The International Ozone Association

is pleased to present the

22nd World Congress & Exhibition

28 June — 3 July 2015, Barcelona, Spain

Ozone and Advanced Oxidation
Leading-edge science and technologies

PROGRAMME
BOOK OF ABSTRACTS

Water Treatment
Science and Technology
Research Development Events Members
Knowledge Advances
Standards Awards
Fundamentals
Field application Industry News
Food Processing Engineering
Ozone Therapy Worldwide
Agriculture Publications

IOA 3
2015 WORLD CONGRESS & EXHIBITION

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Ozone and Advanced Oxidation
Leading-edge science and technologies

WELCOME ADDRESS

Achim RIED,
IOA President

Santiago ESPLUGAS,
IOA-EA$_3$G 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 Barcelona, one of Europe's most fascinating cities.

Barcelona is a Mediterranean and cosmopolitan city, recognized for innovation and creativity. The capital city of Catalonia is one of the top 10 visited cities in the world and has become the headquarters of many important congresses and exhibitions around the globe.

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 Barcelona city.

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-EA_3G

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 Barcelona Congress.

FOR FURTHER CONTACT

INTERNATIONAL OZONE ASSOCIATION

IOA-EA_3G Secretariat

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COMMITTEES

Chair

- Achim RIED, Germany | IOA President

Organizing Committee

- Santiago ESPLUGAS, Spain | 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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- Sylvie BAIG | Dr., Suez environnement, Treatment solutions, FR
- Miray BEKBÖLET | Professor, Ege University, TR
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- Márcia DEZOTTI | Professor, Federal University of Rio de Janeiro, BZ
- Nathalie KARPEL VEL LEITNER | CNRS Research Professor, Poitiers University, FR
- Cheddly TIZAOUI | Dr., Swansea University, UK

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- Ziad FAHMY | Dr., Chief of the Augusta Clinic in Rheumatology Bad Kreuznach, DE
- Olga LEÓN | Prof., Havana University, CU
- Nabil MAWSOUF | Prof., Cairo University, EG
- Renate VIEBAHN-HAENSLER | Dr., Med. Ozone Society, DE
- Mark WEISER | Dr., Dental Clinic Santa Barbara, US

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:

- **AirSep Corporation** | Coffee break sponsoring, Exhibition
- **Arvia Technology Ltd.** | Exhibition
- **BMT Messtechnik** | Exhibition
- **Dr. J. Hänsler GmbH OZONOSAN** | Exhibition
- **LIMICEN OZONE R&D Center** | Exhibition
- **MAZZEI Injector / Copersa** | Exhibition
- **Pacific Consolidated Industries** | Exhibition
- **STATIFLO International Ltd** | Exhibition
- **SUEZ environnement** | Platinum and Special Prize sponsoring, Exhibition
- **XYLEM Services GmbH** | Platinum sponsoring, Exhibition

- **Aigües de Barcelona** | Technical tour
- **L'Aquarium de Barcelona** | Technical tour
- **Grupo Pacifico** | Event organizer
- **Universitat de Barcelona** | Organization support

Platinum Sponsors

GENERAL INFORMATION

Language

English will be the official language.

Congress Venue

World Trade Centre Barcelona
Moll de Barcelona, 08039 Barcelona. Spain
www.wtcbarcelona.com/en/

WTCB has a truly privileged location right on the Barcelona sea front. Among its surroundings are Port Vell, Las Ramblas, the Barrio Gótico, the Borne district, the sea-front promenade and the beaches of Barceloneta.

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*

Cover scientific sessions, electronic proceedings, abstracts book, exhibits, welcome reception, lunches, refreshments, internet access.

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 is open upon request to the secretariat.

Additional registration is required for

• Technical tour T1 ** Sant Joan Despí Drinking Water Plant	Thursday 2 July. Includes bus transfer and lunch. Minimum number of 30 registrations is required per visit.
• Technical tour T2 ** L'Aquàrium de Barcelona	Friday 3 July. Includes lunch and entrance fees for the public visit of the aquarium. Minimum number of 30 registrations is required per visit.
• Congress dinner	Wednesday 1st July. Number of registrations is limited to 280.
• Accompanying person registration	Cover welcome reception and lunches from 29 June to 1st July
• Cultural tour C1 *** Montjuïc and waterfront	Monday 29 June afternoon. Minimum of 30 registrations is required per visit. Cover bus transfer, guide and entrance fees.
• Cultural tour C2 *** Barcelona city tour	Tuesday 30 June. Minimum of 25 registrations is required per visit. Cover bus transfer, guide, entrance fees and lunch.
• Cultural tour C3 *** Figueres and Dali museum	Wednesday 1st July. Minimum of 25 registrations is required per visit. Cover 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.
• Additional lunch ticket	Reservation opened to exhibit's visitor only

* 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 poster must register and attend the congress.

Cancellation policy

Notification of cancellation must be received by the Congress Secretariat in writing. Full refunds will be provided if notified by May 11, 2015. A 50% refund will be provided if notified by June 5. No refund will be provided after June 5.

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, June 28 17:00 – 18:30
- Monday, June 29 07:00 – 17:00
- Tuesday, June 30 08:30 – 17:00
- Wednesday, July 1 08:30 – 16:15

Badges

The wearing of badges is compulsory inside the Congress Centre. They are necessary to access all scientific sessions, exhibits, lunches, 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 Port Vell room. Punctuality is essential.

Meeting point

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

Wifi

A Wifi connexion will be available for each delegate.

Barcelona

Barcelona is one of Europe's most fascinating cities.

The following is a list of musts in Barcelona. They are all well worth a visit and just a few minutes away from the Congress venue.

- As a leading example of Mediterranean cuisine, Barcelona boasts a striking variety of culinary delights. These range from a broad selection of rice-based dishes on the sea front to Ferran Adrià's ground-breaking, avant-garde cuisine.
- Architectural jewels such as the Gaudi's Sagrada Familia and La Pedrera, a museum devoted entirely to Picasso, modernist promenades, theatres and concert venues, and contemporary-art exhibitions all make Barcelona one of the most sought-after cultural destinations in the world.
- The city is also famous for its shopping areas and streets, which showcase a variety of styles and fashions. The Paseo de Gracia is home to famous luxury brands, but if you're looking for a more off-beat, personal approach to fashion the Borne quarter is the place for you.
- Those who dare venture into the Barcelona night can expect a vibrant nightlife featuring discotheques of all kinds, live-music venues, and unforgettable cocktail bars, all filled with cosmopolitan people out to have a good time.

Enjoy your stay

GENERAL PROGRAMME

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

- Attendance by 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 170 scientific presentations arranged in 30 sessions in 3 parallel tracks. All topics of current or future interest are covered.
- A large industry leading Exhibition, only few stands still available
- 2-day exclusive plant tours to the ozone installations - San Joan Despí Drinking Water Plant and L'Aquàrium de Barcelona
- And social and cultural events for the enjoyment of the delegates and their guests: welcome reception, celebratory Congress Dinner, Awards Ceremony, 3 tours to discover the prestigious places Montjuic Montjuïc and waterfront, Barcelona City, Figueres and its Dali Museum,
- All in the Spain's world-famous environment and hospitality.

Schedule of the congress program

28 June 28	Hour	29 June 29					30 June 30					1st July					2 July	3 July
	7:00	Registration																
	8:30-9:30	Opening					S10	S11	S12	E	C2	S22	S23	S24	E	C3	T1	T2
	9:30 -10:10	Exhibition discovery																
	10:30-11:00	S1	S2	S3	E		Break					Break						
	10:30 13:00						S13	S14	S15			S25	S26	S27				
	13:00-14:30	Lunch					Lunch					Lunch						
14:00 Stand assembling	14:30 16:00	S4	S5	S6	E	C1	S16	S17	S18	E		S28	S29	S30	E			
	16:30-17:00	Break					Break					16h15: Awards & Closing						
17:00 Registration Poster panels	17:00 18:30	S7	S8	S9			S19	S20	S21									
19:00 Welcome Reception												20:00 Congress Dinner						

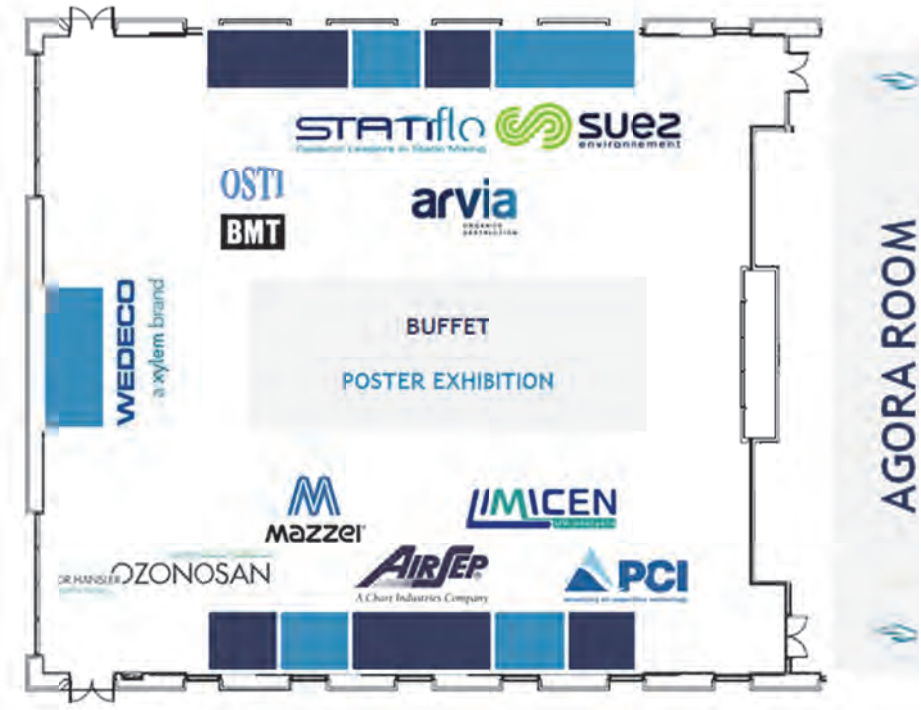
With S: Scientific Session; E: Exhibition; C: Cultural tour; T: Technical tour

S1	Fundamentals – Part 1	S11	Application in Drinking Water	S21	Micropollutants Control: Part 1. At full scale
S2	Ozone for Agrifood	S12	Ozone in Medicine – Part 4	S22	Design and Engineering Aspects – Part 1
S3	Ozone in Medicine – Part 1	S13	Advanced Oxidation: UV and ozone systems	S23	Industrical Waters
S4	Fundamentals – Part 2	S14	Advanced Oxidation: Ozone systems	S24	Micropollutants Control – Part 2
S5	Ozone and Advanced Oxidation for Agrifood	S15	Ozone in Medicine – Part 5	S25	Workshop – Access to ozone mass transfer parameters
S6	Ozone in Medicine – Part 2	S16	Advanced Oxidation: Catalytic ozonation	S26	Workshop – Young Ozone People
S7	Fundamentals – Part 3	S17	Water Reuse Purpose	S27	Workshop – IOA highlights
S8	Applicability in Waters	S18	Water Disinfection Target	S28	Design and Engineering Aspects – Part 2
S9	Ozone in Medicine – Part 3	S19	Advanced Oxidation: Photo-Fenton systems	S29	Applications in Industrial Processes
S10	Advanced Oxidation: Photocatalytic systems	S20	In Relation to Activated Sludge	S30	Micropollutants control – Part 3

EXHIBITION

Monday June 29 to Wednesday July 1

Leading companies 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.



Arvia Technology - www.arviatechnology.com

The Arvia ODC (Organics Destruction Cell) is a scalable water treatment process to remove and destroy organics in situ. Waste is treated in two simple simultaneous steps of adsorption and destruction.

Arvia treated water flows back into the system until pollutants have been removed to the required level. Clean water flows from the bottom of the cell so it can either be reused or discharged.

The Arvia ODC is the first process capable of destroying recalcitrant, stable organics and also trace level pollutants such as Metaldehyde to safe regulatory levels (sub 0.1 ppb) onsite without the use of chemicals.

The Arvia process is highly effective in treating problem pollutants including priority substances, emerging contaminants, stable and trace organics found in a range of industrial effluents.

Improve Your Process Efficiency

- Energy used is proportional to the waste stream organic load and not the flow rate
- Construction is modular and thereby scalable to your requirements
- The ODC has no moving internal parts, meaning minimum maintenance work is needed

BMT MESSTECHNIK GMBH, Berlin - www.bmt-berlin.de - http://osti-inc.com

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

Chart Industries – AIRSEP - www.chartindustries.com/Businesses/AirSep

AirSep Corporation – A Chart Industries Company, offers innovative, non-cryogenic oxygen supply solutions as an alternative to cylinder or liquid supplies. By providing an unlimited supply of oxygen on-location, an AirSep Oxygen Generator eliminates regular oxygen deliveries.

AirSep offers a large 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.

Dr. Hänsler OZONOSAN - www.ozonosan.de

The leading company in ozone technology for the use of ozone in Medicine and Hygiene

Nowadays the Low-Dose-Concept of medical ozone is considered to be a part of biological medicine, i.e. complementary to conventional medicine. Over the last decades its mode of action and pharmacology are well documented and published on an international basis; now forms of applications, dosages and treatment strategies are standardized, summarized and published as the Guidelines for the use of ozone in medicine. 30 years ago, the situation was different, and the introduction of ozone met with criticism and even resistance from the representatives of conventional medicine.

For more than 55 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 alpha plus, OZONOSAN photonik and OZONOSAN boardcase 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. Our factory has received official recognition, fulfils all the requirements according the European Directives for Medical Devices MDD (93/42EWG), for which reason all our products are marked CE 0535.

The OZONOSAN therapy system is optimally complemented by our training manual and reference books, which became standards in ozone therapy and finally part of the guidelines, see www.ozonosan.de.

International congress activities, seminars and workshops to spread the scientific background of medical ozone and its safe use in therapy are among the principal features of the company's activity; high demands are made on a team of 20 + 10 specialists, every employee fully motivated and able to contribute his/her experience and enthusiasm.

Rely on our technological and scientific know how and our competent team in all questions as far as ozone therapy is concerned.

LIMICEN Ozone R&D Center - www.limicen.net

LIMICEN OZONE R&D CENTER designs and manufactures a series of UV analyzers for ozone concentration measurement, from high volume (mg/L) to very low volume (ppm), including ozone in water measurement, in the design and technique: double UV light bean is assembled in a small boxes, just as simple as installing amodule, and with auto zeroing within bean cell without any zero gas, the product is widely applied to ozone generator outlet concentration measurement, ozone leakage monitor, and ozone measurement ozone dissolving in water

Mazzei Injector Company, LLC - www.mazzei.net

Ozone Contacting Systems - Ideal for Retrofit, Expansion and New Construction

- *Energy Efficient – Compact – Low Maintenance*
- *Injector-Basin Nozzle Manifolds*
- *Injector-Pipeline Flash Reactors*

PCI - http://pci-intl.com

PCI Gases is a global leader in on-site oxygen generation systems using a propriety Vacuum Swing Adsorption (VSA) PROCESS. This technology offers many advantages over conventional technology, leading to the lowest operating cost in its area.

Statiflo - www.statiflo.com

Statiflo is the world's leading company for the development and application of static mixing technology for the water industry. Products include pipeline mixers, channel mixers and gas dispersion systems which have been proven to be the premium system for dissolving large volumes of Ozone into water. Applications include: disinfection, pesticide removal, colour, taste & odour removal and iron oxidation. Numerous site tests have shown Ozone transfer efficiency to be typically 98% and with the minimal power requirements of the system, this technology offers a very rapid return on investment.

With increasing demands on water resources, reuse of municipal effluents has drawn considerable attention and tertiary treatment by ozone is widely accepted as an effective treatment. Statiflo has been fully involved in this development by adapting the successful Statiflo GDS gas dispersion system to transfer large dose rates of ozone at various treatment stages to wastewater plants. The effectiveness of the side stream system combined with the all important contactor mixer in the main stream has resulted in high ozone transfer efficiencies. The side stream flow rates are considerably less than venturi systems and with the low headloss static mixers the overall energy requirements are less resulting in energy savings and greater overall mass transfer efficiencies.

SUEZ environnement - www.ozonia.com – www.suezenvironnement.com

We are at the dawn of the resource revolution. In a world facing high demographic growth, runaway urbanization and the shortage of natural resources, securing, optimizing and renewing resources is essential to our future. SUEZ ENVIRONNEMENT (Paris: SEV, Brussels: SEVB) supplies drinking water to 92 million people, delivers wastewater treatment services to 65 million, collects waste produced by almost 50 million, recovers 14 million tons of waste each year and produces 5,138 GWh of local and renewable energy. With 80,990 employees, SUEZ ENVIRONNEMENT, which is present on all five continents, is a key player in the sustainable management of resources. SUEZ ENVIRONNEMENT generated total revenues of €14.3 billion in 2014.

SUEZ environnement with its purification and disinfection systems entity is a worldwide manufacturer and distributor of Ozone systems, UV systems and Membranes systems. It is the leader for drinking and wastewater treatment for municipalities and for industrial solutions such as ballast water treatment, COD removal, air disinfection for industries such as Oil and Gas, pharmaceutical, food and beverage, aquaculture, and many other industries.

DEGREMONT, OZONIA and all companies of the Group operate under the brand SUEZ environnement.

Wedeco, a Xylem brand - www.xyleminc.com

Wedeco was founded in 1975 in Herford, Germany to develop chemical-free and environmentally friendly water treatment technologies, including ultraviolet light and ozone systems. There are more than 250,000 installed Wedeco systems for UV disinfection and ozone oxidation globally in private, public utility and industrial locations. Wedeco introduced ozone technology in 1988 and has been expanding internationally ever since. UV disinfection systems have a number of applications including water treatment and aquaculture. Ozone disinfection systems have applications in drinking water, wastewater, process water, product polishing, bleaching, ozonolysis / synthesis and deodorization.

