration of gaseous ozone combined with the optimal range of temperatures can preserve yellow-fleshed Soreli kiwifruit quality.

16.2. Effects of continuous low ozone exposition on ariane apples in cold storage conditions with modified atmosphere

V. Lemetter, M. Pages, D. Kleiber, J. Joulie, S. Maldes, F. Violleau (France)

In view of economic damage caused by storage diseases and consumers' desire to reduce the use of chemicals in food processing, an alternative is to be found to replace antifungal treatments. This study presents the effects of gaseous ozone as an antifungal treatment in a modified atmosphere during apple storage. The assay is done in three reduced industrial-like storage rooms, containing each 700 kg of Ariane apples (control room, 100 ppb and 400 ppb of ozone). After several months of classical conditions, ozone atmospheres are maintained for six weeks. At the end of the experiment, total skin fungal population was compared on OGA culture media, as well as the number of visually infected apples and the total amount of pesticides residues. Finally, discriminant sensorial analyses were conducted to assess if ozone atmosphere induce a difference on the organoleptic qualities of the fruits.
Visual count of diseased apples shows that the contamination by Phytophthora spp. is divided at least by half between control and ozone samples. Regarding microbiological analyses, ozone significantly lowered the number of colonies, dividing it by three to six depending on the concentration used. However, the 400 ppb treatment induced the emergence of few black spots, due to a too high concentration of ozone. Treatments do not seem to have an impact on pesticide residues, results showing no significant differences between the chambers. Finally, sensorial analyses realised 0, 4 and 8 days after the opening of the chambers showed statistically significant difference between ozone and control samples, with a tendency of control samples being blander. As a conclusion, an atmosphere of 100 ppb of gaseous ozone treatment is effective to lower the losses due to storage diseases and does not seem to negatively affect sensorial properties of the fruit. It could thus be an alternative to chemicals used in the orchard, after a phase of optimisation of the treatment.

16.3. Researches on active and passive monitoring aeromicroflora in milk processing units and the results obtained following use the GF3XO-15 ozone generator

I.E. Popa, G. Puchianu, D.V. Enache (Romania)

In order to verify the efficiency of air treatment with ozon in the raw milk processing units, the microaeroflore was monitored from some spaces from raw milk processing, taking samples using active procedures (by taking certain amounts of air). The microbiological examinations performed were: detection of the total number of aerobic bacteria (NTG) / m3 of air and the number of yeasts and molds / m3 of air.
A special sampling device was used to collect the air samples, the air being sucked directly onto the surface of the solid culture media (Plate Count Agar and DG18). The sampling was carried out in two distinct time periods: one in which no microbiological airborne decontamination equipment was used and the other one using ozone generating equipment of the GF3XO-15 class.
They have the following features: they can handle a maximum air volume of up to 2400 m3, produce ozone up to 15 g /hour, the dimensions are reduced (350 x 160 x 260 mm), require a supply voltage of 230V / 50Hz / 16W. Generators GF3XO-15 are designed to destroy molds and microorganisms, while having a clear deodorizing and disinfecting action of the air in its operating areas. They also have the specificity that they can operate in damp environments, the electronic components being introduced into a resin-protector (solid state system).
After the sampling, during the two time periods, the experiments were carried out by laboratory examinations, by incubating the culture media at different temperatures depending on the target organisms (aerobic germs or yeasts and molds) and then we determined the microbiological load of air by estimating the number of micro-organisms expressed as cfu / m3 .
As a result of the experiment, we have found that ozone generating equipment of the GF3XO-15 class produces a significant improvement in microclimate conditions, the effect being considerably diminishing the risk of microbiological contamination on the various stages of processing the rawmilk with pathogenic microorganisms and alteration present in the air.

16.4. Short-term ozone treatments during postharvest manegement influence grape volatile composition

S. Río Segade, M. Vilanova, M. Pollon, S. Giacos, C. Carboni, L. Rolle (Italy, Spain)

Ozone is an efficient sanitizing agent increasingly used in wine industry because of its strong oxidizing properties. In postharvest grapes, treatments with ozone can stimulate defense responses by synthetizing secondary metabolites against oxidative stress. In the present study, the effect of postharvest short-term ozone treatments was evaluated on free and glycosylated volatile organic compounds (VOCs) of Moscato bianco winegrapes (Vitis vinifera L.). Two different ozone concentrations (30 and 60 µL/L) and exposure times (24 and 48 h) were investigated just after treatment (fresh grapes) and after partial dehydration up to 20% weight loss (withered grapes). The results evidenced that short-term ozone treatment caused a significant decrease in total contents of free VOCs in fresh grapes, mainly terpenes. Linalool, geraniol and nerol are the major aromatic markers of Moscato bianco grapes and they are of great importance in white aromatic cultivars to produce high quality wines. Significant changes were not observed in geraniol and nerol contents in fresh grapes whereas ozone entailed a significant decrease of free linalool contents in fresh grapes, the less stressful ozone treatment showing the smaller linalool degradation. However, the stronger and longer ozone treatment induced the synthesis of this compound probably in response to higher abiotic stress. In withered grapes, this same ozone treatment also reduced the loss of free linalool by water loss even though total VOCs and terpenes remained relatively stable. Furthermore, ozone promoted the synthesis of other terpenes in withered grapes. Total glycosylated VOCs and terpenes were less sensitive to ozone. This study highlighted that ozone can be directly applied on aromatic grape varieties prior to winemaking for sanitizing purposes without affecting sharply the aromatic profile of fresh grapes and even improving it in withered grapes.