Xylem (XYL) is a leading global water technology provider, enabling customers to transport, treat, test and efficiently use water in public utility, residential and commercial building services, industrial and agricultural settings. The company does business in more than 150 countries through a number of market-leading product brands, and its people bring broad applications expertise with a strong focus on finding local solutions to the world's most challenging water and wastewater problems. Xylem is headquartered in Rye Brook, N.Y., with 2013 revenues of $3.8 billion and more than 12,500 employees worldwide. Xylem was named to the Dow Jones Sustainability World Index for the last two years for advancing sustainable business practices and solutions worldwide.

The name Xylem is derived from classical Greek and is the tissue that transports water in plants, highlighting the engineering efficiency of our water-centric business by linking it with the best water transportation of all — that which occurs in nature.

SOCIAL AND CULTURAL EVENTS

Welcome reception

On Sunday 28 June from 19:00

Room **Port Vell** of World Trade Centre Barcelona

The menu, tapas in the pure Catalan tradition.

Congress dinner

Wednesday 1 July from 20:00.

Restaurante la Bodeguita del Poble
Plaza Aragonesa - Poble Espanyol
Phone:(+34)934 246 110 - 620 092 756
www.labodeguitadelpoble.com

The restaurant la Bodeguita del Poble is situated in El Poble Espanyol, a unique picturesque location in Barcelona. Since more than a decade it has been offering guests a very pleasant environment where they can enjoy an exquisite "cuisine" within an amusing and original ambience.

After dinner and show comes the fun. Guests are invited in the discotheque where your evening will be livened up with music and dance until sunrise without the need to change the location.

The entry to the Poble Espanol is included.

SPECIAL EVENTS - Awards ceremony

Wednesday 1 July from 16:15

Numerous awards will be presented during the closing session, for recognition of:

- Special contributions to the IOA Association,
- The quality of presentations made by Doctorate Students,
- The best poster presentation.

CULTURAL TOURS

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

Cultural Tour C1 - MONTJUÏC AND WATERFRONT

For a panoramic discovery of Barcelona

Monday 29 June Afternoon - Half day tour

Departure to Plaza de España to see all the buildings built due to the World's Fair in 1929. Fist stop at Olympic Stadium and second stop at Mirador del Alcalde to see the panoramic view over Barcelona. The tour continues along the water front to see the Barceloneta beach and the Olympic Village. Drive along the waterfront to see the new architecture in Barcelona, the district 22@ where you will see the most modern design buildings at Diagonal Mar / Forum area. Drive along the 13.5 km of Diagonal Avenue up to go back.

Duration: 3 hours.

Cultural Tour C2 - BARCELONA CITY TOUR

Enjoy Barcelona to its fullest

Tuesday 30 June - Full day tour

Departure from the WTC for Barcelona full day sightseeing. During this tour we will see the most important sites of the city like the Historical Gothic Quarter, Las Ramblas with the Boquería Market, The Spanish Village built because of the World?s Fair in 1929 and the Olympic Ring. We cannot miss the amazing Gaudí constructions so we also will see the façades of the modernist buildings located at Passeig de Gràcia like Casa Batlló or Casa Milà and the Gaudí master piece still under construction: La Sagrada Familia. We also will see the exterior of this magnificent construction started in 1882. Back at WTC.

Duration: approx. seven and half hours. Lunch included.

Cultural Tour C3 - FIGUERES AND DALI MUSEUM

Iconic visit if any

Wednesday 1 July - Full day tour

The old theatre of Figueres, the town where Salvador Dalí was born, is now the "Theatre Museum Dalí". After the museum "El Prado" in Madrid, it is the most visited museum in Spain. It contains paintings, sculptures, drawings and sketches by the artist. It is original and spectacular in keeping with the wonderful personality of the famous surrealist painter. Lunch in Roses, beautiful village situated in a bay with 3000 years of history. Afternoon free to see the bay and shopping before return to Barcelona.

Duration: approx. eight hours. Lunch included.

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. All tours depart from and return to the Congress center WTCB. Special registration is required. The fee includes bus transfer and lunch. Valid ID card or passport is required.

Technical Tour T1 - Sant Joan Despí Drinking Water Treatment Plant
by Aigües de Barcelona and Cetaqua

Thursday 2 July - Full day tour

Built and inaugurated in 1955, since it was set up the Sant Joan Despí Drinking Water Treatment Plant applied the most advanced water treatment technologies. The improvements to its processes include ozone treatment and recently reverse osmosis.

The drinking water treatment plant at Sant Joan Despí treats water from the Llobregat River. At that point, the river has received effluents from industrial and urban WWTPs, influence of agricultural and mining activities. The high anthropogenic influence of the water makes it necessary to add an ozone treatment in order to remove several organic and inorganic compounds which cannot be efficiently removed with the more common treatments as flocculation or activated carbon.

The last of the important works executed at Sant Joan Despí has been the start-up of a treatment process using ultrafiltration membranes and reverse osmosis on a fraction of the water. This technology makes possible to guarantee the achieving of the health standards set for trihalomethanes (disinfection by-products) since they eliminate practically all organic and inorganic precursors that are involved in the generation of these compounds.

After more than half a century of operation, the Sant Joan Despí plant is still one of the main supply sources of Barcelona metropolitan area providing almost 50% of the annual drin-king water using a sophisticated treatment line that enables flows of up to 5.3 m3/s to be processed, using technology that has converted it into one of the most complete drinking water plants in Europe.

The visit will cover water treatment works and research and demonstration facilities on AOPs. It is planned to carry out an explanation of the models; the Metropolitan Area and the treatment of the DWTP.

Agbar
Museu
de les Aigües

It will continue at the Agbar Foundation's headquarters in Can Serra building at the Cornellà Station, which was built in the late 19th and early 20th century to pump drinking water from the River Llobregat aquifer to the expanding city of Barcelona.

After lunch at the private restaurant there, the Museu Agbar de les Aigües will offer visitors to share a benchmark industrial heritage in Europe, from which to project and share values associated with water culture, as well as respect for the environment and sustainability.

The Museu Agbar de les Aigües is a contemporary museum devoted to water, intended to promote knowledge and values through a living, learning and leisure experience. The Permanent Exhibition is located inside a large modernist building, designed by the architect Josep Amargós i Samaranch in Cornellà de Llobregat.

Technical Tour T2 - L'Aquàrium de Barcelona

Friday 3 July - Full day tour

L'Aquàrium de Barcelona is the largest Mediterranean-themed aquarium in the world. Behind the aquariums at L'Aquàrium de Barcelona, a large team of highly-qualified professionals using the latest technology look after the wellbeing and health of over 11,000 sea creatures. In order to fill the 21 aquariums, about 6 million litres of seawater are needed.

Behind the aquariums, there is another side to L'Aquàrium de Barcelona. A large team of highly-qualified professionals using the latest technology look after the wellbeing and health of over 11,000 sea creatures.

Temperature, salinity, water quality, lighting and the recreation of each ecosystem are painstakingly analysed to ensure that all aquarium inhabitants, some of which are especially difficult to keep in captivity, can be accommodated.

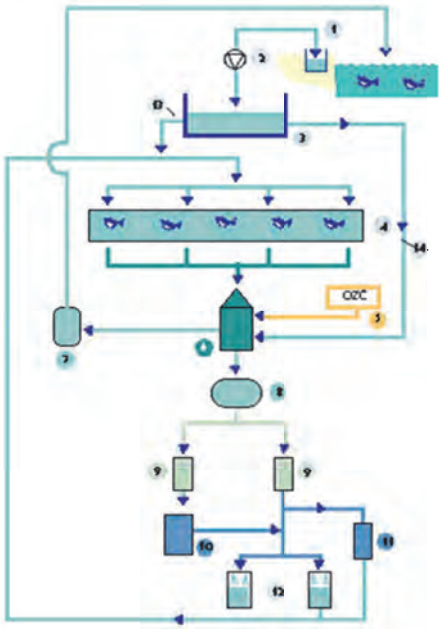
L'Aquàrium's biologists have the great responsibility of looking after marine animals from over 450 different species, ranging from tiny invertebrates to penguins and sharks measuring more than 3 metres. It is not an easy task since each of the species that inhabits L'Aquàrium requires special attention, and in some cases, has to be treated with extreme delicacy.

Since L'Aquàrium de Barcelona opened, research has been a major priority and, through this work, it has gained international recognition as a research centre. Particularly notable are the agreements L'Aquàrium has signed with various universities and research centres.

L'Aquàrium also has sophisticated purification system that operates in a semi-closed cycle. The water is treated and recycled through the facilities with a turnover time of about 1½ hours. Only a small amount of water from outside is supplied on a daily basis to compensate for evaporation and trace element loss.

Purification is necessary for many reasons. As leftover food and natural waste excreted by the organisms (containing high levels of ammonia) degrades biologically, secondary nitrite and nitrate compounds are formed, which are highly detrimental to the health of marine life.

Treatment particularly involves an ozone production system and ultraviolet light to remove undesirable bacteria, oxygenate the water and facilitate the flocculation of proteins prior to removal by filtration. These systems, which are used in most aquariums around the world, The final disinfection of the water is also required to prevent biological hazards when the water leaves L'Aquàrium.



This flowchart shows the main elements of L'Aquàrium's purification system.

1. Wells
2. Pump
3. Storage tank
4. Aquariums
5. Ozone
6. Skimmer
7. Steriliser
8. Sand filter
9. Ultraviolet light
10. pH tower
11. Exchanger
12. Biofilter

Following the technical tour, the delegates will have the opportunity to discover the 14 aquariums that represent the Mediterranean's different marine communities.

Suez environnement, as the world's largest producer of purification and disinfection systems for ozone, UV and membranes systems is sponsoring the 22nd IOA world congress & exhibition organised by the International Ozone Association.

World Trade Center, Barcelona, Spain
28 June – 3 July

Visit us at the Exhibition Area on booth #4 and follow us on Twitter @ozonia_Solutions so you do not miss a bit!

Our group of experts will participate in the following scientific sessions:

monday, 29 June

4.2 Impact of ozone application to primary urban wastewaters: micropollutant and organic matter change
Session 4 - Fundamentals – Part 2
14:50 – 15:10

tuesday, 30 June

16.2 Urban wastewater treatment by catalytic ozonation
Session 16. Advanced Oxidation: Catalytic ozonation
14:50 – 15:10

21.1 First full-scale application of ozonation for wastewater treatment in Switzerland: elimination of micropollutants and formation of oxidation products
Session 16. Advanced Oxidation: Catalytic ozonation
17:00 – 17:40

21.2 Optimisation of full-scale ozonation tertiary treatment for micropollutants removal
Session 16. Advanced Oxidation: Catalytic ozonation
17:40 – 18:00

wednesday, 1 July

23.5 Ozonation and UV radiation as alternatives to chemical biocides for cooling water
Session 23. Industrial waters
09:50 – 10:10

24.1 The contribution of analytical and chemometric tools for the performance assessment of several wastewater treatment technologies
Session 24. Micropollutants control – Part 2
08:30 – 08:50

24.4 Pharmaceuticals removal in wastewater by biological treatment and tertiary ozonation
Session 24. Micropollutants control – Part 2
09:30 – 09:50

Ozone as active substance under the Biocidal Products Regulation
Workshop – IOA highlights
11:00 – 13:00

30.5 Ecotoxicological evaluation of wastewater treated by conventional biological and ozonation processes
Session 30. Micropollutants control – Part 3
15:50-16:10

come and discover the future of Ozone applications!

ozone, UV, and membrane systems

suez environnement

SCIENTIFIC AND TECHNICAL PROGRAMME

The Scientific Programme includes:

Close to 170 presentations

- Long oral presentations (LP)
- Short oral presentation for poster introduction (SP) and Poster exhibition

Organized in 30 sessions arranged in three parallel tracks.

S1	Fundamentals – Part 1	**S11**	Application in Drinking Water	**S21**	Micropollutants Control: Part 1. At full scale
S2	Ozone for Agrifood	**S12**	Ozone in Medicine – Part 4	**S22**	Design and Engineering Aspects – Part 1
S3	Ozone in Medicine – Part 1	**S13**	Advanced Oxidation: UV and ozone systems	**S23**	Industrical Waters
S4	Fundamentals – Part 2	**S14**	Advanced Oxidation: Ozone systems	**S24**	Micropollutants Control – Part 2
S5	Ozone and Advanced Oxidation for Agrifood	**S15**	Ozone in Medicine – Part 5	**S25**	Workshop – Access to ozone mass transfer parameters
S6	Ozone in Medicine – Part 2	**S16**	Advanced Oxidation: Catalytic ozonation	**S26**	Workshop – Young Ozone People
S7	Fundamentals – Part 3	**S17**	Water Reuse Purpose	**S27**	Workshop – IOA highlights
S8	Applicability in Waters	**S18**	Water Disinfection Target	**S28**	Design and Engineering Aspects – Part 2
S9	Ozone in Medicine – Part 3	**S19**	Advanced Oxidation: Photo-Fenton systems	**S29**	Applications in Industrial Processes
S10	Advanced Oxidation: Photocatalytic systems	**S20**	In Relation to Activated Sludge	**S30**	Micropollutants control – Part 3

Monday, 29 June

Plenary session. Opening

Hour	
08:30	**Opening Addresses**, *Achim Ried, IOA President and Santiago ESPLUGAS, IOA-EA$_3$G President*
	Congress introduction, *Michel ROUSTAN, Renate VIEBAHN, Scientific Committee*
	IOA General Assembly
09:30	**Exhibition discovery**

Session 1. Fundamentals – Part 1

Hour	Presentation		ID
10:10	LP	**1.1 Determination of ozone Henry's constant using different analytical methodologies** *J. Ferre-Aracil, S. C. Cardona, J. Navarro-Laboulais (Spain)*	137
10:30	LP	**1.2 Comparative study of competitive kinetics and stopped flow method on the determination of rate constants of steroids degradation using ozone** *R. Vallejo-Rodríguez, V. Flores-Payán, E. León-Becerril, A. López-López (Mexico)*	128
10:50	LP	**1.3 Evaluation of N-oxide venlafaxine transformation product kinetics during ozonation** *I. Zucker, A. Riani, D. Avisar, H. Mamane (Israel)*	103
11:10	LP	**1.4 Sulfaquinoxaline degradation and toxicity reduction by photocatalysis** *V. Ribeiro Urbano, M. Guedes Maniero, J. Roberto Guimarães (Brazil)*	155
11:30	LP	**1.5 Degradation kinetic evaluation of Bisphenol A with ozone using the Stopped-Flow instrumental technique** *V. Flores-Payán, R. Vallejo-Rodríguez, M. Murillo-Tovar, E. León-Becerril, A. López-López (Mexico)*	129
11:50	LP	**1.6 A comparative study: degradation of 2,5-dichlorophenol in a wastewater and distilled water by ozone and ozone-UV** *J. C. Alexander, C. R. Ramírez-Cortina (Mexico)*	158
12:10	LP	**1.7 Comparison of Ozone and Ferrate for Oxidation of Disinfection Byproduct Precursors** *D. A. Reckhow, Y. Jiang, X. Ma, J. Bliss, J. Gao, J. Goodwill, J. E. Tobiason (USA)*	102
12:30	LP	**1.8 Effect of ozonation on THM formation in swimming pool water — laboratory study** *K. M. S. Hansen, A. Spiliotopoulou, W. Akram Cheema, H. R. Andersen (Denmark)*	144
13:00	**Lunch**		

Session 2. Ozone in Agrifood

Hour	Presentation		ID
10:10	LP	**2.1 Modification of the molecular properties of wheat grain storage proteins by ozonation** *P. Gozé, L. Rhazi, A. Pauss, T. Aussenac (France)*	192
10:30	LP	**2.2 Ozone as degradation agent of bifenthrin residues in stored rice grains** *M. Ávila, L. Rita Faroni, F. Heleno, M. Eliana Queiroz, L. Philip Costa, R. Iglesias, L. Prates (Brazil)*	179
10:50	LP	**2.3 Stability and antibacterial activity of ozonized sunflower oils.** *S. Moureu, F. Violleau, D. Ali Haimoud-Lekhal, A. Calmon (France)*	151
11:10	LP	**2.4 Ozone effects on fungal material** *M. Pagès, D. Kleiber, F. Violleau (France)*	150
11:30	LP	**2.5 Effects of spraying ozonated and electrolyzed water on survival of cultivable fungi, bacteria and yeasts of grape** *A. Raio, A. Feliciani, V. Ferri, C. Carboni (Italy)*	190
11:50	LP	**2.6 Passive refrigeration and ozone-enriched atmosphere to extend the shelf life of baby leaf lettuce, arugula and red chicory** *T. Yaseen, E. Damara, M. Gallo, F. Santoro, C. Carboni, A. Maria D'Onghia (Italy)*	247
12:10	SP	**2.7 Effect of ozone treatments on wine grape microbiota, skin mechanical properties and phenolic compounds extractability** *V. Englezos, F. Torchio, S. Giacosa, F. Cravero, S. Río Segade, J. Laureano, K. Rantsiou, C. Carboni, L. Rolle, V. Gerbi, L. Cocolin (Italy, Brazil)*	094
12:20		**Discussion**	
13:00	**Lunch**		

Session 3. Ozone in Medicine – Part 1

Hour	Presentation		ID
10:10	LP	**3.1 Ozone Therapy - State of the Art.: Evidenced Based Medicine. Metaanalysis.** *R. Viebahn-Hänsler (Germany)*	214
10:30	LP	**3.2 Mechanisms of action of ozone, recent literature, and newly discovered biochemical pathways** *L. Re, G. Malcangi, C. Gagliardi, N. M. Rampoldi (Italy)*	123
10:50	LP	**3.3 Ozone ameliorates the age-related oxidative stress changes in rat liver and kidney: effects of pre- and post-ageing administration** *M. Safwat, M. El-Sawalhi, N. Mawsouf, A. Shaheen (Egypt)*	116
11:10	LP	**3.4 Ozone therapy versus newer modalities. Efficacy in diabetic foot ulcers. Clinical review** *A. M. Fathi, M. N. Mawsouf, R. Viebahn-Hänsler (Egypt, Germany)*	213
11:30	LP	**3.5 Ozone therapy in Multiple Sclerosis** *V. Simonetti (Italy)*	078
11:50	LP	**3.6 Ozone in oncology and preclinical models in lung diseases** *B. Clavo, N. Santana-Rodríguez, P. Llontop, C. Méndez, K. Zerecero, D. Fiuza (Spain)*	238
12:10		**Discussion**	
13:00	**Lunch**		