16.5. Effectiveness of ozonated water treatment on microbial control and storage quality of different Citrus fruit species

M.C. Strano, F.V. Romeo, P. Foti, M. Allegra, C. Carboni (Italy)

The effectiveness of ozonated water on development of postharvest decays was evaluated on three species of citrus fruit. Tarocco oranges (Citrus sinensis (L.) Osbeck), clementines (C. clementina Hort. ex Tan.) and lemons (C. limon (L.) Burm.) were dipped in ozonated water at 3 and 6 ppm for 3 min. at room temperature. Untreated fruit (not washed) and fruit dipped in tap water for 3 min. were used as control. Microbial reduction, decay incidence, physiological disorders, weight loss and physical-chemical parameters were assessed soon after the treatments and during storage, at 4°C for oranges and clementines and at 10°C for lemons, with 90% RH (Relative Humidity) for all treatments. For statistical analysis three replicates of all treatments were used. Data were analyzed by ANOVA and means were separated by Tukey's HSD test.
The effect of the two ozone concentrations tested showed a significant microbial reduction, compared to the untreated control, only for Tarocco orange and Clementine. Concerning lemons a significant reduction was observed only soon after the treatments (T0). Regarding decay incidence, physiological disorders and physico-chemical parameters, different results were obtained among citrus species and during storage.

16.6. Effect of two different application methods of ozone on *geobacillus stearothermophilus* spores

E. Sarron, D. Marier, S. Gauthier, S. Baig, B. Picoche, P. Sajet, P. Gadonna-Widehem (France)

G. stearothermophilus spores have a significant resistance to a lot of physical and chemical agents. We have tested different application methods and concentrations of ozone, a powerful oxidizing agent, on lyophilized and fresh spores at different water activities (Aw). No significant effect of gaseous ozone concentration was observed on fresh and lyophilized *G. stearothermophilus* spores stored at different Aw, in any tested ozone concentrations, for 30 minutes. However, an aqueous treatment of spore suspensions at 3.8 g/Nm^3 reduced spores counts by 5.5 CFU/mL in 25 minutes.

Session 17. Workshop Ozone plant design: Key questions

Design data: Lab to full scale
Design/engineering
Safety
Cost

Session 18. Ozone in Medicine – Part 4 / Case reports, preclinical trials

18.1. Ozone Therapy and Its Usefulness in a Wide Variety of Ailments: A Systems Medicine Approach

L. Re (Italy)

Notwithstanding the use of Ozone Therapy (OT) in medicine has become widespread in many countries of the world, its real pharmacological action remains not completely clarified.
We know that other than its uses as disinfectant, well documented by the literature since the beginning of the past century, the more recent medical use of ozone in several pathologies as described by the international literature is still poor investigated.

18.2. Medical ozone an important part of COPD-therapy

R. Thiele (Austria)

An impressive new experience I should not hide any more.
I want to share this successful development in the therapy of COPD.
So far I can only report a few cases I have been able to help (about 30) but there is one who was so happy that he wrote a book to tell all his fellow sufferers there is a way to get a better way of life and quality of life again, to be able to breathe more air again, to be able to climb more stairs again, to be able to sleep better again, and …in short- living without fear again.
The book called "The Snorting Wolf" - daily fight, findings and Tips & Advices of a patient written by Wolfgang Bankowsky.
The Magic of Ozone or the beginning of a new way in the common therapy of COPD?
Why can ozone improve the existing possibilities of COPD therapy or complement them in such a way that the success of therapy becomes greater?

18.4. Effect of ozonation over the therapeutic properties of different vegetable oils with low ozonation degree

F. Antunez, P. Guerra-Blanco, T. Poznyak, I. Chairez, J. Dueñas Moreno (Mexico)

The aim of this work was to study the effect of ozonation over the therapeutic properties of different vegetable oils, as well as the relationship of the ozonation degree of them with these effects. Arnica, grape seed, Calendula, castor, aloe Vera, cotton, avocado, coconut, and olive oils were ozonated under the same experimental conditions, and then they were clinical tested for several diseases related to infectious skin injuries and wound healing, such as diabetic necrobiosis. The ozonation degree of oils was quantified by the total unsaturation method (TU), which was used to determine the oxidizable substrates contained in oils. The initial TU of oils was between 4.28 and 5.46 mmol/g_{oil}, and the ozonation degree was between 9.9 and 28.1%. The therapeutic effects of the oils were improved by ozonation and even extended, namely, the oils demonstrated new therapeutic effects, which were absent before ozonation. The clinical effects of the different ozonated oils showed a strong dependence on their nature, which suggest that these effects are related not only with the ozonides, that are the principal ozonation reaction products of the oils, but the minor compounds (polyphenols, pigments, vitamins, etc.) contained in oils, and their ozonation reaction products may also be involved in the observed therapeutic effects.

18.5. Life quality study in relation to alternative infusion solution: conventional versus glucosate

M. Martinelli, F. Giovannangeli (Italy)

Objective: To evaluate the clinical efficacy of ozonized glucose solution compared to MAT by analyizing the QoL in patients affected by several disease.
Methods: 120 subjects underwent as outpatients to 18 systemic ozone session with the following protocol: 2 treatment session every week for the first 6 weeks followed by a weekly treatment session for the following 6 weeks for a total of 18 sessions in 12 weeks. Patients were divided in three subgroups of therapy: Group 1 received only MAT (18 session), Group 2 only ozonized glucose solution (18 session), group 3 MAT alternated to ozonized glucose solution (9 MAT and 9 glucose). Quality of life was evaluated by the use of Short-Form 36. All patients filled out the questionnaire before entering the study and after the last therapy session. Possible adverse events related to the treatment were recorded. Has been evaluated global results for all aggregated patients independently from the group they were included in and the results separated for the three groups and eventual differences among the 3 groups.