Session 4. Fundamentals - Part 2

Hour	Presentation		ID
14:30	LP	**4.1 Evaluation of competitive reactions of high concentration substrates with ozone** *T. Mizuno, H. Tsuno, M. Sato, A. Hasunuma, S. Kumagai, Y. Suzuki, N. Sakagami (Japan)*	136
14:50	LP	**4.2 Impact of ozone application to primary urban wastewaters: ozone transfer and organic matter change** *M. Marce, S. Baig, S. Esplugas (Spain, France)*	160
15:10	LP	**4.3 Dissolution of nanosilver during ozonation of wastewater** *V. Yargeau, M. T. K. Nguyen, L. Telgmann, C. Metcalfe (Canada)*	135
15:50	LP	**4.4 Effect of mono-metallic and bi-metallic supported catalysts on nitrobenzene ozonation** *A. Abdedayem, M. Guiza, A. Ouederni (Tunisia)*	142
16:10	LP	**4.5 Reaction-reactor modeling and kinetics of anthraquinone dye oxidation using ozone and UV radiation** *M. E. Lovato, M. L. Fiasconaro, J. P. Torrez, J. C. Andini, C. A. Martín (Argentina)*	076
16:30	**Break**		

Session 5. Ozone and Advanced Oxidation in Agrifood

Hour	Presentation		ID
14:30	LP	**5.1 Application of ozone/oxygen in the water treatment of shrimp farms** *T. Naheiri, D. LeClercq, T. Elzey, J. Capettini (USA, France)*	180
14:50	LP	**5.2 A review of ozone applications in food industry** *F. Violleau (France)*	122
15:10	LP	**5.3 Sulfate radical-based advanced oxidation process (SR-AOP) for winery wastewater treatment** *J. Rodríguez-Chueca, T. Silva., C. Amor, M.S. Lucas, J.A. Peres (Portugal)*	148
15:30	LP	**5.4 Application of UV-LEDs photo-fenton to candied fruit wastewater treatment** *C. Amor, J. Rodríguez-Chueca, J. Fernandes, M. S. Lucas, P. Tavares, J. A. Peres (Portugal)*	149
15:50		**Discussion**	
16:30	**Break**		

Session 6. Ozone in Medicine – Part 2

Hour	Presentation		ID
14:30	LP	**6.1 Paradigm change: "The Ozone a therapeutic mediator in MODIC processes"** *P. Osvaldo Alberto (Argentina)*	232
14:50	LP	**6.2 Treatment of symptomatic spinal degenerative pathologies by means of Oxigen-Ozone gas mixture. Observations after 23 years experience.** *A. Alexandre, M. De Pretto, L. Corò, H. Badreddine, A.M. Alexandre, S. John, M. Brunori (Italy)*	208
15:10	LP	**6.3 Combined intradiscal and periganglionic injection of medical ozone and periganglionic administration of steroids and anesthetic for the treatment of lumbar disc herniation: effects on disc size and lumbar radiculopathy** *T. Lehnert, V. Jacobi, T. J. Vogl (Germany)*	075
15:30	LP	**6.4 Ozone Therapy in Dentistry. A Brief Review for Physicians** *W. C. Domb (USA)*	201
15:50	LP	**6.5 Integration of ozone therapy for head and neck infective and chronic disease** *P. Mollica, K. Rockefeller (USA)*	197
16:10	LP	**Discussion**	
16:30	**Break**		

Session 7. Fundamentals – Part 3

Hour	Presentation		ID
17:00	LP	**7.1 Comparison of ozone- and UV- based techniques for the removal of metaldehyde** *D. Vulpe, C. Tizaoui (UK)*	229
17:20	SP	**7.2 pH-Sensitivity Effects of Generalized Ozone Decomposition Models** *J. Ferre-Aracil, V. Flores-Payán, A. López-López, S. C. Cardona, J. Navarro-Laboulais (Spain, Mexico)*	126
17:30	SP	**7.3 Kinetic Analysis of Ozone Gas Decomposition on MnO_2 Catalyst Supported on Alumina** *A. Roca, A. Chica, S. C. Cardona, J. Navarro-Laboulais (Spain)*	146
17:40	SP	**7.4 Analysis of the effect of the activated carbon amount in a batch ozonation-adsorption process** *J. I. Lombraña, A. Menéndez, I. Alegría (Spain)*	177
17:50	SP	**7.5 Influence of the control regime in ozonation efficiency of the basic cationic dye rhodamine 6G** *J. I. Lombraña, A. de Luis, C. Rodriguez (Spain)*	185
18:00	SP	**7.6 Disinfection effect of ballast water by a combination of ozone and bromine compound under low salinity water condition** *S. Park, S. Yoon, T. Park (Korea)*	088
18:10	SP	**7.7 Removal of pharmaceuticals from water by the ozone/activated carbon coupling** *P. Nebout, O. Chedeville, S. Delpeux, A. Di Giusto, B. Cagnon (France)*	207
18:20		**Exhibition**	

Session 8. Applicability in Waters

Hour	Presentation		ID
17:00	LP	**8.1 Ozone consumption efficiency on water decolorization process** *A. Menéndez, J. I. Lombraña (Spain)*	176
17:20	SP	**8.2 Removal of xenobiotics and generation of by-products by ozonation in the context of tertiary treatment** *B. Mathon, C. Pelletier, C. Miege, P. Bados, M. Coquery, J.-M. Choubert (France)*	070
17:30	SP	**8.3 Photolysis, ozonation and chlorination of flame retardants in water treatment** *R. Salgado, C. Chanfana, S. Martins, D. Galhanas, L. Epifâneo, J. Paulo Noronha (Portugal)*	164
17:40	SP	**8.4 Analysis of microbiological quality of surface waters in Ebro river basin as a first approach to establish the origin of the present contamination** *A. López, R. Mosteo, M. P. Ormad, J. L. Ovelleiro (Spain)*	107
17:50		**Exhibition**	

Session 9. Ozone in Medicine – Part 3

Hour	Presentation		ID
17:00	LP	**9.1 Experimental estimation of microcirculation adaptation to systemic injection of the ozonized saline** *S. P. Peretyagin, A. K. Martusevich, P. V. Peretyagin (Russia)*	091
17:20	LP	**9.2 Characterization of ozone decomposition in different aqueous solutions used in medicine and correlation with their bactericidal effect** *K.N. Kontorchshikova, A. Pérez, T. Poznyak, I. Chairez, A. A. Sibirkin, L.M. Obukhova (Russia, Mexico)*	184
17:40	SP	**9.3 The increase of treatment's efficacy of duodenal ulcer in patients aged 40-50 years.** *A. V. Bulat, V. V. Bulat (Moldovia)*	195
17:45	SP	**9.4 Local and systemic action of ozonids contained cosmetic gels on organism** *O. Bitkina, S. Peretyagin, A. Solovieva, O. Grechkaneva, A. Martusevich, M. Bugrova, P. Peretyagin, N. Prodanets (Russia)*	218
17:50	SP	**9.5 Ozone Therapy in Dentistry. A Brief Review for Physicians** (cont'd) *W. C. Domb (USA)*	201
17:55	SP	**9.6 The lipid metabolism and matrix metalloproteinase-9 in patients with metabolic syndrome** *C. Kontorshchikova, J. Tikhomirova, E. Koroleva (Russia)*	182
18:00	SP	**9.7 Distinctive features of medical ozone generator for ozonated liquids prepearing with various density** *T. Barkhotkina, R. Tomashevskyi, N. Mahonin (Ukraine)*	202
18:05	SP	**9.8 Scalar Wave Morphogenetic Field Mechanics and Ozone Therapy as a Revolutionary Model for Bioenergetic Regeneration** *J. Rivera-Dugenio (USA)*	200
18:10	SP	**9.9 Prospects for combined treatment of chronic non specific endometritis with ozone and Bacteriophage therapy** *N. Nikishov, G. Grechkanev, T. Motovilova, I. Ponomaryova, T. Boychenko, I. Zelenskaya, A. Soshnikov (Russia)*	219
18:15	SP	**9.10 Comparative study of action of ozone and singlet oxygen on blood oxidative metabolism in vitro** *A. A. Martusevich, A. K. Martusevich, S. P. Peretyagin (Russia)*	092

Tuesday, 30 June

Session 10. Advanced Oxidation: Photocatalytic systems

Hour	Presentation		ID
08:30	LP	**10.1 Cyanide removal from water by photocatalytic treatments with TiO_2** *N. Miguel, L. Alonso, N. Pueyo, S. Escuadra, R. Mosteo (Spain)*	082
08:50	LP	**10.2 Removal of acid red 1 by TiO_2 nanoparticles coated polyethersulfone membrane under UV irradiation** *I. Kovács, S. Kertész, S. Beszédes, C. Hodúr, I. Zita Papp, Á. Kukovecz, Z. László (Hungary)*	093
09:10	LP	**10.3 Nano-structured N-doped TiO_2 photocatalytic membranes for water treatment** *I. Horovitz, D. Avisar, R. Grilli, A.-D. Enevoldsen, D. Di Camillo, M. A. Baker, L. Lozzi, H. Mamane (Israel, UK, Denmark, Italy)*	101
09:30	LP	**10.4 Heterogeneous photocatalysis using supported Nano-TiO_2 for micropollutant elimination** *M. Micó, M. Arnaldos, T. De la Torre, C. Rodríguez, C. Fernández-Rodríguez, J. M. Doña Rodríguez, J. Juan Malfeito (Spain)*	227
09:50	LP	**10.5 New insights into mechanism of enhanced photocatalytic efficiency of metal ion doped TiO_2** *Y. Xie, J. Xiao, H. Cao (China)*	173
10:10	SP	**10.6 Photoelectrocatalytic degradation of pharmaceutical pollutant in wastewater** *S. Wohlmuth da Silva, B. Szortika, D. Mara Walker, M. A. Siqueira Rodrigues, A. Moura Bernardes (Brazil)*	071
10:20	SP	**10.7 Coated mesh reactor for the elimination of gaseous pollutants via heterogeneous photocatalysis** *C. Passalía, E. Nocetti, O. Alfano, R. Brandi (Argentina)*	196
10:30		**Break**	

Session 11. Applications for drinking water

Hour	Presentation		ID
08:30	LP	**11.1 Peroxone in drinking water treatment: Dutch challange** *A. Knol, K. Lekkerkerker-Teunissen, C. Houtman, J. Scheideler, A. Ried, H. Van Dijk (The Netherlands, Germany)*	109
08:50	LP	**11.2 Seasonal occurence of micro pollutants in drinking water sources - evaluation of treatment strategies using AOPs and ozonation** *J. Scheideler, B. Holden, K.-H. Lee (Germany, UK, Korea)*	205
09:10	LP	**11.3 Rapid bench scale experiments for the selection of a treatment strategy for drinking water production** *T. Merle, W. Pronk, U. Von Gunten (Switzerland)*	130
09:30	LP	**11.4 Production of micro-pollutants free and bio-stable drinking water – An insight study of the multi-barrier concept** *J. Wang, Y. Zhang, E. Wong, A. Ried, R. Xie, C. Qin Wei, Y. Xing, L. Zhang (Germany, Singapore)*	085
09:50	LP	**11.5 Determination of optimum O_3 dose in drinking water treatment in Korea** *J.-W. Kang, S. Kim, M. Kwon, W.-H. Joe (Republic of Korea)*	138
10:10	SP	**11.6 Effect of Pre-Ozonation on Haloacetic Acids formation in Ganga River Water at Kanpur** *P. Bose, N. Rao (India)*	125
10:20	SP	**11.7 Water treatment plants using large stainless steel filters: New perspectives for ozone biofiltration process** *M. Brugger, S. Forberg Liane (Germany, Norway)*	234
10:30		**Break**	

Session 12. Ozone in Medicine – Part 4

Hour	Presentation		ID
08:30	LP	**12.1 Targets of medical ozone in rheumatoid arthritis. How they impact in the clinical scenery?** *O. S. León Fernández, R. Viebahn-Haensler, L. Delgado Roche, B. Tamargo Santos, I. Wilkins Pérez, G. López Cabreja, I. Serrano Espinosa (Cuba, Germany, Mexico)*	209
08:50	LP	**12.2 Treatment of the diseases of Temporo Mandibular Joint with ozone and PRP infiltrations** *F. Pastor Loscertales (Spain)*	212
09:10	LP	**12.3 Knee osteoarthritis. Predictive factors for ozone treatment** *J. Baeza Noci (Spain)*	193
09:30	LP	**12.4 Correlation of plasma Interleukin 1 levels with disease activity in rheumatoid arthritis (RA) with and without ozone. A clinical study** *Z. Fahmy (Germany)*	210
09:50		**Discussion**	
10:30		**Break**	

Session 13. Advanced Oxidation: UV and ozone systems

Hour	Presentation		ID
11:00	SP	**13.1 On the reaction mechanism of DEET removal through visible light assisted photocatalytic ozonation with WO_3 catalyst** *E. Mena, A. Rey, F. J. Beltrán (Spain)*	119
11:10	SP	**13.2 Removal of phenyl urea based herbicides by combination of ozone and photocatalysis under N-doped titania** *R. R. Solís, F. J. Rivas, O. Gimeno, E. Mena (Spain)*	120
11:20	SP	**13.3 Formulation and assessment of indoor photocatalytic paints active under visible light** *F. Salvadores, O. M. Alfano, M. de los Milagros Ballari (Argentina)*	110
11:30	SP	**13.4 Caffeine degradation in WWTPs effluents for agricultural reuse by photocatalysis with titanium dioxide** *S. Escuadra, L. Altabás, N. Miguel, M. P. Ormad (Spain)*	086
11:40	SP	**13.5 Solar radiation activation of ozone for the degradation of water pollutants** *A. M. Chávez, A. Rey, P. M. Álvarez, F. J. Beltrán (Spain)*	121
11:50		**Exhibition**	
13:00		**Lunch**	

Session 14. Advanced oxidation: Ozone systems

Hour	Presentation		ID
11:00	LP	**14.1 Photodegradation of dioxin-like compounds by pulsed xenon lamp irradiation** *S. Shashkovskiy, A. Seliverstov, I. Zhelaev, V. Arkhipov, Y. Goldshteyn, B. Ershov (Russia)*	217
11:20	LP	**14.2 Ozonation degree effect on physicochemical evaluation of four ozonated vegetal oils** *P. Guerra Blanco, T. Poznyak, I. Chairez, M. Brito-Arias (Mexico)*	172
11:40	SP	**14.3 Surfactant treatment with activated carbon adsorption, oxidation with ozone and peroxone** *C. Rita Ramírez-Cortina, M. Soledad Alonso-Gutiérrez (Mexico)*	159
11:50	SP	**14.4 Removal of cyanide in the presence of solids in industrial wastewater by using hydrogen peroxide and ozone** *N. Pueyo, M. P Ormad, N. Miguel, J. L. Ovelleiro (Spain)*	087
12:00	SP	**14.5 Treatment of municipal primary and secondary wastewater effluents by non catalytic and catalytic ozonation** *M. Marce, J. Arnal Moreno, R. C. Martins, R. M. Quinta-Ferreira, S. Esplugas (Spain, Portugal)*	161
12:10	SP	**14.6 Advanced oxidative treatment for waste water contaminated by pharmaceutical products** *C. Vreuls, A. Wilmot, M. Cludts, P. Lefèbvre, N. Gillard, B. Heinrichs, S. Lambert (Belgium)*	251
12:20		**Exhibition**	
13:00	**Lunch**		

Session 15. Ozone in Medicine – Part 5

Hour	Presentation		ID
11:00	LP	**15.1 Major Ozone Autohaemotherapy (AHT) in spinal degenerative pathologies** *S. John, F. Jacob, A. Alexandre (Italy)*	242
11:20	WS	**15.2 Medical Workshop** *Dr. Aziz, Dr. Habig*	
13:00	**Lunch**		

Session 16. Advanced Oxidation: Catalytic ozonation

Hour	Presentation		ID
14:30	LP	**16.1 Development of novel catalytic materials for removal of emerging organic pollutants by catalytic ozonation** *S. S. Sable, P. P. Ghute, F. Medina, S. Contreras (Spain)*	134
14:50	LP	**16.2 Urban wastewater treatment by catalytic ozonation** *C. Crousier, J.S. Pic, J. Albet, S. Baig, M. Roustan (France)*	249
15:10	LP	**16.3 The decomposition of Humic Acid in catalytic ozonation** *C.-N. Chang, L.-W. Lu, Ho-Wen Chen (Taiwan)*	220
15:30	LP	**16.4 Catalytic ozonation with γ-Al_2O_3 to enhance the degradation of refractory organics in water** *J. Vittenet, W. Aboussaoud, J. Mendret, J.-S. Pic, H. Debellefontaine, N. Lesage, K. Faucher, M.-H. Manero, F. Thibault-Starzyk, H. Leclerc, A. Galarneau, S. Brosillon (France)*	240
15:50	LP	**16.5 Assessment of a non-woven fiber paper coated with ruthenium nanoparticles for catalytic ozonation** *P.-F. Biard, B. Werghi, I. Soutrel, A. Denicourt-Nowicki, R. Orhand, A. Couvert, A. Roucoux (France)*	112
16:10	LP	**16.6 Use of a trickle bed reactor for heterogeneous catalytic ozonation of phenol** *L. Briceño, E. Duran (Costa Rica)*	169
16:30		**Break**	

Session 17. Water Reuse Purpose

Hour	Presentation		ID
14:30	LP	**17.1 A hybrid process of ozonation and short soil aquifer treatment for water reuse** *I. Zucker, H. Mamane, H. Cikurel, M. Jekel, U. Hübner, D. Avisar (Israel, Germany)*	095
14:50	LP	**17.2 Study of the influence of Advanced Oxidation Processes as a pretreatment of a Reverse Osmosis from an ultrafiltred water reclamation** *C. Mesa, I. Martin, B. Lefèvre, O. Gibert, X. Bernat (Spain)*	117
15:10	LP	**17.3 Treatment of nanofiltration concentrates by ozonation for wastewater reuse: optimization of operational parameters** *A. Azaïs, J. Mendret, S. Brosillon (France)*	118
15:30	LP	**17.4 Combining adsorption with advanced oxidation – A case study** *M. G. Conti-Ramsden, N. W. Brown, M. Khan, N. De Las Heras-Rodriguez (UK)*	186
15:50	LP	**17.5 Wastewater disinfection by ozone: water reuse** *J. A. Perdigón-Melón, A. Luminita Petre, J. Benito Carbajo, R. Rosal, E. Garcia-Calvo (Spain)*	157
16:10		**Discussion**	
16:30		**Break**	

Session 18. Water Disinfection Target

Hour	Presentation		ID
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14:50	LP	**18.2 Wastewater matrix effect on disinfection with LP/UV and MP/UV radiation** *R. Salgado, C. Hipólito, D. Galhanas, L. Epifâneo, J.P. Noronha (Portugal)*	163
15:10	LP	**18.3 Influence of hydraulics on disinfection efficiency** *M. Roustan (France)*	166
15:30	SP	**18.4 Disinfection of simulated municipal wastewater effluent by ozonation at laboratory and pilot scale** *P. Valero, R. Mosteo, R. M. de Castro, M. J. Quero-Pastor, M. Hinojosa, A. Acevedo, M. P. Ormad (Spain)*	074
15:40		**Discussion**	
		Exhibition	
16:30		**Break**	

Session 19. Advanced Oxidation : Photo-Fenton systems

Hour	Presentation		ID
17:00	LP	**19.1 Photo-Fenton degradation of a herbicide with simulated solar radiation. Kinetic model using the ferrioxalate complex** *O. Alfano, L. Conte, A. Schenone, E. Albizzati (Argentina)*	108
17:20	LP	**19.2 Assessment of Fe(III)-NTA use in photo-Fenton at neutral pH** *R. F. Dantas, A. De Luca, S. Esplugas (Brazil, Spain)*	236
17:40	SP	**19.3 Solar photo-fenton oxidation of levofloxacin antibiotic at near neutral pH with ferrioxalate complexes** *A. A. Nogueira, M. Dezotti, R. A. R. Boaventura, V. J. P. Vilar (Portugal, Brazil)*	252
17:50		**Discussion**	
		Exhibition	

Session 20. In relation to Activated Sludge

Hour	Presentation		ID
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17:20	LP	**20.2 Effects of persulfate and peroxide treatment on components and dewaterability of waste urban sludge** *N. Bilgin Öncü, N. Mercan, D. Aydın, I. Akmehmet Balcıoğlu (Turkey)*	206
17:40	LP	**20.3 Evaluation of excess sludge reduction and bacterial inactivation using ozone ultra-fine bubble (nanobabbles)** *K. Hashimoto, T. Okuda, W. Nishijima, K. Sawai, N. Sumida (Japan)*	131
18:00	LP	**20.4 Behavior of trace materials in ozone-added activated sludge process** *F. Nishimura, Y. Okada, Y. Nakagawa, M. Masuda, H. Tsuno (Japan)*	174
18:20		**Discussion**	

Session 21. Micropollutants control – Part 1. At full scale

Hour	Presentation		ID
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17:40	LP	**21.2 Optimisation of full-scale ozonation tertiary treatment for micropollutants removal** *Y. Penru, C. Miège, A. Roussel-Galle, L. Dherret, A. Guillon, M. Esperanza, S. Martin Ruel, M. Coquery, J. M. Choubert (France)*	226
18:00	LP	**21.3 Application of ultraviolet absorption measurement for closed-loop control of tertiary ozonation** *M. Stapf, U. Miehe (Germany)*	153
18:20	SP	**21.4 Determination of estrogenic activity at a waste water treatment plant with full scale ozonation using *Arxula adeninivorans* yeast estrogen screen assay** *F. Itzel, L. Gehrmann, C. Portner, H. Herbst, G. Kunze, T. C. Schmidt, J. Tuerk (Germany)*	154

Wednesday, 1st July

Session 22. Design and Engineering aspects – Part 1

Hour	Presentation		ID
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08:50	LP	**22.2 Implementation of ozonated water pulverization: characterization of the ozone desorption** *M. Tournois, M. Pages, M. Roustan, D. Kleiber, F. Violleau, G. Hébrard (France)*	143
09:10	LP	**22.3 Retrofit of ozone contact basins with Sidestream Venturi gas injection** *J. R Jackson, S. S. Pathapati (USA)*	178
09:30	LP	**22.4 Ozone concentrations exceeding 15wt% on an industrial scale?** *N. Brüggemann, M. Salvermoser, T. Pühmeier, R. Fiekens, R. Fietzek (Germany)*	221
09:50	LP	**22.5 The influence of sample tubing material on accuracy of low ozone concentration measurement** *A. Scholz, F. Wallner (Germany)*	069
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10:30	**Break**		

Session 23. Industrial waters

Hour	Presentation		ID
08:30	LP	**23.1 Removal of Hard COD in industrial wastewater – comparison of different treatment solutions based on Chemical Coagulation, DAF, Ozone and Bio Filter** *A. Ried, I. Zhu, T. Getting (Germany, USA)*	204
08:50	LP	**23.2 Ozonation of landfill leachate: cost effectiveness and insights on conversions of organic matter** *M. Chys, W. T.M. Audenaert, V. Oloibiri, K. Demeestere, S. W.H. Van Hulle (Belgium)*	099
09:10	LP	**23.3 Evaluation of UV, UV/H_2O_2 and UV/$Na_2S_2O_8$ systems for the treatment of industrial waters - organics degradation and disinfection** *Š. Bártová, P. Kůs, V. Šmejdová, K. Vonková, H. Šveda, J. Říhová Ambrožová (Czech Republic)*	124
09:30	LP	**23.4 The new concept of catalytic ozonation process, OCS: example of waste from the power sector containing nitrogen organic compound** *F. Pontlevoy, E. Azokpota, F. Leroux (France)*	228
09:50	LP	**23.5 Ozonation and UV radiation as alternatives to chemical biocides for cooling water** *S. Chéret, S. Baig (France)*	260
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10:30	**Break**		

Session 24. Micropollutants control – Part 2

Hour	Presentation		ID
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08:50	LP	**24.2 Determination of transformation products from the ozonation of pharmaceuticals and their detection in treated wastewaters** *M. Bourgin, E. Borowska, J. Hollender, C. S. Mcardell, U. Von Gunten, (Switzerland)*	140
09:10	LP	**24.3 Ozonation for degradation of pharmaceutical of hospital wastewater** *K. M. S. Hansen, A. Spiliotopoulou, R. Kumar Chhetri, M. Escolà Casas, K. Bester, H. R. Andersen (Denmark)*	145
09:30	LP	**24.4 Pharmaceuticals removal in wastewater by biological treatment and tertiary ozonation** *B. Domenjoud, A. Gonzalez Ospina, E. Vulliet, S. Baig (France)*	248
09:50		**Discussion**	
10:30	**Break**		

Session 25. Workshop –Access to ozone mass transfer parameters

Hour		ID
11:00	**Overview of mass transfer modelling** **Review and discussions on experimental methods**	
13:00	**Lunch**	

Session 26. Workshop – Young Ozone People

Hour		ID
11:00	**Spot presentations by Young Ozone People, by experienced Ozone People** **Discussion**	
13:00	**Lunch**	

Session 27. Workshop – IOA highlights

Hour		ID
11:00	**27.1 Ozone as active substance under the Biocidal Products Regulation** *B. Paolini, T. Pühmeier, J. Mielcke, M. Rothe, M. Hoffmann, J. Ryckeboer (Switzerland, Germany)* **Review of industry and technical news** *IOA Ozone engineering group*	224
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Session 28. Design and Engineering aspects – Part 2

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14:50	LP	**28.2 Upgrading an Older Ozone System to Achieve Optimal Treatment Performance** *C. Schulz, M. Bayan (USA)*	241
15:10	LP	**28.3 The synergistic effects of designing ozone with a biologically active filter** *I. Zhu, T. Getting, A. Ried, A. Wieland (USA, Germany)*	203
15:30	LP	**28.4 Research and development, implementation and operation of industrial experience systems for ventilation and decomposition of ozone** *I. Tkachenko, S. Tkachenko, V. Lunin (Russia)*	156
15:50	LP	**28.5 Control Strategies for Wastewater Applications of Ozone** *M. Oneby (USA)*	261

Session 29. Applications in Industrial Processes

Hour	Presentation		ID
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14:50	LP	**29.2 Ozone delignification of lignocellulosic waste for sugar availability** *P. Arenas-Cárdenas, A. López-López, E. León-Becerril (Mexico)*	127
15:10	LP	**29.3 Advanced oxidation processes for the regeneration of siloxane-exhausted adsorbents** *A. Cabrera-Codony, R. Gonzalez-Olmos, M. J. Martín (Spain)*	114
15:30	LP	**29.4 Effect of different UV lamp configurations and reactor geometries in a bench scale UV and ozone system for VOC abatement in air streams** *F. Montecchio, J. Delin, J. Mills, K. Engvall, R. Lanza (Sweden, UK)*	139
15:50	LP	**29.5 Preparation and characterization of modified PVDF membrane by gamma-ray irradiation for water reuse** *S. J. Lim, T.-H. Kim, I. H. Shin (Republic of Korea)*	225

Session 30. Micropollutants control – Part 3

Hour	Presentation		ID
14:30	LP	**30.1 Removal of a recalcitrant anticancer drug from water with ozone based technologies** *R. Gonzalez-Olmos, L. Ferrando-Climent, A. Anfruns, S. Rodriguez-Mozaz, D. Barceló (Spain)*	080
14:50	LP	**30.2 Investigation of ozone based processes for removal of benzothiazoles** *J. Derco, M. Melicher, J. Dudas, J. Kecskes (Slovakia)*	231
15:10	LP	**30.3 Robust fluorescence and UV-vis correlation models for real-time control and assessment of micropollutant removal from secondary effluent using ozonation** *M. Chys, S. W.H. Van Hulle, E. Deniere, L. Vergeynst, H. Van Langenhove, I. Nopens, K. Demeestere, W. T.M. Audenaert (Belgium)*	097
15:30	LP	**30.4 UV photolysis and UV/H_2O_2 photolysis processes for estrogens removal in water** *B. Cédat, C. de Brauer, H. Métivier, J. N. Levrard (France)*	141
15:50	LP	**30.5 Proposal to optimize ecotoxicological evaluation of wastewater treated by conventional biological and ozonation processes. A summary** *A. Wigh, S. Bony, A. Devaux, A. Gonzalez-Ospina, B. Domenjoud, S. Aït-Aïssa, N. Creusot, C. Bazin (France)*	250

Plenary session

16:15 **Awards Ceremony**

Process Control for Ozonation Systems: A Novel Real-Time Approach
H.-P. Kaiser, O. Köster, M. Gresch, P.M.J. Périsset, P. Jäggi, E. Salhi, U. von Gunten (Switzerland)

Synthesis and Conclusions
Announcements

17h30 Adjourn

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ABSTRACTS OF PRESENTATIONS

Monday, 29 June

Plenary session. Opening

Opening Addresses, *Achim Ried, IOA President and Santiago ESPLUGAS, IOA-EA$_3$G President*

Congress introduction, *Michel ROUSTAN, Renate VIEBAHN, Scientific Committee*

Session 1. Fundamentals – Part 1

1.1 Determination of ozone Henry's constant using different analytical methodologies

J. Ferre-Aracil, S. C. Cardona, J. Navarro-Laboulais (Spain)

Different procedures for measuring the concentration of ozone in aqueous buffered solutions have been reviewed for the determination of Henry's constant at different temperatures and pH. Iodometry, Indigo Trisulfonate and Iron (II) chemical methods were compared with the direct UV absorbance measurement of the ozone at 258 nm. From these data a new value for the molar extinction coefficient of ozone is proposed as 3840 ± 109 M^{-1} cm^{-1}. The ozone solubility was found constant with pH ranging from 2 to 7.6. The solubility of ozone was measured between 5 and 35 ºC resulting in a dimensionless solubility ratio of H_0 = 1.797 exp[0.0277·t(ºC)] .

1.2 Comparative study of competitive kinetics and stopped flow method on the determination of rate constants of steroids degradation using ozone

R. Vallejo-Rodríguez, V. Flores-Payán, E. León-Becerril, A. López-López (Mexico)

Currently, the emerging contaminants (ECs) are not regulated by international environmental authorities; these include steroids such as estradiol (E2) and ethynilestradiol (EE2), which cause problems of estrogenicity in living beings in quantities of 1 ngL^{-1}, specifically in fish, which generate sexual differentiation problems. Steroids are hardly degraded by conventional methods such as activated sludge processes or coagulation-flocculation treatment; and ozonization is an option for its effective degradation. The aim of this research was to assess the competitive kinetic and stopped flow technique on obtaining the degradation kinetics by ozonization of two steroids, E2 and EE2, present in ultrapure spiked water. The kinetic competitive used sodium phenolate as reference compound. The stopped flow kinetic utilized a SFM-3000/S equipment of BioLogic brand. Both series of experiment were performed at pH 6 and 21 °C and using tertbutyl alcohol as scavenger. Second order rate constants were in the order of 10^6 and 10^5 $M^{-1}s^{-1}$ for E2 and EE2 respectively, for both methods. The E2 and EE2 degradation by stopped flow is scarcely reported by literature; hence, the value kO_3 obtained is contribution of this research. The values of kO_3 of two method of degradation were similar to reported by other studies. Therefore, a second achievement of this research is the validation of the second order constant for steroids by the stopped flow technique. The technique is applicable for degradation of other ECs or other steroids and could be applied in water treatment at industrial level.

1.3 Evaluation of N-oxide venlafaxine transformation product kinetics during ozonation

I. Zucker, A. Riani, D. Avisar, H. Mamane (Israel)

Venlafaxine is an antidepressant found in several environmental samples at the concentrations ranged from several ng/L to as high as 2 µg/L. The purpose of this study is to examine the kinetics of ozone reaction with venlafaxine in secondary effluents. Different conditions were set in order to measure the formation and elimination yields of the N-oxide transformation product. The maximum yield of N-oxide-venlafaxine is strongly influenced by pH and the hydroxyl radicals' exposure. Rate constants of ozone and hydroxyl radicals with N-oxide-venlafaxine were determined using competition kinetics. Further investigation led to identification of other oxidation products in an attempt to demonstrate a complete mass balance.

1.4 Sulfaquinoxaline degradation and toxicity reduction by photocatalysis

V. Ribeiro Urbano, M. Guedes Maniero, J. Roberto Guimarães (Brazil)

Sulfaquinoxaline is one of the emerging contaminants that has been found in environmental waters and the consequences for human health are not completely known. In this study were evaluated the degradation of sulfaquinoxaline by two photocatalitic processes (UV/TiO_2 and UV/TiO_2/H_2O_2) and assessed the toxicity reduction of the solutions during the assays. After the degradation processes, sulfaquinoxaline (C_0 = 500 µg L^{-1}) samples were concentrated by SPE and they were quantified by HPLC. Sulfaquinoxaline degradation was higher than 99% after 11 minutes of reaction when applied UV/TiO_2 (20 to 100 mg L^{-1} TiO_2) and UV/TiO_2/H_2O_2 (5 mg L^{-1} e 100 mg L^{-1} TiO_2 and 0.8 mmol L^{-1} H_2O_2) processes. The advanced oxidation process that presented higher degradation rate (k = 6.08 x 10^{-1} min^{-1}) was UV/TiO_2/H_2O_2 (50 mg L^{-1} TiO_2 and 0.8 mmol L^{-1} H_2O_2). For both photocatalytic processes (UV/TiO_2 and UV/TiO_2/H_2O_2), solutions toxicity increased throughout the reaction time3

1.5 Degradation kinetic evaluation of Bisphenol A with ozone using the Stopped-Flow instrumental technique

V. Flores-Payán, R. Vallejo-Rodríguez, M. Murillo-Tovar, E. León-Becerril, A. López-López (Mexico)

This research was focused on obtaining the kinetics degradation of bisphenol A (BPA) by ozonization in spiked ultrapure water. Currently, a number of compounds known as emerging contaminants (ECs) are not regulated by international environmental authorities; these include the

BPA which interferes with secretion, transport, action or elimination of natural hormones that are responsible for the maintenance of homeostasis and reproduction. BPA is used in the manufacture of polycarbonate plastic and epoxy resin and this compound has been found in the influent and effluent of wastewater treatment plants, surface water and groundwater sources. BPA are hardly degraded by conventional methods such as activated sludge processes or coagulation-flocculation treatment; and ozonization is an option for its effective degradation. The method used for obtaining the degradation kinetic of steroids in this research was the stopped flow technique. Second order rate constant were of $1.11x10^4$ $M^{-1}s^{-1}$ at pH 2 with and without t-OH; at pH 4, it was $1.24x10^4$ $M^{-1}s^{-1}$ with t-OH and $1.78x10^4$ $M^{-1}s^{-1}$ without t-OH. This last value of the rate constant without t-OH is slightly higher than the other constants, because of the little contribution of radical pathway; however, at pH 2 the value of k_{O3} with and without t-OH is practically the same that the value at pH 4 with t-OH. Literature have scarcely reported the k_{O3} value, so that the value obtained is a contribution of this research. The stopped flow is a quickly technique that is applicable for degradation of BPA and other ECs, obtaining reliable data in real-time.