Wednesday, 23 October

Session 19. New challenges in wastewaters – Part 1

19.1. TReating Urban Micropollutants and Pharmaceuticals in wastewaters: new solution involving synergetic biological and chemical oxidation using ozone

B. Domenjoud, A. Gonzalez Ospina, A. Kiss, A. Bergé, E. Vulliet, M. Marce, S. Esplugas, S. Bony, A. Devaux, A. Wigh, S. Baig (France, Spain)

The environmental and human health risks induced by the presence of trace contaminants on the environment are nowadays of general acceptance among the scientific community as well as for the public authorities. Urban wastewater treatment plants (WWTP) were not conventionally designed to deal with trace organic contaminants. They are perceived as a continuous and major source of emission of micropollutants (Greaud-Hoveman, 2008). Tertiary ozonation has demonstrated high performances covering a wide range of contaminants elimination and to be economically suitable. This is supported by a growing number of serious studies and by the fact that national strategies usually opt for a solution including an ozonation step (Reungoat et al, 2012). Nevertheless, the implementation of tertiary ozonation on site supposes an ozone contactor that has a substantial footprint in regard to the available space on most of the existing WWTP. In addition, a subsequent biological step is frequently seen to limiting the emission of some undesired by-products, whose formation mainly depends on the application conditions of ozone. Ozone attack on organics can be highly selective. Based on the competition between ozone reactions, an innovative approach was designed. It consists in integrating ozone oxidation to aerobic biological treatment. Applications of ozone upstream the biological treatment and on the sludge recycling stream, both at a same time or separately, were investigated.

19.2. Micropollutant removal – full-scale reality for the largest sewage treatment plant in Switzerland

L. Dinkloh, T. Puehmeier, A. Ried, H. Stapel, S. Bressmer, C. Abegglen (Germany, Switzerland)

The term “micropollutant” is synonymous for thousands of emerging man-made substances such as residues of pharmaceuticals, cosmetic products, pesticides and biocides.
Conventional sewage treatment plants typically do not provide a sufficient barrier to protect all aquatic life and drinking water sources from micropollutants discharged with the treated effluent.
In many countries there is now a focus on these new contaminants. The approach of micropollutant removal processes of two countries (namely Germany and Switzerland) are addressed. In particular, the micropollutant removal process of one reference – the largest sewage treatment plant in Switzerland – is being further explored.

19.3. Degradation of pharmaceuticals in waste water treatment plant effluent by ozonation and ozone based advanced oxidation

B. Delfos, B. Martijn, H. Bruning, J. Kruithof (The Netherlands)

In a joint research effort Water Authority Hoogheemraadschap Hollands Noorderkwartier and PWN Water Supply Company North Holland investigated the feasibility of pharmaceutical degradation in waste water treatment plant effluent by oxidative treatment. A bench scale equipment is developed to operate O_3 and O_3/H_2O_2 experiments in a semi batch mode. Based on bromate formation four O_3 and two O_3/H_2O_2 dosing regimes are identified to degrade 9 priority pharmaceuticals. Six pharmaceuticals diclofenac, trimethoprim, sulphamethoxazol, carbamazepine, sotalol and propanolol are degraded for more than 99% by an ozone dose of 7 mg/L without a significant bromate formation. For a high degradation of ibuprofen, iopromide and metformine O_3/H_2O_2 treatment must be applied to avoid bromate formation. By both O_3 and O_3/H_2O_2 treatment the response in 5 bioassays is decreased significantly, showing that formation of brominated high molecular organics and pharmaceutical metabolites do not have a negative impact on water quality. Because of these positive results pilot research will be initiated and a demonstration plant project will be developed.

19.4. Coupling ozonation and nanofiltration for removal of pharmaceuticals pollutants in wastewater for sustainable reuse

Z. A. Yacouba, J. Mendret, F. Zaviska, G. Lesage, S. Brosillon (France)

Nowadays, water scarcity and quality are big challenges facing humanity in many places around the world. To solve this problem, municipal wastewater (WW) is thus considered to be an alternative water source for various applications after proper treatment. Nonetheless, urban WWs are increasingly contaminated with organic micropollutants (OMPs). Although their concentration in urban WWs is often very low (≤ 10 µg/L), their effects can be disastrous because of their potential persistence in the environment, their possible endocrine disrupting effect

and their accumulation in biological bodies. In addition, human and veterinary antibiotics have been found widespread in different environmental compartments due to their persistence and low degradability. As a consequence, the presence of antibiotic resistance genes (ARGs) is increasing in the environment. These toxic compounds have become a major issue for the Water Utilities (REACH 2006, WFD 2000 and 2012) and legislations in European Union in the coming years will be tightened with regard to OMPS in municipal WW and to their discharge. These evolutions are driving the WW treatment to come up with advanced technologies. In this view, membrane processes, more specifically nanofiltration and reverse osmosis, have gained huge interest recently as its act as a physical barrier against OMPs and can insure reliable and very good water quality for reuse. However, membrane processes are only separation step which must be combined with advanced oxidation processes to eliminate such refractory organic pollution.
The objective of this study is to develop an innovative and advanced integrated "membrane and oxidation" system for the treatment of municipal WW by coupling membrane bioreactor (MBR), nanofiltration (NF) and ozonation (O3). Such processes can work synergistically to efficiently treat secondary effluent containing a cocktail of priority substances targeted by the legislation and offer safe and affordable WW reuse.