1.6 A comparative study: degradation of 2,5-dichlorophenol in a wastewater and distilled water by ozone and ozone-UV

J. C. Alexander, C. R. Ramírez-Cortina (Mexico)

In recent years, there have been increases in contamination of water supplies and health problems, due to the lack, or improper treatments of effluents of many chemical industrials that contain high concentration of refractory compounds such as chlorophenols. To evaluate the effectiveness of ozone and ozone-UV processes on the degradation and biodegradability of chlorophenolic compounds, in particular 2, 5-dichlorophenol (DCP), a comparative study was carried out in a bubble column reactor with a volumetric mass transfer (k_La) of 1.58 min^{-1}. Utilizing a high concentration of 2,5-DCP (3.06 mM) in aqueous solutions of distilled water and wastewater, at pH 7 and applied ozone dose of 37 mg/L. The results obtained, showed that 2,5-DCP was completed degraded with an ozone dose of approximately 1.2 g/h in both solutions with O_3 and O_3-UV processes. The best results were obtained with the ozone-UV processes, showing that the addition of photolysis treatment (UV lamp intensity = 4 mW/cm^2) to ozone, accelerated the mineralization (53%) and biodegradability (BOD_5/COD) of 2,5-DCP from 0.2 to 0.85 in the wastewater. The toxicity of 2,5-DCP and its oxidation by-products were monitored at different time interval utilizing activated sludge respiration inhibition test. Test analyses showed that O_3 and O_3-UV treatments were effective in reducing the toxicity of 2,5-DCP and its by-products, which were less toxic to the microorganisms in activated sludge, than the untreated 2,5-DCP (EC_{50}= 50 mg/L). The results achieved in this work, showed that the presence of organic/inorganic matters in the wastewater, had a positive effect on the oxidation of 2,5-DCP, which supports the potential use of ozone and ozone-UV processes for the treatment of effluent with high concentration of chlorophenols.

1.7 Comparison of ozone and ferrate for oxidation of Disinfection Byproduct Precursors

D. A. Reckhow, Y. Jiang, X. Ma, J. Bliss, J. Gao, J. Goodwill, J. E. Tobiason (USA)

Ferrate is a promising alternative oxidant and disinfectant. Among its many desirable impacts, ferrate can play a role in controlling disinfection byproducts (DBPs). In this study, ferrate was examined and compared to ozone as a pre-oxidant for the purpose of partly destroying DBP precursors in natural organic matter. Laboratory results show the two oxidants to have very similar impacts on THM, HAA and DHAN precursors at similar doses. This promotes the idea that ferrate could be viewed as an alternative to ozone for the purposes of DBP control.

1.8 Effect of ozonation on THM formation in swimming pool water — laboratory study

K. M. S. Hansen, A. Spiliotopoulou, W. Akram Cheema, H. R. Andersen (Denmark)

Ozonation experiments were performed with pool filling water (drinking water; unchlorinated groundwater), pool water and pool water mixed with filling water and artificial body fluid to evaluate the effect of ozonation on total trihalomethane (TTHM) formation during subsequent chlorination. The lifetime of ozone followed first order kinetic and in the filling water the half-lifetime was 4 min while for the mixture and the pool water it was 8 and 11 min, respectively. When the ozonated was repeated the half-lifetime of ozone increased to 17-19 min in all samples. The subsequent chlorination revealed that ozone removed reactivity of the dissolved organic carbon toward chlorine for the filling water and the mixed water samples and decreased TTHM formation. For the pool water samples, a higher TTHM formation was observed in ozonated than non-ozonated water. Thus, in the filling water and the mixed water samples ozone reacted directly with the pollutants resulting in short lifetimes of ozone and removed reactivity of the pollutants towards chlorine oxidation and prevented TTHM production. Whereas in the pool water samples, due to the long lifetime ozone decomposed to hydroxyl radicals, which then reacted with the pollutants and increased the chlorine reactivity of the pollutants. Thus, it was observed that ozone reacted markedly different in swimming pool water than in drinking water. Therefore, ozonation in pool water should be designed such that ozone mostly react with fresh pollutants from bathers and filling water before chlorine has time to oxidise it, since ozonation of aged pool water might increase TTHM production in short term.

Session 2. Ozone in Agrifood

2.1 Modification of the molecular properties of wheat grain storage proteins by ozonation

P. Gozé, L. Rhazi, A. Pauss, T. Aussenac (France)

In this study, we report the effects of ozone treatment of different bread wheat grains on the molecular distribution of the storage proteins and their effects on alveographic properties of the flours from ozonated grains. Two wheat cultivars differing on their HMW-GS composition and technological properties were used. Protein solubility evaluated by the Extractable Protein/Total Protein ratio significantly decreased with the ozone treatment and remarkable protein polymers/aggregates were observed in both reduced and non-reduced SDS-PAGE patterns. In addition, ozonated samples displayed increased molecular weight distribution as determined by an A-FFFF method. Protein oxidation by ozone (via disulfide-sulfhydryl interchange reactions and formation of tyrosine bonds) is the main suggested phenomenon which could explain these modifications. All these protein structure modifications have an important effect on bread-making quality of wheat flour (i.e. increase in tenacity and decrease in extensibility of dough).

2.2 Ozone as degradation agent of bifenthrin residues in stored rice grains

M. Ávila, L. Rita Faroni, F. Heleno, M. Eliana Queiroz, L. Philip Costa, R. Iglesias, L. Prates (Brazil)

The excessive use of pesticides in stored grains contaminates food with the residues of these products. Therefore, this work aimed to evaluate ozone potential to degrade bifenthrin residues in stored rice. The rice grains were sprayed with a solution containing bifenthrin at a concentration of 4 mg kg^{-1}. Ozone was applied at a concentration of 3 mg L^{-1} and continuous flow of 1.0 L min^{-1} in periods of time ranging from 1 to 10 h. The rice samples were submitted to solid-liquid extraction at low-temperature partitioning (SLE/LTP) for chromatographic analysis (GC/ECD). It was observed that bifenthrin decomposition increased with the time of exposure to ozone gas and it was obtained 94% of degradation.

2.3 Stability and antibacterial activity of ozonized sunflower oils.

S. Moureu, F. Violleau, D. Ali Haimoud-Lekhal, A. Calmon (France)

Ozonized vegetable oils are well identified as antibacterial compounds. However, their use requires having data on their stability. The aim of this study was in a first step to investigate the stability of ozonized oil stored in different conditions. In that purpose, high oleic sunflower oil was ozonized for 4 hours and stored in four different conditions: −20 °C, +4°C, room temperature and +37 °C. The peroxide index (IP), the acidity value (AV), the gas chromatography and infrared profile and the antibacterial activity (against *Streptococcus uberis*) were determined for each sample after 0, 1, 3, 6 and 9 months of storage. In a second step, the antibacterial activity of sunflower oils ozonized under

different conditions was assessed on three bacterial strains: *Staphylococcus aureus, Escherichia coli and Streptococcus uberis*.
The results of the stability study showed a quick decrease of the IP and an increase of the AV for the samples stored at room temperature and at +37 °C whereas the samples stored at +4°C and −20 °C remained more stables. These changes had no significant impact on the antibacterial activity which remained the same. Concerning the effect of reaction conditions, the more efficient ozonized oils were obtained when water was added to the media and the efficiency was different from one strain to another.

2.4 Ozone effects on fungal material

M. Pagès, D. Kleiber, F. Violleau (France)

Botrytis cinerea and *Neofabraea alba* cause illness on fruits. These fungi are dispersed by spores. Their control is mainly managed by fungicide treatments but their use is currently controversial. Ozone is a strong oxidant well-known for its disinfectant capacity and its low remanence. In this study, the effects of ozone dissolved in water on fungal spores aqueous solutions were investigated. Ozone treatment was applied on conidia aqueous suspensions in order to determine the minimal efficient dose to limit conidia germination and to observe and understand the mechanisms involved in the spores inactivation. For the two fungi, these tests confirmed the efficiency of ozone bubbling. This *in vitro* model allows identifying the minimum efficient dose against conidia which is 0.07 $mg.mL^{-1}$ of ozone. In the case of *Botrytis cinerea,* the germination rate is lower than 3 % when the ozone concentrations are high (> 10 $g.m^{-3}$) even if the period of treatment is short (0.5 minute). When the ozone concentration is 1 or 2 $g.m^{-3}$, the treatment must be applied for more than 0.5 minute to be efficient. The consequences of the ozone treatment on the fungal cell membrane have been analyzed: the concentrations of malondialdehyde, mainly produced by lipid peroxidation, increase with the ozone doses and the inactivation rate. These results, obtained for the two fungi, suggest that the lipid peroxidation, and consequently the alteration of the membrane integrity, are implied in the antifungal properties of ozone.

2.5 Effects of spraying ozonated and electrolyzed water on survival of cultivable fungi, bacteria and yeasts of grape

A. Raio, A. Feliciani, V. Ferri, C. Carboni (Italy)

The aim of this study was to determine the effect of ozonated (OW) and electrolyzed water (EOW) on the epiphytic microflora living on leaves and berries grape grown in the field. OW and EOW were produced on site using prototypes supplied by Industrie De Nora S.p.A. The most representative groups of epiphytic microrganisms were analyzed: fungi, bacteria and yeasts. Microbiological analyses were performed by dilution plating method using agar media specific for the different groups of microrganisms. Results of the first leaf sampling showed that both OW and EOW reduced fungal and bacterial populations, while yeasts were not affected by the treatments. A second group of analysis was performed on leaves and berries before grape harvest. In this case, the effect of OW and EOW treatments on total fungi, bacteria and yeasts was statistically similar to that of fungicides alone. Similarly, the analysis of *Botrytis* spp. on berry surface evidenced that the population of this pathogen on OW and EOW treated plants was at the same level of those treated with fungicides. Preliminary results presented in this study show that the integration of OW or EOW with chemical treatments could be a possible strategy to reduce the heavy environmental impact due to pesticides during grape cultivation.

2.6 Passive refrigeration and ozone-enriched atmosphere to extend the shelf life of baby leaf lettuce, arugula and red chicory

T. Yaseen, E. Damara, M. Gallo, F. Santoro, C. Carboni, A. Maria D'Onghia (Italy)

The preservation of appearance, texture, flavour, nutritive value and microbiological quality are the objectives pursued by the control of vegetable post-harvest diseases. Microorganisms growing during postharvest processing and storage can prejudice these characteristics. In order to check the efficacy of passive refrigeration system (PRS) with ozone for the control of postharvest alteration and spoilage, a study was conducted during August - October 2014 on Baby Leaf lettuce, arugula and red chicory. Vegetables were stored in a PRS container at 1°C in four separate chambers ozone-modified atmosphere 0, 0.1, 0.3 and 1 ppm. Storage in a common refrigeration container at 1°C was considered as control. Decline symptoms, weight losses and microbial population concentrations were evaluated for all tested vegetables. Firmness was assessed just for red chicory. Sampling was performed after 10, 15 and 30 days of cold storage. Results shows that the storage of red chicory at 1 $nL\ L^{-1}$ozone guaranteed a lower weight loss and a partial control of mesophilic aerobic bacteria, yeast and fungi as compared to conventional control. Baby leaf lettuce and arugula, showed chlorophyll and Water Index (WI) higher than those found under conventional storage. The positive effect of new storage conditions was also found in the lowering of the Yellow Index (YI). Passive refrigeration with ozone at 0.1 and 0.3 ppm maintained the on Baby Leaf lettuce, arugula in excellent condition for 22 days of storage showing values of all detected parameters with significant differences from the control; similar results were obtained on red chicory after 30 days of storage. At the contrary, Baby Leaf lettuce, arugula vegetables stored conventionally declined completely after 15 days.

2.7 Effect of ozone treatments on wine grape microbiota, skin mechanical properties and phenolic compounds extractability

V. Englezos, F. Torchio, S. Giacosa, F. Cravero, S. Río Segade, J. Laureano, K. Rantsiou, C. Carboni, L. Rolle, V. Gerbi, L. Cocolin (Italy, Brazil)

In recent years there is an increasing interest towards innovative, environmentally-friendly and human healthy sanitizing products. In this context, the use of ozone (O_3) in food industry is gaining attention in the last decades due to its ability to inactivate a wide spectrum of undesirable microorganisms, and its rapid degradation without leaving residues and unpleasant odours that could affect negatively the quality of the treated food. In this study, the effectiveness of gaseous ozone as sanitizing agent on the microbiota of wine grapes was evaluated. Furthermore, the impact of the berry treatment with ozone was investigated on skin mechanical properties and anthocyanin extractability because they are parameters of great importance for the production of quality red wines. A commercial ozone generator machine with a nominal production rate of 32 g O_3/h was used, and berry treatments were done at a dose of 30 µL/L O_3 gas. The results revealed a decrease of about 1 Log/mL in the grape microbiota after 12 and 24 hours of berry treatment. These results are promising because the postharvest ozone treatment of wine grapes could help to control the grape yeast microbiota. Furthermore, ozone treatment usually increased skin hardness, which may promote the extraction of phenolic compounds from the skins during long macerations. However, in short macerations, the results showed that the anthocyanin extractability was not facilitated in ozone treated berries. The use of ozone at doses and times large enough for an effective sanitizing effect on red wine grapes prior to winemaking did not affect significantly total anthocyanin concentration after seven days of maceration and, in turn, likely the chromatic quality of the resulting wines.

Session 3. Ozone in Medicine – Part 1

3.1 Ozone Therapy - State of the Art.: Evidenced Based Medicine. Metaanalysis.

R. Viebahn-Hänsler (Germany)

Despite the fact that its mechanisms of action are well known and established, its indications and forms of application have been backed by preclinical and clinical studies, and guidelines for ozone therapy have been internationally published, the use of ozone in medicine is still controversially discussed. By means of literature data analysis, the authors here demonstrate that the main procedure in systemic ozone treatment, i.e. MAH (major autohemotherapy), in all its classical indications associated with chronic inflammatory conditions, is safe, effective and evidence-based.

3.2 Mechanisms of action of ozone, recent literature, and newly discovered biochemical pathways

L. Re, G. Malcangi, C. Gagliardi, N. M. Rampoldi (Italy)

Ozone therapy is widely used worldwide since many years. Recently, the widespread use of this complementary therapy has been accomplished by an increased number of basic and clinic papers published on international journals. The first theory on ozone action was based upon the fact that the exposure to low, non-toxic, ozone doses could increase the efficacy of the endogenous antioxidant system by increasing the production or the activity of some enzymes exerting a key role in the mitochondrial respiratory chain. Many of the basic mechanisms are now well outlined. In addition, the modulation of interleukins productions and of some biochemical pathways related to inflammation and pain, indicates the rationale of its use in many pathological conditions related to pain, inflammation and age disorders. Our paper deals on the mode of action of ozone that, with a hormetic mechanism, appears to be more similar to xenobiotic stress model than to a pure pharmacological action. Indeed, our recent work in vivo on patients treated with major autohemo therapy (MAH), demonstrated the increase of Nrf2 level ($P<0.01$) in peripheral blood mononuclear cells (PBMC) immediately after exposition of blood to ozone. This effect is maintained 30 min after, when the increment in Nrf2 was detected ($P<0.05$) in total circulating PBMC. After a series of MAH's, Nrf2 returned normal. These data demonstrate by the first time *in vivo* the activation of the Nrf2 pathway by a low dose of ozone and the activation of the feedback mechanism that induce the synthesis of proteins which favour the cell survival.

3.3 Ozone ameliorates the age-related oxidative stress changes in rat liver and kidney: effects of pre- and post-ageing administration

M. Safwat, M. El-Sawalhi, N. Mawsouf, A. Shaheen (Egypt)

The ageing process is known to be accompanied by increased oxidative stress and compromised antioxidant defenses. Controlled ozone administration has been shown to be effective in various pathophysiological conditions with an underlying oxidative burden. However, its effect on the biochemical alterations associated with the ageing process has been rarely studied.
The present study was carried out to study the role of ozone in counteracting the state of oxidative stress associated with ageing in the rat liver and kidneys using two experimental models. In the pre-ageing model, ozone was administered prior to the onset of ageing at adulthood and continued after the start of the ageing process (3 month-old rats until the age of 15 months). While in the post-ageing model, ozone was administered after ageing has begun and lasted for one month (14 month-old rats until the age of 15 months).

3.4 Ozone therapy versus newer modalities. Efficacy in diabetic foot ulcers. Clinical review

A. M. Fathi, M. N. Mawsouf, R. Viebahn-Hänsler (Egypt, Germany)

Background: Diabetic foot ulcers are associated with significant morbidity. Approximately 14% of diabetic ulcers lead to amputation. Conventional treatment modalities are often of limited success in promoting complete wound closure. Successful wound management involves optimizing patient local and systemic conditions in conjunction with an ideal wound healing environment. Many different topical products have been developed to influence this wound environment. In addition, a wide variety of advanced treatment modalities for diabetic foot ulcers, such as Topical growth factors, VAC (Vacuum Assisted Closure) Therapy, and hyperbaric oxygen therapy (HBOT), are available now. Clinical studies of these products have shown some evidence of improved wound healing compared to standard wound care.
Objective: This clinical review of the current state of the art in wound-healing evaluate the efficacy of ozone therapy with its different techniques (in a multidisciplinary approach), compared to conventional and newer products and modalities in the treatment of chronic diabetic foot ulcers.

3.5 Ozone therapy in Multiple Sclerosis

V. Simonetti (Italy)

I have been using ozone-therapy for 20 years and since 2000 I have been a member of the board of Italian Society of oxygen-ozone-therapy and I send you greetings for SIOOT. Today I will tell you about using ozone-therapy in MS, that I have been treating for 18 years.
Are there any neurologist among you? Did any of you treated any MS patients with ozone-therapy?
Why didn't you treat them? Maybe you have heard that you do not get good results?
Many slides that you will see later have bibliography. Until 2000 in Italy a lot of Doctors considered ozone-therapy effect as placebo: I think also here it was the same. Today thanks to all that believed and believe in the ozone isn't like this any more.

3.6 Ozone in oncology and preclinical models in lung diseases

B. Clavo, N. Santana-Rodríguez, P. Llontop, C. Méndez, K. Zerecero, D. Fiuza (Spain)

The aim of this work is to show a backgorund, preclinical studies and some clinical data about the potential beneficial effects of ozone therapy in cancer patients, and some related studies carried out in our institution.
Several preclinical studies have shown that ozone induces radio-mimetic and synergistic effects with radiotherapy, increase chemo-sensitivity in colon carcinoma cells resistant to 5-fluorouracil or inhibits tumor progression in neuroblastoma as well as in uterine, lung and breast cancer cells. However, these effects of ozone are not directly applicable to clinical ozone therapy, where ozone has not a direct contact with tumor cells and the therapy is usually realized by auto-hemotransfusion or by rectal insuflation.

Session 4. Fundamentals - Part 2

4.1 Evaluation of competitive reactions of high concentration substrates with ozone

T. Mizuno, H. Tsuno, M. Sato, A. Hasunuma, S. Kumagai, Y. Suzuki, N. Sakagami (Japan)

Ozonation has been widely applied in public water and sewage treatment plants, and industrial wastewater treatment processes. In some industrial wastewater treatment, there are organic and inorganic substrates in high concentration, which are identified as individual substrates in some case and a main purpose of ozonation is to oxidize and remove them. This study examined reactions of nitrite ion (NO_2^-), azide ion (N_3^-) and dibutyl phosphate (DBP) separately using a lab scale reactor and the competitive reaction among nitrite ion, azide ion and dibutyl phosphate using a mock-up scale reactor including some by-products.
Nitrate ion (NO_3^-) was stoichiometrically produced by the oxidization of NO_2^- with ozone. NO_2^- was detected in a whole experimental time and NO_3^- was formed as a terminal substrate of the oxidization of N_3^- with ozone. A 79% of nitrogen was released through this reaction. The absorption of ozone was distinctly different in the oxidization of DBP and the oxidization efficiency of DBP was similarly different at the different condition, however the oxidization pathway of DBP seemed similar regardless of the difference mentioned above.
A chemical reaction-based model was applied based on the experimental results. All of the parent substrates, intermediate substrates and final products and the ozone absorption ratio were well reproduced by a model simulation. Namely, the competitive reaction was also well reproduced. The process consisting of basic experimental evaluation of each substrate and the mixture of substrates, modelling of each reaction and the multiple reactions, is a good procedure and this kind of chemical reaction-based model is a good tool to predict substrate concentrations even in the higher concentration.

4.2 Impact of ozone application to primary urban wastewaters: ozone transfer and organic matter change
M. Marce, S. Baig, S. Esplugas (Spain, France)

Ozonation have shown good results in organic matter removal and disinfection of urban wastewater after biological treatment. Indeed, the presented work aims to study the benefits of ozone application in early step of the treatment line. Therefore, ozone was applied to different primary effluents from municipal wastewater treatment plant. The ozone consumption can be described by IOD in the case of ozone fast reactions and the subsequent first order rate for slower reactions. Both parameters depend on the water quality as it can be notice by the large range of IOD determined (70-370 mg/L). Regarding the ozone impact in organic matter, different behaviours were observed depending on the transferred ozone doses. Even though, few changes have been observed at low ozone dose transferred lower than the IOD. The first kinetic stage of organic matter removal covers totally the IOD completion in the case of primary effluents. More studies should be done to investigate the ozone application to primary effluents.

4.3 Dissolution of nanosilver during ozonation of wastewater
V. Yargeau, M. T. K. Nguyen, L. Telgmann, C. Metcalfe (Canada)

The objective of this work was to investigate the fate of silver nanoparticles (AnNPs) during disinfection of wastewater using ozonation. Experiments were conducted at lab-scale by exposing suspensions of AnNPs to aqueous solutions of ozone of varying concentrations. Samples were collected before exposure and after exposure to ozone over time. Concentrations of total silver and dissolved silver were measured using ICP-OES and changes in the size or concentration of particles were determined using dynamic light scattering (DLS) and single particle ICP-MS (spICP-MS) analytical techniques. Measured concentrations of dissolved silver indicated that ozonation increased the dissolution of AgNPs, from 1% after a week in the control not exposed to ozone to a 43% dissolution in the solution exposed to ozone at a molar ratio of 3:1 (O_3:Ag). This trend was further evidence by a decline in the mean size of the AgNPs. Future testing is currently done with other AgNPs suspensions.

4.4 Effect of mono-metallic and bi-metallic supported catalysts on nitrobenzene ozonation
A. Abdedayem, M. Guiza, A. Ouederni (Tunisia)

Nitrobenzene (NB) is a toxic and poorly biodegradable contaminant, usually found in wastewater. This compound could be effectively eliminated using advanced treatment processes. This paper compares experimental results on detoxification systems based on ozone oxidation and catalytic ozonation process using different supported catalysts (Cobalt or/and Copper) based on olive stone activated carbon: Co-AC, Cu-AC and Cu-Co-AC. The effect of various parameters on process rates and removal efficiencies was studied, including: impregnation rate, pH and the presence of hydroxyl radical scavenger (tert-butyl alcool). Results show that ozone oxidation combined with activated carbon and supported catalysts increase the overall NB oxidation rate with respect to the ozonation process. Only 45% of NB removal was achieved using ozonation alone compared to 99.9%, 84% and 77% NB removal using respectively Co-AC, Cu-AC, and AC as catalysts. Rate constant of ozone decomposition using different catalysts was determined respecting the second order model. It was demonstrated that adding catalysts on the surface of activated carbon enhances significantly ozone decomposition into hydroxyl radicals.

4.5 Reaction-reactor modeling and kinetics of anthraquinone dye oxidation using ozone and UV radiation
M. E. Lovato, M. L. Fiasconaro, J. P. Torrez, J. C. Andini, C. A. Martín (Argentina)

Decolorization and mineralization of an anthraquinone dye, C.I. Reactive Blue 19 (RB19), by single ozonation, single UV radiation and ozonation combined with UV radiation (O_3/UV) was carried out in a laboratory-scale experiment. O_3/UV treatment resulted more effective for RB19 mineralization than the other two methods. The effect of several operational parameters, including initial dye concentration, pH, ozone dose, and UV radiation on the degradation of the dye and reduction of total organic carbon (TOC) was investigated. Major intermediates of RB19 degradation were identified by gas chromatography/mass spectrometry (GC/MS). A detailed reaction-rector model of the kinetics of RB19 degradation employing ozone with UVC radiation was developed. The description differentiates the existence of illuminated and dark sections of the reacting system. A distinction is made between the mass balances for ozone (operating in a well-stirred, recirculating, continuous flow reactor) and all other intervening species (operating in a well mixed, recirculating batch reactor). The ordinary differential equations resulting from the mass balances are reported. Upon estimation of the missing kinetic constants for RB19, simulation results show good agreement with experimental data.

Session 5. Ozone and Advanced Oxidation in Agrifood

5.1 Application of ozone/oxygen in the water treatment of shrimp farms
T. Naheiri, D. LeClercq, T. Elzey, J. Capettini (USA, France)

White Spot Disease (WSD) is a contagious viral epidemic afflicting shrimp farms worldwide. The shrimp farming industry in Madagascar and Mozambique were infected in September 2011. The disease caused a catastrophic drop in production in 2012: with some farms being dried out, and the rest struggling to avoid a similar fate. The causes of the contamination were determined to be contaminated ballast water and ocean currents carrying the virus to the Mozambique Channel. The reliance on high rates of unfiltered water exchanges to maintain water quality in the shrimp ponds played a major role in spreading the contamination. We will describe a technique that allowed the decontamination of the intake water while greatly reducing the traditional water intake into the shrimp farms. The use of ozone and oxygen dissolution into the sea water intake as well as very aggressive Bio-security measures allowed the Marima operation to produce disease free shrimp As illustrated below, raw sea water is pumped through a stream filter (aperture 1.5mm) to remove floating and suspended materials, crustaceans…. The pretreated sea water is again filtered through a 40 micron self-cleaning drum filter before it is contacted with an oxygen/ozone gas mixture. The last step is to allow the treated water to degas in a holding canal before it is introduced into the shrimp ponds.

5.2 A review of ozone applications in food industry
F. Violleau (France)

This paper briefly reviews the current state-of-the-art and emerging applications of ozone in the food industry. Applications of ozone in various food processing sectors including fresh produce, meat, fish, dried ingredients and liquid foods are widely reported. Ozone also offers the food industry an alternative or complementary cleaning and sanitizing agent. Better and better clarity of the regulatory status of ozone for food applications would greatly facilitate further adoptions.

5.3 Sulfate radical-based advanced oxidation process (SR-AOP) for winery wastewater treatment
J. Rodríguez-Chueca, T. Silva., C. Amor, M.S. Lucas, J.A. Peres (Portugal)

In this paper, the application of Oxone/M^{n+}/UV for winery wastewater treatment was investigated. Firstly, the optimal conditions were reached for COD removal in winery effluents with a COD concentration around 500 mg O_2/L. The optimal conditions were determined as: [Oxone] = 2.5 mM, [$M_2(SO_4)_n$] = 1.0 mM, initial pH = 6.5 and reaction temperature = 323 K. Under the given conditions, 51%, 42% and 35% of COD removal efficiency was achieved after 90 minutes using Fe(II), Co(II) and Cu(II), respectively, in combination with Oxone. The efficiency of the treatment can be increased significantly through the combination with UV radiation. The UV source has influence in the COD removal, the highest yield was reached with UV-A LED lamps (70 W/m^2), follows by lower intensity UV-A LEDs lamps (23 W/m^2) and mercury UV lamp,

achieving 78, 62 and 54% respectively. In addition, the optimal conditions were also able to reach high levels of COD removal in winery effluents with higher COD concentration in combination with UV-A LED radiation (70 W/m^2), achieving 78% of COD removal after 90 minutes of treatment. On the other hand, at 323 K, the best efficiencies were obtained when Co(II) was used as catalyst in combination with Oxone and UV-A LED 70 W/m^2 (78%), while at room temperature the best results were obtained with Fe(II) (65%). Finally, it was demonstrated that the use of reagents in several additions is more efficient than the used of them at once, reaching 87 and 75 respectively in presence of UV-A LED radiation (70 W/m^2), and 85 and 60% in absence of radiation. From this work, it can be concluded that Oxone/M^{n+}/UV-A LED oxidation process demonstrated high degradation efficiencies of COD, and it could be considered as one of the most promising technologies for practical applicability in large scale agri-food effluents treatment.

5.4 Application of UV-LEDs photo-fenton to candied fruit wastewater treatment

C. Amor, J. Rodríguez-Chueca, J. Fernandes, M. S. Lucas, P. Tavares, J. A. Peres (Portugal)

This work reports the treatment of crystallized fruit effluents through the application of a UV-A LED photo-Fenton treatment processes. These effluents are characterized by a very low biodegradability (BOD_5/COD = 0.06 – 0.19), being extremely recalcitrant for biological treatments. In a first instance, a Response Surface Methodology (RSM) was applied to achieve the optimal operational conditions to the UV-A LED photo-Fenton treatment process, maximizing the treatment efficiency by saving chemicals, time and increasing the COD removal. Under the optimal operational conditions ([H_2O_2] = 5459 mg/L, [Fe^{3+}] = 286 mg/L and a reaction time > 180 minutes), it was possible to achieve 45% of COD removal using a first UV-A LED photosystem using an irradiance of 23 W/m^2. This yield was considerably increased with a more powerful second UV-A LED photosystem. This powerful UV-A photosystem allowed achieving COD removals of 64 and 74% with an irradiance of 70 and 85 W/m^2, respectively. Finally, the combination of the UV-A LED photo-Fenton with coagulation-flocculation-decantation (CFD) was performed. Thereby, higher removals of COD were reached (80%), as well as almost total removal of turbidity (99%) and total suspended solids (95%). Biodegradability assays were performed to evaluate the potential combination of the chemical treated effluent with a biological treatment process. The second UV-A LED photosystem combined with Fenton and CFD allowed reaching a biodegradability index (BOD_5/COD) higher than 0.4 and, as such, the effluent can be considered biodegradable. Thus, the biodegradability's increase can allow the application of a conventional biological treatment step immediately after the photochemical/CFD combined process.

Session 6. Ozone in Medicine – Part 2

6.1 Paradigm change: "The Ozone a therapeutic mediator in MODIC processes"

P. Osvaldo Alberto (Argentina)

The MODIC changes are the result of a degenerative process of the endplate, which combines an evolutionary triad: clinically the pain, radiological evidence in the MRI and histological governed by the biomechanics and biochemistry; we developed our therapeutic strategy based on our clinical experience, besides the bibliography correspondence. The signal change of the vertebral endplates and the sub cartilage bone gave to the MODIC the capability of summarize and combine in his classification of the morphologic changes and the causative mechanisms, that until today is not clear enough and we should understand and use therapeutically models that change the paradigm of this phenomenon.

6.2 Treatment of symptomatic spinal degenerative pathologies by means of Oxigen-Ozone gas mixture. Observations after 23 years experience.

A. Alexandre, M. De Pretto, L. Corò, H. Badreddine, A.M. Alexandre, S. John, M. Brunori (Italy)

Disc degeneration is a difficult entity to study; its definition is vague, with diffuse parameters that are not always easy to quantify. In addition, there is a lack of a good animal model. Current treatments are predominantly conservative or, less commonly, surgical. (23)
Open surgery represents an option that is indispensable at times, but has proved to cause a number of complications or adverse effects, which are not clearly defined because the case records are generally confined to short-term follow-up, while complete reviews and metanalysis are lacking. Anyway failures are so frequent to have given rise to a specific pathological entity called the Failed Back Surgery Syndrome. The fact that in the long run a high percentage of patients will suffer recurrence and complications is evident. Research in spine surgery has proposed soft and less invasive techniques. Among these oxygen-ozone injections, which we could experiment in public health System through several years.
We have reviewed the experience given by the paravertebral application of ozone gas, and the one given by the use of intradiscal injection technique and with epiduroscopy, which is the epidural debridment from adhesions and scarring tissue by a flexible silicon endoscope containing a 0.9mm fiberoptics. We have compared experiences made in the past, with the present activity of our group. The senior Author started the activity 23 years ago. Two main differences in the activity: at the time we where using much higher doses than at present; Major Ozone Autohaemotherapy was not regularly included in the treatment for low back pain Patients, as it is now. The habit of including this treatment comes from the influence of Dr Roberto Dall'Aglio, who has been working in cooperation with us for several years. The protocol for these therapies are those suggested by Prof. V. Bocci and Dr. Viebahn. There were no statistically significant differences in the outcome between microdiscectomy and percutaneous intradiscal injection techniques at 18 months after treatment. There is, however, the absolute difference in invasiveness of the approach, the percutaneous procedure being closed and without general anesthesia, using just pharmacological sedation under anesthesiologic control. Microdiscectomy is indispensable in situations of particularly high pain levels and when there is acute and severe motor deficit. The morbility and mortality rates of the microdiscectomy procedure are well known, as is the possibility of engendering FBSS.

6.3 Combined intradiscal and periganglionic injection of medical ozone and periganglionic administration of steroids and anesthetic for the treatment of lumbar disc herniation: effects on disc size and lumbar radiculopathy

T. Lehnert, V. Jacobi, T. J. Vogl (Germany)

Lumbar disc disease accounts for a large amount of lost productivity in the workforce. Accurate diagnosis can be difficult and often requires interpretation. Treatment is controversial. Surgical treatment can be technically simple and professionally gratifying for the surgeon. Noninvasive procedures, minimally invasive percutaneous injection, and surgery represent the spectrum of treatments available in the management of lumbar disc herniation. Noninvasive treatments are plainly the first choice in most cases, but when patients fail to respond, minimally invasive percutaneous injection or surgery is indicated. Minimally invasive treatments were developed to offer good clinical results combined with a well-tolerated, low-cost procedure. In recent years, the procedures were further boosted by a growing number of reports of 5-20% treatment failure rate after surgical discectomy, with failed back surgery syndrome in 15% of cases. Ozone-oxygen therapy is one of the different minimally invasive treatments currently available. It is used in medicine to treat different conditions and is based on exploiting the chemical properties of ozone, an unstable allotropic form of oxygen with the symbol O_3 and a molecular weight of 48kDa. Ozone is now considered a real drug and, after reacting with body fluids, releases messengers and activates several mechanisms which are able to elicit multiple biological effects. The therapeutic window has been defined and, contrary to the dogma that "ozone is toxic any way you deal with it", it has been shown that ozone toxicity can be tamed and even totally avoided.

6.4 Ozone therapy in Dentistry. A brief review for Physicians

W. C. Domb (USA)

The 21st century dental practice is quite dynamic. New treatment protocols and new materials are being developed at a rapid pace. Ozone dental therapy falls into the category of new treatment protocols in dentistry, yet ozone is not new at all. Ozone therapy is already a major

treatment modality in Europe, South America and a number of other countries. What is provided here will not be an exhaustive scientific treatise so much as a brief general introduction into what dentists are now doing with ozone therapies and the numerous oral/systemic links that make this subject so important for physicians so that, ultimately, they may serve their patients more effectively and productively.

6.5 Integration of ozone therapy for head and neck infective and chronic disease

P. Mollica, K. Rockefeller (USA)

Treatment and management of complex chronic disease states within the head and neck have traditionally been treated within the scope and philosophy of allopathic based dental/medical model. Success is therapeutically based upon three stanchions symptomology, pharmacology and surgical intervention. As with the successes of any therapeutic model some complications are possible. Symptomatic treatment does not address the root causality of the disease process. In addition, the patient can experience pharmaceutical side effects and post-surgical compilations such as infection and impaired healing processes. Ozone therapy as part of an Integrative Biologic Dental Medicine model has allowed for a paradigm shift in thinking and approach to the ever-growing problems of therapy resistant infection, aging population and chronic long term aliments.

Session 7. Fundamentals – Part 3

7.1 Comparison of ozone- and UV- based techniques for the removal of metaldehyde

D. Vulpe, C. Tizaoui (UK)

A number of advanced oxidation processes were applied to compare for the removal efficiency of metaldehyde in water samples. The investigated processes comprised of various combinations of O_3, UV, carbon nanotubes (CNTs), H_2O_2, and ultrasound (US). None of the oxidants alone was capable to provide any significant removal of metaldehyde. Combinations of ozone with UV, CNTs, H_2O_2, US/CNTs and US have shown slightly improved removal percentages, by up to 22%, for O_3/US after 30 min reaction. Ozone combined with UV and H_2O_2 resulted in a significant change in metaldehyde concentration, with a 90% removal after 100 min reaction. However, it was found that UV combined with H_2O_2 without ozone was the most effective AOP to remove metaldehyde up to 98.5% in 100 minutes.