19.5. Transformations of protein-like and humic/fulvic-like fractions during post-treatment of wastewater effluent by ozonation

A. Ignatev, T. Tuhkanen (Finland)

Conventional biological treatment incompletely removes many recalcitrant compounds, including known and emerging (micro)pollutants. Through discharge of wastewater effluents wastewater treatment plants (WWTPs) have become point sources of complex contamination of receiving water bodies. Various post-treatment methods, based on ozonation, UV treatment, etc., can solve this issue. However, the diverse chemical nature of wastewater, containing thousands of known and unknown compounds of natural and anthropogenic origin, complicates monitoring of post-treatment efficiency. Traditional parameters, such as chemical and biochemical oxygen demand (COD and BOD), do not provide detailed wastewater characterization. Target analyses, such as HPLC-MS/MS, are expensive, time-consuming, and allows quantifying only a limited number of known pollutants.
Recently, we developed a rapid surrogate method based on high-performance size-exclusion chromatography (HPSEC) to characterize treated and untreated wastewater and to monitor removal of protein-like and fulvic/humic-like fractions in conventional wastewater treatment.
In this study, we applied this HPSEC-UV-fluorescence approach to study transformations of individual DOM fractions during ozonation of secondary wastewater effluent. The effluent was collected from a full-scale WWTP (city of Jyväskylä, Finland) and ozonated in a laboratory. Removal of fluorescence response and UV absorbance (UVA) was analysed as function of consumed ozone dose. For example, an application of 3 mg O3 per L removed 55-60% of tyrosine- and tryptophan-like fluorescence, 40-45% of fulvic/humic-like fluorescence, and ~20% of UVA254 of whole (unfractionated) effluent. At the same time, individual fractions exhibited notably different behaviour: removal of fulvic/humic-like fluorescence varied from >60% for low MW fractions to <10% for high MW fractions.
The results provide new insights into what can be easily removed by ozonation, what may require an advanced oxidation, and how to comprehensively monitor post-treatment of wastewater effluents.

Session 20. Fundamentals – Part 3

20.1. Ozonation using hollow fiber contactor technology for the elimination of pharmaceuticals: state of the art

A. Schmitt, S. Brosillon, J. Mendret (France)

Membrane contactor is a process usually used for the removal or the absorption of a gas into another fluid. The membrane acts as a barrier between the 2 phases and the mass transfer occurs by diffusion and not by dispersion. This work is a state-of-the-art of the application of hollow fiber membrane contactor technology for the ozonation of micropollutants, especially pharmaceuticals. The challenge of removing micropollutants is presented in the introduction. In the first part, the ozonation process is described, in particular chemical reactions induced by ozone and its advantages and disadvantages. In the second part, generalities on membrane contactor technology with hollow fibers are presented. Then, the interest of using a membrane contactor for the elimination of micropollutants is shown, and the effect of several parameters on the ozonation efficiency is described. The impact of the membrane material is also highlighted.

20.2. Impact of Ozone and Biological Filtration on NDMA Formation (WRF 4491 and 4669)

B. Kuhnel, A. Evans, C. Russell, P. Huck, S. Peldszus, W. Mitch, R. Hozalski (USA, Canada)

With the United States Environmental Protection Agency considering whether to regulate nitrosamines (including N-nitrosodimethylamine [NDMA]) in drinking water, utilities practicing or considering implementation of ozonation and/or biofiltration have a significant need to understand which conditions promote or mitigate NDMA formation. Previous research has shown ozone to be effective at reducing NDMA formation in chloraminated distribution systems. Water Research Foundation Project (WRF) 4491 expanded upon prior research by evaluating the risk tradeoffs and unintended consequences of implementing ozone for nitrosamine control. Bench testing showed seasonal variations in NDMA precursor removal by ozone oxidation, highlighting the importance of conducting tests under multiple seasonal conditions. Although testing showed minimal impact of ozonation on concentrations of currently regulated DBPs, at higher ozone to TOC ratios, bromate mitigation would be required. Further, ozonation may need to be coupled with an additional barrier, such as biofiltration, to reduce AOC concentrations prior to finished water distribution.

20.3. Estrone degradation using non-thermal plasma and ozone: kinetics of degradation products

C. Tizaoui (UK)

Being an endocrine disruptor and widely distributed in the aquatic environment, estrone has been the subject of many research studies aimed at developing treatment technologies for its degradation and removal from water. Ozone and a variety of advanced oxidation processes have been found very effective to degrade estrone up to 100% removal and potentially to a complete mineralisation of the molecule under extended oxidation conditions. Most of the studies carried out so far on the oxidation of estrone have focused on the degradation of the parent molecule without providing much information on the degradation products formed nor on their kinetics during the course of the reaction. In this study, results on the degradation of estrone using non-thermal plasma, an emerging water treatment technology, and ozonation, a well established water treatment technology, are discussed. The study used liquid chromatography coupled with mass spectrometry and an in-house data analysis algorithm to identify the degradation products and evaluate their kinetics within a 30 minute reaction time. The results are significant

when oxidation is used to remove estrone so the change of toxicity and the type of residual species remaining in water is correlated to the reaction time.

20.4. Accelerated oxidation of iopamidol by ozone/peroxymonosulfate (O_3/PMS) process: Kinetics, mechanism and simultaneous reduction on iodinated disinfection by-products formation potential

H. Dong, Y. Mao, L. Zhang, Z. Qiang (China)

Iopamidol (IPM) is a potential iodine source for formation of toxic iodinated disinfection byproducts (I-DBPs) during disinfection. In this work, we assessed the degradation kinetics and mechanism of IPM by combination of ozone (O_3) and peroxymonosulfate (PMS, HSO_5^-) and its effect on the formation of iodinated trihalomethanes (I-THMs) during chlorination. It was found that the degradation of IPM could be accelerated by O_3/PMS process. The formed hydroxyl ($HO^•$) and sulfate ($SO_4^{•-}$) radicals were the major contributors. With the identification of second order reaction rate between $SO_4^{•-}$ and IPM ($k_{SO_4^{•-}, IPM} = 1.6 \times 10^9\ M^{-1}\ s^{-1}$), the contribution of $HO^•$ to the degradation was determined to be 78.3%. Alkaline circumstance could facilitate the degradation of IPM and the effects of natural organic matter (NOM) and alkalinity on the degradation of IPM were limited in O_3/PMS system. The degradation pathways of IPM by O_3/PMS system included amide hydrolysis, amino oxidation, hydrogen abstraction, deiodination and hydroxyl addition. Interestingly, the oxidation of IPM by O_3/PMS system also decreased its I-THM formation potential. After the oxidation of IPM, the formed I-THMs from 5-μM IPM decreased from 14.7 μg L^{-1} to 3.3 μg L^{-1} during chlorination. Although the presence of NOM provided the precursor of I-THMs during the chlorination of IPM, O_3/PMS system decreased the I-THM formation potential 71%. The oxidation of released iodide into iodate effectively inhibited the formation of I-THMs. This study provides a new option not only for the accelerated degradation of IPM, but also for the control of I-DBPs formation.

20.5. A novel kinetic ozonation model for prediction of bromate formation, bromate mitigation and trace organic contaminant removal

W. Audenaert, G. Bellandi, R. Mack Pearce, I. Takács, P. Buehlmann, S. Hogard, G. Salazar-Benites, U. Rehman, I. Nopens, C. Wilson, C. Bott (Belgium, USA, France)

To meet primary MCLs for bromate and trace organic contaminants (TrOCs) and to maximize TOC removal in downstream biofiltration, it is important to optimally operate and design ozonation processes based on kinetic process understanding. In this study a novel kinetic ozonation model was developed predicting ozone, HO*, TrOC and bromate concentrations dynamically based on real-time data. Also, the impact of nitrite and ammonia on the overall process was taken into account. The aim was to balance complexity in order to have a reliable, yet applicable model. The model was developed and applied in the framework of HRSD's innovative water reuse project SWIFT (swiftva.com) in eastern Virginia, US. SWIFT aims to treat wastewater effluent to drinking water standards for managed aquifer recharge.

20.6. How to predict bromate formation during ozonation

S. Baig, M. Roustan (France)

The question of ozonation performances 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 21. Ozone in Medicine. Workshop: Ozone in Inflammatory Conditions

21.1 The effect of ozone on colonic epithelial cells

H. Himuro, H. Matsumura, T. Abe (Japan)

We found that intrarectal administration of ozone gas induced transient colonic epithelial cell damage characterized by the impairment of cell survival pathways. However, the damaged cells were rapidly extruded from the epithelial layer, and appeared to immediately stimulate turnover of the epithelial layer in the colon. It is possible that ozone gas is able to trigger damage induced rapid regeneration of intestinal epithelial cells.

21.2 Ozone workshop: Ozone as a complimentary therapy in medicine in the fields of chronic inflammatory disease

M. Schreiber (Germany)

In a busy physicians clinic specialising in chronic disease, medical ozone has found its place as a valuable instrument because of its mode of action. The stimulation of the glutathion circle stimulates the scavengers of cells thus helping chronic inflammatory processes to heal, such as rheumatoid arthritis, chronic inflammatory bowel syndrome or oncological problems caused by chemotherapy. Different forms of application are demonstrated.

21.3 Possible errors in pain treatment with ozone

S. Tiron (Romania)

Objective: Increasing the effectiveness of ozone therapy by eliminating diagnostic and procedural mistakes. This presentation is made based on (more than) 3000 patient's experience.
The pain treatment with ozone is an excellent one. So … why don't we have 100% results?

21.4 Trigeminal nevralgia treated with ozone

S. Tiron, V. Simonetti, M. Marcvart, L. Rajnoveanu (Romania, Itlay)

Objective: Based on medical data on our own clinical observation upon a consistent lot of pacients we have describe the beneficial effect of ozonetherapy on trigeminal nevralgia.

Session 22. New challenges in wastewaters – Part 2

22.1. Successful Treatment of Micropollutants and Recalcitrant COD from Wastewater using the Nyex™ Combined Adsorption and Electrochemical Regeneration (AOP) Process

M. A. Khan, M. Massaros, D. Zulfiqar, E. Carson (UK)

Improvements in analytical techniques coupled with increasing research in the field of organic freshwater pollution mean that focus is being directed at ways to cleanse waters of organic contaminants. Whilst individual organic compounds may not present particularly high toxicity alone, mixtures of contaminated waters may pose cumulative effects greater than the sum of risks posed by individual contaminants due to inherent difficulty in ecotoxicological quantification of mixtures of chemicals. Worries about ecosystem damage, carcinogenicity and endocrine disruption are among key concerns. In addition, regulation for COD discharge into sewers or the environment is now becoming much more stringent for manufacturing facilities. These factors have led to increasing resources directed at improving efficacy of water treatment practices overall.