7.2 pH-sensitivity effects of generalized ozone decomposition models

J. Ferre-Aracil, V. Flores-Payán, A. López-López, S. C. Cardona, J. Navarro-Laboulais (Spain, Mexico)

A generalized ozone decomposition model is proposed valid for all the pH range. The model is defined by 10 apparent pH-dependent kinetic rate constants. A sensitivity analysis of these constants has been carried out considering the ozone depletion and the hydrogen peroxide formation. It can be concluded that only 4 kinetic rate constants are relevant for the ozone. The model has been experimentally checked following the ozone depletion in phosphate buffered solutions.

7.3 Kinetic Analysis of Ozone Gas Decomposition on MnO_2 Catalyst Supported on Alumina

A. Roca, A. Chica, S. C. Cardona, J. Navarro-Laboulais (Spain)

The ozone catalytic decomposition on manganese dioxide supported on commercial alumina based catalysts is studied in this work. Characterization of the catalytic material has been carried out by XRD, QA and BET area in order to determine its most relevant physic-chemical properties. The synthetized catalyst was tested in a fixed bed plug flow reactor under controlled conditions to determine their catalytic activity. A preliminary kinetic study of the reaction is also conducted, determining the main kinetic rate constants for the ozone decomposition and analysing the effect of the temperature on the reaction.

7.4 Analysis of the effect of the activated carbon amount in a batch ozonation-adsorption process

J. I. Lombraña, A. Menéndez, I. Alegría (Spain)

In this work, a mathematical model has been proposed as a basis for the study of the combined adsorption-ozonation process (Ad/Ox) with the complexity involved in a three-phase system. The description of this operation involves the consideration of several parameters regarding kinetic and adsorption phenomena of the system. This paper presents the analysis of Ad/Ox process compared with the simple ozonation, checking the favorable effect of the presence of activated carbon (AC) in ozonation, both primary degradation and mineralization of phenol solutions. The study focuses on Ad/Ox with granular activated carbon (GAC), and analyzes the phenol degradation kinetics depending on the amount of AC. In this way it was possible to establish an order of priority in the relevance of the parameters of the proposed mathematical model. It was found that the adsorption constant may vary meaningfully in the same process. Finally, the paper studies the behavior of GAC after using a given number of cycles. The kinetic coefficients concerning the liquid medium and the solid were estimated allowing to explain changes in process efficiency.

7.5 Influence of the control regime in ozonation efficiency of the basic cationic dye rhodamine 6G

J. I. Lombraña, A. de Luis, C. Rodriguez (Spain)

The oxidation of rhodamine 6G (R6G) in aqueous solution by ozone process was investigated in a pilot scale ozonation reactor. The mathematical model proposed in this work study the effect of the controlling step, whether mass transfer or chemical reaction, based on the ozone balance to the reacting system in a wide range of pH, showing that initially, dealing basically with primary degradation, the process is controlled by the G-L mass transfer step but, as the R6G ozonation progresses, the process becomes to be controlled by the kinetic reaction between ozone and R6G. The particular effect of pH, depending on the controlling step (mass transfer or chemical reaction), is decisive to select the most suitable pH under performance criteria of pollutant removal.While the 99% of rhodamine dye is removed during mass transfer control stage regardless of pH values, the percentage of TOC removal is increased during kinetic reaction control step and the most favourable pH, given the mass transfer characteristics of this study, was found at intermediate pH.

7.6 Disinfection effect of ballast water by a combination of ozone and bromine compound under low salinity water condition

S. Park, S. Yoon, T. Park (Korea)

Ozone has effective biocide and the main disinfectant in the seawater but a less effectiveness in case of low salinity water and fresh water. Because there is low content of bromine compound of fresh water, an amount of TRO generated by ozonation decrease rapidly. In this study, increased biocidal effect on low salinity ballast water was evaluated using a combination of ozone and bromine compound.
The ozonated oxygen stream was introduced into the ballast water as it was taken aboard through a venturi system in a side stream and then remixed into the main stream of the ballast water by the Single Point Injection System. Sodium bromide solution was injected into the upstream of side stream to reacted with ozone in ballast water. Water quality was measured including TRO and dissolved ozone during treatment process. Removal efficacy of zooplankton and phytoplankton was analyzed using stereoscopic microscope and fluorescence microscope, respectively. To detect TRO production, TRO Analyzers were installed and checked automatically. TRO was produced after sodium bromide was injected during ozonation of water. To determine biocidal effect, microorganisms were sampled during ballasting and deballasting and were analyzed. Zooplankton and phytoplankton group were significantly eliminated after treatment with combination of ozone and bromine compound. The present results demonstrated that treatment of low salinity ballast water using a combination of ozone and bromine compound was more effective for eliminate microorganisms than single ozone treatment. Furthermore, TRO is remaining in the treated ballast water and inhibit re-growth of microorganisms.

7.7 Removal of pharmaceuticals from water by the ozone/activated carbon coupling

P. Nebout, O. Chedeville, S. Delpeux, A. Di Giusto, B. Cagnon (France)

The treatment by adsorption, ozonation and ozone/activated carbon coupling of a solution containing six pharmaceutical compounds (metoprolol, ketoprofen, carbamazepine, terbutaline, fluoxetine and sulfamethoxazole) chosen among different pharmaceutical classes has been investigated. The efficiency of the processes was estimated through the removal of each target pollutant and the evolution of toxicity (inhibition of *Vibrio Fisheri* bioluminescence). The influence of pH, ranging from 3 to 7, on the processes efficiency was also studied. In each experimental condition, the fastest removal of the pharmaceutical compounds was achieved with ozone/activated carbon coupling. Nevertheless, the oxidation processes lead to the formation of toxic by-products which significantly increase the toxicity of the treated effluent. Their removal would require extending the treatment time and/or optimizing the process. Adsorption on activated carbon does not lead to the formation of by-products but it requires a long treatment time, especially for the most soluble compounds.

Session 8. Applicability in Waters

8.1 Ozone consumption efficiency on water decolorization process

A. Menéndez, J. I. Lombraña (Spain)

The aim of this work is to study the effectiveness of ozonation on decolorization taking into account ozone dosage. The fluorescent cationic dye Rhodamine 6G (Rh6G), a xanthene derivative used as an active medium for a large variety of dye lasers, was chosen as a model of dyes due to its particular behaviour at different pH values. Its dimerization and protonation make it interesant for analizing its ozonization also affected by the pH. For practical purposes, effect of pH on ozone dosage was studied.

8.2 Removal of xenobiotics and generation of by-products by ozonation in the context of tertiary treatment

B. Mathon, C. Pelletier, C. Miege, P. Bados, M. Coquery, J.-M. Choubert (France)

This work gives an in-depth overview of the chemical oxidation by ozone of selected xenobiotics present in effluents of conventional wastewater treatment plants. We performed a qualitative and quantitative overview of literature data describing the ozonation of 12 xenobiotics (pesticides and pharmaceuticals). In this aim, we built a database by compiling the results of experimental ozonation assays in lab and real scale conditions found in the literature. Special attention was devoted to selecting the data and compiling reliable results relevant to removal efficiencies. We also included metadata such as experimental operating conditions and by-products information. We classified these 12 xenobiotics into 3 groups according to the range of their direct kinetic rate constants (k_{O3}). We proposed best ozone doses for the elimination of xenobiotics by ozone. Finally, we performed experiments in semi-batch reactor applying ozone with secondary effluent previously spiked with a cocktail of 12 xenobiotics. We compared our results with existing results of the database obtained under similar ozone doses.

8.3 Photolysis, ozonation and chlorination of flame retardants in water treatment

R. Salgado, C. Chanfana, S. Martins, D. Galhanas, L. Epifâneo, J. Paulo Noronha (Portugal)

Flame retardants (FR) are added to different materials to reduce the risk of fire. They save lives, prevent injuries and property losses, and protect the environment by helping to prevent fires. In Western Europe, the average annual growth rate for 2007–2012 for all flame retardant chemicals is expected to be just over 3% in volume terms. The benefits of flame retardants must necessarily be balanced with the risks posed by these high production volume chemicals for human health and ecosystems. Several studies have determined that these compounds can lead to the emergence of several diseases as hormonal problems, neurological deficit, allergies and even cancer. These compounds are difficult to biodegrade in wastewater treatment plants (WWTP), and they can absorb to the sludge and/or be discharged by the WWTP effluent in the river basin. The dynamic of the adsorption equilibrium in the environment through the adsorption soil and sediments can promote the entrance in the urban water cycle, through the surface and groundwater and reach the drinking water system. Many studies reported the detection of FR in surface and groundwater used often for drinking water source. The degradation of triphenylphosphate (TPP), Hexabromocyclododecane (HBCD), Dibromoneopenthyl glycol (DBNPG), tetrabromobisphenol A (TBBPA) and the bisphenol-A (BPA) under three different oxidation/disinfection technologies (e.g. photolysis, ozonation and chlorination) as an *ex-situ* water treatment (WT) technology is the main goal of this study. The degradation of the target compounds are incomplete for the hydraulic retention time normally applied for the oxidation and disinfection purposes and an additional polish step with activated carbon is convenient in the water treatment. The use of photolysis, ozone and chlorine can promote the formation of by-products, in some cases, more toxic than the target compound. This study shows an important contribution for the determination of the kinetic parameter to help in the design of the WT facilities and the by-products generated during the oxidation process can be also removed with the activated carbon and reduces the impact in human health when these compounds are present in surface and groundwater, source for drinking water systems.

8.4 Analysis of microbiological quality of surface waters in Ebro river basin as a first approach to establish the origin of the present contamination

A. López, R. Mosteo, M. P. Ormad, J. L. Ovelleiro (Spain)

European Union Water Framework Directive (WFD) sets the objective of achieving the 'good status' of all surface and ground waters by the present year. In Spain, The Confederación Hidrográfica del Ebro (CHE) controls water masses in Ebro watershed by means of the CEMAS network (Control of the Status of Surface Water Bodies), that includes the monitoring of protected areas in order to fulfil current laws and to establish a quality status. About 130 sampling points are controlled in surface waters and total coliforms, *Escherichia coli*, Streptococci and Salmonella are analysed to determine microbiological quality. Although at the present time more than 95% of urban wastewater in areas with more than 500 inhabitants is treated, Municipal Wastewater Treatment Plants don't have disinfection systems so that effluents contain an elevated microbiological contamination. The aim of this work is to analyse the microbiological quality of surface waters in Ebro watershed by studying microbiological results of CEMAS control network. Some wastewater treatment plants effluents are also analysed to establish, as a first approach, the origin of the microbiological contamination in receiving waters. The microbiological analysis obtained in CEMAS control network show concentrations up to 10^4UFC/100ml of total coliforms and the presence of Salmonella in the 13% of sampling points in the period of analysis. On the other hand the results obtained at MWTPs showed a concentration at the effluent of 10^4-10^6UFC/100ml of total coliforms, 10^3-10^5UFC/100ml of *E.coli*, 10^2-10^4UFC/100ml of streptococci. An impact related to the discharge in surface waters of treatment plant effluents is observed.

Session 9. Ozone in Medicine – Part 3

9.1 Experimental estimation of microcirculation adaptation to systemic injection of the ozonized saline

S. P. Peretyagin, A. K. Martusevich, P. V. Peretyagin (Russia)

The aim of this paper is study of microcirculation state under prolonged parenteral use of the ozonized saline. experiment was performed on 40 Wistar rats, divided into 4 groups. Rats of first group (n=10) got 30 infusions of saline daily (control group). Animals of second, third and fourth groups (n=10 in each group) were infused with ozonized saline (saturating ozone concentration – 3000, 10000 and 40000 mcg/l, ozone dose – 0,6; 2 and 8 mcg, respectively) during 30 days. experiment was performed on 40 Wistar rats, divided into 4 groups. Rats of first group (n=10) got 30 infusions of saline daily (control group). Animals of second, third and fourth groups (n=10 in each group) were infused with

ozonized saline (saturating ozone concentration – 3000, 10000 and 40000 mcg/l, ozone dose – 0,6; 2 and 8 mcg, respectively) during 30 days. Microcirculation state was studied by lazer Doppler flowmetry with "LAKK-02" device (Moscow, Russia) and by morphological investigation of vascular structure. Intensity of microcirculatory blood flow, its regulatory mechanisms and bypass activation degree. Registration of microcirculation was executed under combined anaestesia («Zoletil» + «Xylavet»). Statistical analysis of the data was performed with Statistica 6.0 program. Our investigation allow to state that prolonged (30 days) infusions of ozonized sodium chloride solution lead to prevalent increasing of microcirculation intensity in comparison with use of oxygenated saline. It is important that most optimal action on microcirculation state was observed for low ozone doses (3000 mcg/l). This tendency was supported with dynamics of regulatory mechanisms. Thus, the most optimal effect is providing adaptation of microcirculation should be recognize for the use of low doses of ozone (0.6 mcg/day).

9.2 Characterization of ozone decomposition in different aqueous solutions used in medicine and correlation with their bactericidal effect

K.N. Kontorchshikova, A. Pérez, T. Poznyak, I. Chairez, A. A. Sibirkin, L.M. Obukhova (Russia, Mexico)

Dissolved ozone in differente susbstances has been used as bactericidal substance for many years. The present study analyzed the effect of dissolved ozone concentration, its self-decomposition kinetics, byproducts distribution and the presence of chlorine ions on bactericidal effectivity of different ozonated solutions. These parameters and the ozone residence time were determined using injectable water (as reference) and physiological solution (NaCl, 0.9%) under the same operational conditions: ozone concentration in the gaseous phase of 4.6, 10, 20 and 30 ± 0.2 mg/L, that produced (according to Henry's law) 1.15, 2.5, 4.0 and 7.5 ±0. 2 mg/L in aqueous phase, respectively. A kinetic study was carried out to characterize the ozone self-decomposition. The ozone decomposition rate was 1.5 times higher in physiological solution than injectable water. This fact was explained by the presence of chlorine ions (as a result of NaCl dissociation), which reacted with ozone. In the case of the experiments when lowest ozone concentrations in the gaseous phase (0.59 and 0.67 mg/L) were used, the accumulation of anions of chlorinated acids was observed. When dissolved ozone concentrations were lower than 0.67 mg/L, an insignificant presence of hydrogen peroxide (about 0.0004%) was found. The bactericidal efyciency of dissolved ozone and its byproducts (self-decomposition) at higher ozone concentration in the gaseous phase (30 mg/L) was studied with *E. Coli* and *P. Auroginosa.* For both microorganisms, the best desinfectation percentages were obtained when the ozonated physiological solution was the carrier medium: *E. Coli* was deactivated in 12 hours and *P. Aeruginosa* in 8 hours.

9.3 The increase of treatment's efficacy of duodenal ulcer in patients aged 40-50 years.

A. V. Bulat, V. V. Bulat (Moldovia)

Ulcer disease is important in the structure of internal organs' affection, constitutes a common disease of gastrointestinal tract and continues to be one of the main problems of gastroenterology. Recently significantly increased the frequency of given disease registration in middle age patients, however patients of 40 - 50 years reach about 18% of all patients with ulcer disease.

9.4 Local and systemic action of ozonids contained cosmetic gels on organism

O. Bitkina, S. Peretyagin, A. Solovieva, O. Grechkaneva, A. Martusevich, M. Bugrova, P. Peretyagin, N. Prodanets (Russia)

In dermatocosmetologic practice a lot of drugs and physiotherapy procedures are using for correction of local lipodystrophy, aging skin atrophy, improvement of mechanical skin property, skin pigmentation, elastans, microcirculations parameters, barrier epidermis functions. But some of them have wide spectrum of contraindications and demonstrates temporary effect. Last years cosmetic gels and creams contained active oxygen specimens earned a positive estimation. But its local and systemic sanogenetic effects have been investigated deficiently. Aim of this work is investigation of local bloodstream reactions and systemic responses of organism homeostasis in epicutaneous applications of cosmetic gels contained different amount of active oxygen as ozonids form.

9.5 Ozone Therapy in Dentistry. A Brief Review for Physicians (cont'd)

W. C. Domb (USA)

See abstract 6.4

9.6 The lipid metabolism and matrix metalloproteinase-9 in patients with metabolic syndrome

C. Kontorshchikova, J. Tikhomirova, E. Koroleva (Russia)

Metabolic syndrome has attracted special attention of many researches for the last decade. It can be explained by its wide distribution and further development of serious pathology such as diabetes mellitus 2 type and cardiovascular diseases.
The aim of the study was to investigate the serum biochemical parameters in patients with metabolic syndrome before and after ozone therapy. The investigations were carried out in blood plasma in 221 patients. Ozone therapy course of 10 procedures (ozone concentration of 400 µg/l in 0,9% NaCl solution) done intravenously every second day was administered to all patients. We analysed the obtained parameters of lipid metabolism (total cholesterol, triglycerides, Chol. HDL, Chol. LDL, apoA, apoB, free fatty acids) and activity of matrix metalloproteinase-9 (MMP-9).
The results revealed that hypertriglyceridemia exists only in the third of patient population. While the high level of free fatty acids is demonstrated in 100% persons with the pathology observed and is 0,83 ± 0,06 mmole/L on average. High level of free fatty acids leads to accumulation of lipid metabolism intermediates, which inhibit insulin signal transmission and is caused insulin resistance. 71.6% of metabolic syndrome patients had the increased serum matrix metalloproteinase-9 (MMP-9) activity. Under the influence of low ozone therapeutic doses the normalization of parameters of lipid metabolism (total cholesterol, triglycerides, Chol. HDL, Chol. LDL, apoA, apoB) took place, reduction of free fatty acid level by 16%. Ozone therapeutic procedures caused the decrease in activity of MMP-9 in 73% of cases. Thereby we notice importance of the lipid parameters testing in diagnostics of MS on early stage and probable usage these lipid parameters and MMP-9 as criteria of therapy safety.

9.7 Distinctive features of medical ozone generator for ozonated liquids prepearing with various density

T. Barkhotkina, R. Tomashevskyi, N. Mahonin (Ukraine)

Currently used quite a large number of methods local and systemic impact of medical ozone in a wide range of pathological conditions of organs and systems.
Ozone and various ozonated products (saline, bidistilled or distilled water, different oils) are recommended by many authors. Their application in various areas of medicine possess many positive properties and allow to solve the difficulties in the treatment of a wide range of diseases, which cannot be solved by medicamentous means of traditional medicine.