22.2. Strategies for enhanced ozone-resistant micropollutants abatement in wastewater and alternatives for process monitoring

A. Cruz-Alcalde, S. Esplugas, C. Sans (Spain)

Although ozone is an effective technology for micropollutants abatement in wastewater effluents, there are some compounds which are not effectively degraded at the currently employed ozone doses. In this work, the removal of ozone-resistant micropollutants at extended ozonation conditions was tested in different effluents covering a wide range of water qualities. The implementation of the peroxone process (i.e., combination of ozone and hydrogen peroxide) was also assessed with the same purpose. Results showed how ozone doses up to 4 times the currently employed ones would be necessary to ensure a significant (*e.g.*, 80%) degradation of acetamiprid, here employed as ozone resistant micropollutant. Adding hydrogen peroxide to the system increased the oxidation performance with estimated energy savings related to oxidant usage of about 30% (compared to single ozonation). The latter is only achieved when implementing the peroxone process with simultaneous addition of both oxidants. On the contrary, if addition of hydrogen peroxide is conducted before ozone bubbling, energy savings are not so significant (about 9%). Thus, the simultaneous addition of both oxidizing agents is recommended. Also in this study, two different strategies for process modelling and ozone-resistant micropollutants monitoring at real time were tested and validated. One was based on the R_{OHO3} concept and the assessment of ozone consumption. The other focused on continuous UV absorbance measurements. In any case, both practices allowed to estimate the hydroxyl radical exposure during the processes application. By combining these correlations and second-order kinetics, successful predictions of ozone-resistant micropollutants abatement could be performed for different compounds, effluent qualities and oxidation processes.

22.3. Removal of microcontaminants from water in presence of microplastics

T.G. de Aragão Belé, T.M. Bragadin de Castro, J. Cristale, R. Falcão Dantas (Brazil)

It exists a high possibility that micro plastics can protect organic contaminants during wastewater and water treatment. Microplastics are tiny plastics particles with less than 5mm and they have been already reported as contaminants carriers. Wastewater treatment plants are a known source of microplastics into the environment, and the scientific community still not know their effects in the environment after long periods of time. This study aimed to recognize if micronized polyethylene, the most widely produced plastic in the world, can protect organic contaminants from ozone oxidation, thus giving us a hint from what they behaviour should be in a wastewater treatment plant. Two organophosphate contaminants were used: Chlorpyrifos (CPF) and Dychlorvos (DDCV). Experiments were assessed contaminating one liter of distilled water in a reactor for a concentration of 2mg.L of each contaminant. Ozone dosage was 33,4mg.L-1 and samples were taken following time protocol within a 30 minutes window. Extraction was done by liquid-liquid extraction and validated for quality assurance. At a final step, samples were analysed by gas chromatography coupled with a mass spectrometer. It is possible to observe differences between the contaminants degradation rates with and without the presence of micronized polyethylene.

Session 23. Applications in Industrial Processes – Part 1

23.1. Color stripping of the reactive dyed fabric by conventional and ozone assisted process-a comparative study

A. Powar, A. Perwuelz, N. Behary, L. Hoang, T. Aussenac (France, Romania, China)

The discoloration of the Reactive Black 5 azo dyed cotton textile was studied by ozone assisted process and the conventional reductive treatment. The ozonation process comprised of different parameters like pH, ozone concentration (g/m3) and the treatment time. The results obtained showed that the discoloration with ozone is better than the conventional concerning the lightness but with a yellowish color. The color stripping rate was almost the same in both the process around 98-99%. However, the strength losses were less in the conventional process.
Therefore, the ozonation process seems to be a good option for the discoloration process in the textile wet processing sector.

23.2. On the mechanism of wood pulp oxidation during ozone bleaching

D. Lachenal, F. Pouyet, J. Perrin, E. Montet (France)

Bleaching cellulosic pulp with ozone is an efficient process because it reacts very readily with unsaturated organic compounds. Applied to the phenolic moieties in residual lignin, this reaction causes lignin degradation and dissolution. The parallel degradation of cellulose during pulp ozonation is generally explained by the formation of hydroxyl radicals when ozone reacts with lignin. It was found during this work that the formation of hydroxyl radicals is much more general than anticipated since it occurs also when non aromatic carbon-carbon double bonds react with ozone. Acetovanillone, maleic acid, and 2,5-dimethyl 2,4-hexadienedioic acid were treated by ozone under the conditions of pulp ozone delignification and the hypothetical formation of hydroxyl radicals was followed by ESR spectroscopy, using 5, 5-dimethyl-pyrrolidine-

1-oxyl (DMPO) as the spin trapping substance. In all cases OH radicals were observed. Several blank experiments, including the addition of H_2O_2, one possible product of the Criegee general reaction, indicated that the OH radicals would result from the direct reaction of ozone with the compound. This finding suggests that OH radicals are formed not only when ozone reacts with lignin (represented here by acetovanillone), but also with hexenuronic acids (hexA) (represented here by maleic acid), and muconic acid derivatives which are the primary oxidation products of lignin (represented here by the hexadienedioic acid).
Therefore the key to improved selectivity of ozone delignification would be to minimize the reaction of ozone with carbon-carbon double bond structures. One way is to reduce the amount of HexA prior to ozone application (e.g. by hot acid treatment) when hardwood kraft pulps are processed. Another way is to limit the presence of muconic acids as much as possible. This can be achieved by splitting the ozone charge and applying an alkaline extraction after each ozonation phase.
Selective TCF bleaching sequences were designed based on these principles. One promising approach is the A(ZE)(ZE)(ZE) type sequence in which the Z stages are carried out with 1-2 kg O_3/o.d.t pulp in a mixer at 70°C for a very short time, immediately followed by an alkaline extraction at the same temperature. The A-(ZEO)-(ZEO)-(ZP) sequence (TCFz) was applied on a mixed hardwood kraft pulp and compared with the the conventional D-(EP)-D-D sequence (ECF), where EO and EP stands for alkaline extraction in the presence of oxygen and hydrogen peroxide, respectively. Strength properties were the same and the TCFz pulp exhibited better brightness stability, likely because of better purity, as shown by UVRR spectroscopy. TCFz sequences are promising processes to reduce the environmental impact of pulp bleaching.

23.3. Comparison of bleaching treatments of linen fabrics for clothing and furniture applications: conventional versus ozone

A. B. Rhouma, A. Perwuelz, N. Behary, X. Legrand, L. Hoang, T. Aussenac (France)

Linen is a local fiber mostly produced in France. It is well known by its important properties such as biodegradability, mechanical properties and the facility of cultivation. It doesn't need pesticides or any chemical additives. It is often used for clothing, furniture and as a reinforcement in composite materials. Many chemical treatments should be done to prepare the fabric for the dyeing process, such as scouring and bleaching which consume lots of water and chemical products. Many studies were carried to look for sustainable solutions to reduce environmental impact of conventional pre-treatments. Ozone is generated from oxygen or from dried air and experiments could be performed at ambient conditions without any chemical additives. Ozone is a powerful oxidizing agent which has proved its ability to bleach pulp fibers and to decolorize cotton fabrics dyed with a reactive color. This study explores the ability of ozone treatment to substitute conventional chemical bleaching of linen fibers.

23.4. Evaluation of excess sludge reduction using ozone ultra-fine bubble

K. Hashimoto, T. Marushima, S. Nakai, W. Nishijima, H. Motoshige (Japan)

A method combining solubilization of excess sludge using ozone and microbial decomposition process has been used as the most reliable technology for excess sludge reduction. To improve the efficiency of the ozonation step, ozone was supplied as ultrafine bubble (UFB). The killing of bacteria in excess sludge by ozone UFB was more effective than ozone microbubble and ozone milli-bubble. The shear force of the UFB generator was reduced the floc size in the sludge by an order of magnitude and improved the killing efficiency of bacteria by ozone. In addition, penetration into the floc of ozone UFB was twice higher than that of dissolved ozone. It was suggested that the killing of bacteria in the sludge is higher when ozone UFB treatment is used because of the synergistic effect of reducing floc size and improving penetration. In addition, in the full-scale excess sludge reduction process, the reduction ratio of excess sludge was achieved 92% when the excess sludge was treated with ozone UFB at 15 mg-O_3/g-MLSS, which was about 1/3 of the conventional method.

Session 24. Ozone in Medicine. Workshop: Ozone in Dentistry

24.1 Systemic ozone therapy and the local use of ozonized water and ozone ointment in dentistry and dental surgery

W. Schueler (Germany)

The local use of ozonized water-oxygen-spray in the oral cavity in order to create forced oxidation of toxins e.g. of dental origin, controlled by olfactorically organoleptically analysed distinctive features, is an important tool to detect and degradate toxic deposits in oral tissues..
The necessity of the combination of local ozone therapy in dentistry and the systemical ozone therapy in form of MAHT and/or RI arises e.g. from the prolonged detoxification process that follows up the local toxine degradation in oral tissues and the jaw bone marrow by forced oxidation.
This needs support of the liver and the kidney and the phase 2 of the detoxification process.
In this workshop the practical procedures of the local use of ozonized water and ozone ointment in all fields of dentistry will be shown by pictures.

24.2 Integration of ozone with photon-induced photo-acoustic streaming (PIPS) for enhanced outcomes in endodontic therapy

P. Mollica (USA)

Endodontic therapy is a treatment procedure to preserve the structural integrity by elimination of infected and necrotic soft tissue of a tooth. Based upon the complex biologic architecture of a tooth pathogenic forms routinely remain entrapped. The resultant is chronic infection and inflammatory conditions which has far reaching negative effects on a patient. Integration of PIPS with ozone addresses this structural and infective issue resulting in enhanced long-term improved outcomes.

Session 25. New challenges in wastewaters – Part 3

25.1. Performic Acid: An alternative chemical disinfectant for Reuse application, evaluation of its bactericidal efficacy, impacts on the natural environment and facilities: feedback after 18 months of use as tertiary treatment of urban waste water

P. Aubeuf-Prieur, M. Hesampour (France)

Tightening regulations on bathing water required alternative solutions for disinfecting treated wastewater to be evaluated. An alternative to traditional chorine based, or physical disinfection such as UV, Kemira proposed KemConnect DEX, an efficient oxidizing agent for disinfection of treated wastewater.
Results of 18 months trial at city of Beatriz indicated that all criteria set up by sanitation including E.coli and enterococcus has met when KemConnect DEX applied. It provided a lower cost (CPAEX and OPEX) option for disinfection of treated wastewater.

25.2. Impacts of water matrix on the efficiency of micropollutants elimination from urine by ozonation

J.S. Pic, H. Deng, C. Guigui (France)

Urine wastewater is characterized by a high concentration of inorganic ions, ammonia and organic chemicals. Even though urine only represents one percent of the total flow of municipal wastewater, it is still the main contributor to unwanted pharmaceutically active compounds (PhACs) in municipal wastewater treatment plants. At present, ozonation process has been acknowledged as an effective technology to abate urine-derived micropollutants (Dodd et al., 2008). However, very high doses of ozone are required to reach a satisfactory oxidation degree for model micropollutants contained in real effluents obtained from the hydrolysis of fresh urine (Dodd et al., 2008; Pronk et al., 2007). This is likely to be linked to the competitive reactions towards molecular ozone of the different constituents (inorganic ions, ammonia and organic matters) present in hydrolyzed urine. To address this point, a series of ozonation experiments was carried out in different water matrices. The results obtained are useful to understand the contribution to ozone consumption and the impacts of water matrix on the degradation rate of PhACs by ozonation. In addition, the influences of water matrix on ozone mass transfer and kinetic regimes were also discussed.

25.3. Catalytic ozonation for municipal wastewater disinfection and micropollutants removal

J. A. Malvestiti, A. Cruz-Alcalde, N. López-Vinent, R. F. Dantas, C. Sans (Brazil, Spain)

Several works in literature demonstrated that catalytic ozonation using metal ions promotes the decomposition of ozone and the formation of hydroxyl radicals (•OH) enhancing the disinfection and refractory micropollutants degradation. The main objective of this work was to evaluate the effects of 1 and 10 ppm Fe^{2+} in municipal wastewater disinfection through *E.coli* inactivation together with cellular adenosine triphosphate (ATP) depletion. Simultaneously, the effect of catalytic ozonation of secondary effluent on the removal of acetamiprid and atrazine was evaluated in semi-continuous operation. Results demonstrated that *E.coli* inactivation increased almost 20% and 40% with 1ppm Fe^{2+} and 10 ppm Fe^{2+} respectively, compared with single ozonation. The bacteria reactivation after the treatments showed that with 10 ppm of Fe^{2+} there was no regrowth. The cellular ATP followed the same trend as the indicator microorganism inactivation, with significant reduction of ATP over the treatment compared to single ozonation. Thus, Fe^{2+} addition to ozonation process provided an increase in simultaneous disinfection and pesticides removal as well as in the inhibition of bacterial reactivation, which resulted in savings between 30 to 50% of ozone dose needs compared with the same attainment in single ozonation.

Session 26. Applications in Industrial Processes – Part 2

26.1. Development and industrial cases of oxidation and ozonation in flow chemistry

J. Vinet, G. Gotti, M. Pages-Homs, F. Violleau, J.C. Monbaliu, G. Gauron (France, Belgium)

Corning® Advanced-Flow™ Reactors have been successfully applied in a variety of flow-chemistry processes including examples of continuous-flow applications where hazardous reactions or extreme process conditions have been used. The presentation will be an opportunity to discuss areas that stretch into the future and will be critical to secure the upcoming of safe chemical industry productions.
This talk will highlight how flow chemistry could bring significant advantage to oxidation processes through three key research application of flow oxidation. Examples of industrial installations will conclude the communication to demonstrate that the industrial continuous production is a reality.

26.2. Comparison of UV/Fenton, UV/H_2O_2, UV/Oxone and Ozone in degrading the naphthenic acids in oil sands process water

H. Demir-Duz, S. Ashagre Messele, M.G. Álvarez, S. Contreras, M. Gamal El-Din (Canada, Spain)

The management of oil sands process water (OSPW) is one of the major problems for Northern Alberta. Because of the zero-discharge policy of Canada, it is stored in tailing ponds, which cover more than 130 km2 of the landscape. This study compares different advanced oxidation processes to find the most effective application for the reclamation of OSPW without any impact to the receiving environment. For this aim, catalytic ozone-based and UV-based treatments with different oxidants have been compared by using granular activated carbon based, heteroatom doped materials as catalysts. Fe (III) impregnation on the catalyst was done to have magnetic particles on the surface and to evaluate their efficiency in Fenton-like processes as part of the UV-based treatments. Preliminary results assessed by synchronous fluorescence spectroscopy (SFS) analysis revealed that it is possible to completely degrade aromatic rings either by ozone-based treatments with low amount of ozone dose or by UV-based treatments. However, according to total organic carbon analysis, only UV-Fenton achieved high rates of mineralization, which was up to 63%.

26.3. Ozone and H_2O_2 in wastewater treatment of a bio-refinery

C. Carboni (Italy)

This work presents the results of the preliminary study on the use of ozone + H_2O_2 for COD reduction in bio-refinery wastewater treatment. The tests and the real application have shown that only ozone treatment is ineffective, while the combination of H2O2 and ozone has created a very effective process.
During the preliminary tests the bio-refinery wastewater was treated with ozone + H_2O_2 in order to achieve the correct sizing of the final plant.
The bio-refinery has a complex plant structure divide into four sections: pre-treatment of materials, transesterification of oils, glycerol distillation and industrial water treatment, anaerobic digestion to produce biogas and final wastewater treatment with ozone + H2O2. The raw material is made up of waste products such as exhausted cooking oil, fatty acid and animal fat. The bio-refinery produces and sells biodiesel, refined glycerol, pitch and electricity. The cod in wastewater ranges from 500 up to 1200 ppm after biological treatment. The bio-refinery wanted to achieve COD levels lower than 500 ppm.

Session 27. Workshop – IOA Highlights on innovation

Market orientation and innovation dynamics
Key issues
Promising advances and developments

Closing session

Awards Ceremony

Including

Research works presentation by the recipient of the Harvey Rosen Award

Research works presentation by the recipient of the Willy Masschelein Prize

Synthesis and Conclusions

Announcements

FURTHER CONTACT

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ANTICIPATE THE NEXT IOA WORLD CONGRESS TO BE HELD IN 2021

Dates: August 30 - September 3, 2021

Location: Windsor, Ontario, Canada

Venue: Caesars Windsor Hotel and Casino

NOTES


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