9.8 Scalar wave morphogenetic field mechanics and ozone therapy as a revolutionary model for bioenergetic regeneration

J. Rivera-Dugenio (USA)

The author proposes an advanced quantum medicine model based upon organic scalar-wave morphogenetic field mechanics, biocybernetic médicine, and ozone thérapie. Individuals with acute, standard and chronic health conditions stem from underlying distortions within the energetic, mental, emotional and physical systems within the biological energetic organism, however, the frequently ignored aspect is not whether the immune system is weak or strong but rather whether the immune system is blind or not. What determines an immune system

being able to recognize and address stressors within the bio-energetic organism is the capacity for uninterrupted cellular communication with the DNA and RNA. It is my experience with treating real-life cases that by understanding and applying the principles of the advanced quantum médicine model (BioCybernetic Médicine, advanced scalar wave morphogenetic field mechanics and ozone thérapie) individuals with acute, standard and chronic health conditions can assist their own immune system via scalar wave information to stimulate the self- regulating healing abilities of their own biological-energetic systems. Over a 12-month period, subjects with acute, standard and chronic health conditions who were treated via advanced scalar-energy technology and revolutionary ozone thérapie protocols achieved higher self-healing rates with no reversion. Data suggests that inclusion of the advanced quantum médicine model within one's own preventative health protocol may lead to important advancements within the current personalized, preventative médicine model.

9.9 Prospects for combined treatment of chronic non specific endometritis with ozone and Bacteriophage therapy

N. Nikishov, G. Grechkanev, T. Motovilova, I. Ponomaryova, T. Boychenko, I. Zelenskaya, A. Soshnikov (Russia)

Chronic inflammation of endometrium is of the possible causes of female fertility problems. Not always is routine therapy with antibacterial chemical agents approved in endometritis. The aim of the clinical trial was to ascertain the resources of the ozone therapy and bacteriophage therapy used as a combined treatment. Ozone therapy of intra-uterine instillations with ozonated normal saline (400 ml), (ozone concentration in ozone/oxygen mixture - 4500 mcg/l). In addition, at the end of ozone procedure polyvalent bacteriophage preparations (4-7 ml-№10) were instilled into uterine cavity. Combination of ozone and bacteriophage therapy in complex anti-inflammatory treatment was found to produce pronounced clinical, local (sanation of endometrium, normalization of vaginal microflora and immunity indices) and systemic (normalization of lipid peroxidation) effects. There is a good prospect for such treatment in case of chronic nonspecific endometritis.

9.10 Comparative study of action of ozone and singlet oxygen on blood oxidative metabolism in vitro

A. A. Martusevich, A. K. Martusevich, S. P. Peretyagin (Russia)

The aim of this work was comparative estimation of ozone and singlet oxygen action on balance of pro- and antioxidant systems in human blood samples in vitro. Blood samples of healthy peoples (n=10) was divides into five vials equally. The first one in each study was control (without any manipulations). The second sample was processed with molecular oxygen (100 ml during 3 min). The third sample was sparged with ozone-oxygen gas mixture (ozone concentration – 500 mcg/l, 100 ml, sparging time – 3 min). The fourth and fifth samples were processed with singlet oxygen-containing gas mixture (generator power – 50 and 100%, respectively; processing time – 3 min). In blood plasma intensity of lipid peroxidation and total antioxidant activity was estimated by Fe-induced biochemiluminescense analysis with special device "BHL-06" (Nizhny Novgorod, Russia). This technique also allowed to registered erythrocytes peroxide resistance. In addition, we studied malonic dialdehyde level in blood plasma and in erythrocytes. It was stated that molecular action of ozone and singlet oxygen on oxidative metabolism in blood samples in vitro is clearly different. The ozone initiates lipid peroxidation with predominant elevation of antioxidant reserves. The singlet oxygen effect includes significant activation of plasma antioxidant potential without intensification of lipid peroxidation processes. It is important that effect of singlet oxygen in dose-dependent. On our opinion, these results are useful for technologies of correction of oxidative stress or misbalance of blood and tissue pro- and antioxidant systems (with the use of inhalations of singlet oxygen-containing gas mixute) and for pretransfusional processing of blood and its main components.

Tuesday, 30 June

Session 10. Advanced Oxidation: Photocatalytic systems

10.1 Cyanide removal from water by photocatalytic treatments with TiO_2

N. Miguel, L. Alonso, N. Pueyo, S. Escuadra, R. Mosteo (Spain)

The cyanide ion (CN^-) is a chemical substance with well known toxic nature. The maximum concentration of CN^- allowed in natural waters is regulated by current legislation. For this reason, it is necessary to know the presence of this substance in wastewaters and, if necessary, reduce it before discharge. Currently there are many treatments capable of removing cyanides from water, but a lot of them do not eliminate completely cyanides or generate toxic by-products. Therefore the cyanide removal from water by TiO_2 photocatalytic treatments is studied. Photocatalytic treatments are advanced oxidation processes capable of degrading a variety of contaminants without generating toxic by-products. Cyanide removal using TiO_2 (1g L^{-1}), H_2O_2 (10 mM) and UV radiation for 30 minutes is studied in synthetic samples with an initial cyanide concentration of 5 mg L^{-1}. The higher removal of cyanides from the water was achieved by the TiO_2/UV treatment (80%). The time of the treatment TiO_2/UV was varied and the CN^- removal of water was practically complete in 80 minutes. The effectiveness of the solar radiation is also checked as a source of UV radiation in the photocatalytic treatment achieving a CN^- removal of water up to 90% after 60 minutes. Finally, TiO_2 photocatalysis is applied to a sample of real industrial wastewater. In this case, CN^- removal is also very effective (> 90% in 100 minutes) although the removal yields obtained some lower (about 10%) in comparison to the obtained in synthetic samples.

10.2 Removal of acid red 1 by TiO_2 nanoparticles coated polyethersulfone membrane under UV irradiation

I. Kovács, S. Kertész, S. Beszédes, C. Hodúr, I. Zita Papp, Á. Kukovecz, Z. László (Hungary)

Polyethersulfone (PES) membranes are used in a wide range for water and wastewater treatment due to their physical and chemical properties, but despite their improved properties membrane fouling remains a problem. In order to overcome this problem a great deal of interest has been focused on modifying membranes with TiO_2 as a photocatalyst to reduce fouling and to make the organic component removal more efficient. In this study polyethersulfone membranes with different pore sizes (0.05 and 0.2 µm) were coated with commercial TiO_2 P25 and synthesized TiO2 nanoparticles (NP) by filtering the TiO_2 solution thruogh the membrane. In order to test the photocatalytic activity of Acid Red 1 dye solutions were filtered with commercial PES membranes with and without TiO_2 coating. Coated membranes had significantly lower fluxes compared to the neat membranes. Contact angle measurements showed that TiO_2 P25 formed a very hydrophilic coat on the membranes on the contrary TiO_2 NP increased the hydrophobicity of the surface. UV irradiation had an effect on both the neat and coated membranes flux values. Relative dye fluxes were calculated against the equivalent water fluxes and were compared. UV irradiation increased the dye elimination efficiency of the coated membranes, which proves the TiO_2 coatings photocatalytic activity.

10.3 Nano-structured N-doped TiO_2 photocatalytic membranes for water treatment

I. Horovitz, D. Avisar, R. Grilli, A.-D. Enevoldsen, D. Di Camillo, M. A. Baker, L. Lozzi, H. Mamane (Israel, UK, Denmark, Italy)

Commercial α-Al_2O_3 photocatalytic membranes with a pore size of 200 and 800 nm were coated with N-doped TiO_2 photocatalytic film using a sol-gel technique for concurrent filtration and photocatalytic oxidation. The concentration of N found by X-ray photoelectron spectroscopy was in the range of 0.3–0.9 atomic percentage with 78–84% coverage. Membrane permeability after coating decreased by 50% and 12% for the 200- and 800-nm membrane substrates, respectively. The photocatalytic activity of the N-doped TiO_2-coated membranes was examined in a laboratory flow cell based on degradation of the model micropollutant carbamazepine and inactivation of MS2 bacteriophage, using a solar simulator as the light source. N-doped TiO_2-coated membranes showed enhanced activity for UV wavelengths, in addition to activity under visible light. Experiments of photocatalytic activity under varying flow rates concluded that the process is in the mass-transfer control regime. N-doped TiO_2-coated membrane was found to be highly efficient for the inactivation of MS2 virus. However, different water quality revealed that virus interaction with the catalytic surface is necessary.

10.4 Heterogeneous photocatalysis using supported Nano-TiO_2 for micropollutant elimination

M. Micó, M. Arnaldos, T. De la Torre, C. Rodríguez, C. Fernández-Rodríguez, J. M. Doña Rodríguez, J. Juan Malfeito (Spain)

Heterogeneous photocatalysis using nanostructured titanium dioxide (TiO2) supported on borosilicate tubes and alumina blocks has been studied for the elimination of emerging contaminants from wastewater effluents. Adherence and aging of the catalyst were studied as well as the influence of the matrix in the photocatalytic kinetics. Operational parameters were also optimized using a model contaminant (methylene blue). The removal rates for three selected micropollutants at optimal operational conditions varied from 3 to 97% depending on the contaminant and the residence time, being necessary a residence time of minimum 2 h in order to achieve acceptable removal rates.

10.5 New insights into mechanism of enhanced photocatalytic efficiency of metal ion doped TiO_2

Y. Xie, J. Xiao, H. Cao (China)

TiO_2 photocatalysis is able to convert photon energy into chemical energy, and it is widely investigated in organics degradation for wastewater treatment [1-2]. Among all the attempts, metal ion doping is a super-simple and high-performant approach to promote the photonic efficiency of TiO_2 [3-4]. The key standpoint favors the role of doped metal ions as electron traps in enhancing surface-charge separation during TiO_2 photocatalysis. Besides that, we demonstrated two disparate impacts of metal ion doping on reactive species generation and further promoting TiO_2 photocatalytic property.

10.6 Photoelectrocatalytic degradation of pharmaceutical pollutant in wastewater

S. Wohlmuth da Silva, B. Szortika, D. Mara Walker, M. A. Siqueira Rodrigues, A. Moura Bernardes (Brazil)

In this work, the photoelectrocatalytic (PEC) process was applied in the degradation of the pharmaceutical active compound (PhAC) azithromycin (Azi) in wastewater. The use of a mixed metal oxide anode composed of titanium doped with (70-30%) TiO_2RuO_2-Ti, UV radiation source of 250 W mercury vapour lamp, a current density of 10 $mAcm^{-2}$ and different treatment times were investigated. The samples were characterized by UV/Vis and total organic carbon (TOC). The reaction kinetics and the electric energy required to degrade a volume of $1m^3$ of contaminated wastewater were calculated and the pH was measured. The cyclic voltammetry was also performed, and the results showed that the Azi presents no reduction neither oxidation peaks. Analysis by UV/Vis showed that Azi does not absorb radiation in the studied spectrum, so it will not be directly degraded by UV radiation. Azi could be degraded by radicals generated in the PEC process. TOC shows a reduction of 52 and 96% after 6 and 12h treatment time, respectively. Based on the treatment time of 12h, the reaction kinetics was calculated presenting a pseudo first-order kinetics and a *k'* value of 0.0045 min^{-1}. The electric energy was also calculated, exhibiting a 6,89 kWh to treat $1m^3$ of contaminated wastewater. PEC process presents promising results in the degradation of Azi. However, studies of ecotoxicity and byproducts formation analysis should be carried out.

10.7 Coated mesh reactor for the elimination of gaseous pollutants via heterogeneous photocatalysis

C. Passalía, E. Nocetti, O. Alfano, R. Brandi (Argentina)

Dichloromethane (DCM) is a typical indoor pollutant which affects the human health. Heterogeneous photocatalysis is a suitable technology for addressing its control. This article presents a study of the photocatalytic oxidation of DCM in the gas phase, employing a coated mesh, laboratory scale, continuous reactor. Results indicate the feasibility of the DCM elimination, with conversion levels within expected values.

Session 11. Applications for drinking water

11.1 Peroxone in drinking water treatment: Dutch challange

A. Knol, K. Lekkerkerker-Teunissen, C. Houtman, J. Scheideler, A. Ried, H. Van Dijk (The Netherlands, Germany)

Advanced oxidation with O3/H2O2 (peroxone) is conducted on pilot scale on pre-treated Meuse river water to investigate the conversion of organic micro pollutants (OMPs) and the formation of bromate. Fourteen selected model compounds are dosed to the pre-treated river water on a regular basis to assess the efficiency of the peroxone process and to establish the influence of the water matrix. The ozone dose is the main factor in the conversion of the model compounds. The conversion of OMPs can be increased by further increasing the ozone dose, however, the ozone dose is limited due to bromate formation. The hydrogen peroxide dosage has only a minor effect on the conversion, but it limits the bromate formation effectively. In terms of limited chemical consumption, maximal conversion and adherence to the strict Dutch guideline for bromate in drinking water of 1 µg/l, a practical full-scale setting is 6 mg/L peroxide and 1.5 mg/L ozone. During the investigation period, the average conversion of the model compounds was well over 70%. The conversion of OMPs is higher at higher water temperatures and lower concentrations of DOC and bicarbonate. The bromate formation also is higher at higher water temperature and lower bicarbonate concentration and proportional with the bromide concentration. The peroxone process can be controlled with the (derived) parameters water temperature, bicarbonate and DOC.

11.2 Seasonal occurence of micro pollutants in drinking water sources – evaluation of treatment strategies using AOPs and ozonation

J. Scheideler, B. Holden, K.-H. Lee (Germany, UK, Korea)

Ozone and advanced oxidation processes based on ultraviolet light, ozone and hydrogen peroxide have proven their reliability and efficiency in removing micro pollutants and taste and odor causing compounds in several full scale installations worldwide. Some of these contaminants only occur for a few months in the raw water source due to agricultural activities or algae blooms. To evaluate the best treatment strategies to target these seasonal issues data from two long period pilot tests have been collected. Pilot tests using Ozone and UV AOP at a water works in the United Kingdom were conducted to evaluate the best treatment strategy to remove pesticides from the water which occurrence and concentration is influenced by farming activities. The tests were conducted in a semi-technical scale providing data for a full scale design and evaluation. At a water work in Korea UV AOP pilot tests were conducted to evaluate the efficient removal of seasonal occurring Taste&Odor compounds. By comparing the results from these studies with previsous studies and data from full scale installations treatment strategies were developed providing the operator with the lowest overall treatment costs considering if it is a retro-fit, new build or upgraded water works.

11.3 Rapid bench scale experiments for the selection of a treatment strategy for drinking water production

T. Merle, W. Pronk, U. Von Gunten (Switzerland)

In the east side of Basel, the strategy for the drinking water provision consists of a succession of artificial and natural treatment steps. River Rhine water is clarified prior to infiltration through canals and ponds in the Hardwald forest. The groundwater is then pumped out of the aquifer after a minimum of 7 days residence time and filtered through a granular activated carbon (GAC) filter as a polishing treatment for micropollutant removal, which accumulated in the soil over many decades and are slowly released in low concentrations. Since GAC filtration has a limited adsorption capacity, it was decided to investigate different treatment steps (e.g. oxidation, combination adsorption/oxidation) with rapid bench-scale experiments.This approach has a general applicability as a comparative decision tool for appropriate treatment of various water resources.

11.4 Production of micro-pollutants free and bio-stable drinking water – An insight study of the multi-barrier concept

J. Wang, Y. Zhang, E. Wong, A. Ried, R. Xie, C. Qin Wei, Y. Xing, L. Zhang (Germany, Singapore)

For drinking water treatment, a filtration step is normally positioned after ozonation.
Xylem and Singapore Public Utilities Board (PUB) started a combined ozone/biofiltration pilot study at a waterworks in Singapore in the beginning of 2014. In addition to confirming the multi-synergies between ozonation and biological activated filtration, the study was aimed to optimize the operation conditions and select the better biofilter media (Anthracite vs. Granular Activated Carbon [GAC]). These tests included adjustment of biofilters Empty Bed Contact Time (EBCT) and run time to observe the various impacts on biofilters performance, e.g. biomass growth on the filter media and Assimilable Organic Carbon (AOC) removal efficiency by the filter. Occasional spiking tests were also conducted with taste & odour compounds as organic impurity indicator to enable evaluation of the fate of these impurity compounds across the filter media. It was found that ozone plus GAC and ozone plus Anthracite ensured the bio-stability of the water in terms of AOC removal in the filter outlet. GAC was more efficient than Anthracite for Taste and Odour compounds removal.

11.5 Determination of optimum O_3 dose in drinking water treatment in Korea

J.-W. Kang, S. Kim, M. Kwon, W.-H. Joe (Republic of Korea)

This study focused on the determination of the optimum O_3 dose for disinfection and oxidation to improve the energy efficiency of drinking water treatment. To determine the optimum O_3 dose in drinking water treatment, we measured the O_3 and OH• exposures in various conditions (i.e., four different water sources, temperatures, and initial O_3 doses). In general, the decomposition of O_3 and the formation of OH• are notably different according to the conditions, but the R_{ct} values show a linear relationship with the *kc* value. Using the relationship equation, the OH• exposure could be calculated throughout the reaction time, and the required O_3 dose could be determined using the proposed equation.

11.6 Effect of pre-ozonation on Haloacetic Acids formation in Ganga river water at Kanpur

P. Bose, N. Rao (India)

The objective this study was to examine the extent of removal of HAA precursors and consequent reduction in HAA formation in Ganga water at Kanpur (GW), which contains appreciable quantities of effluent organic matter (EffOM). The GW samples obtained after coagulation was ozonated at three ozone doses. In all cases, ozonation at progressively higher doses resulted in progressively lower 7-day total HAA values by up to 58 percent.

11.7 Water treatment plants using large stainless steel filters: New perspectives for ozone biofiltration process

M. Brugger, S. Forberg Liane (Germany, Norway)

Ozone bio-filtration is an established process for treating surface water to potable water. This report describes as practical example a new way for realisation of treatment plants using filters in stainless steel manufactured on site. In 2013-2014 an entirely new water treatment plant was built up to reduce the colour and TOC and to increase the hygienic safety using surface water from a Norwegian lake. This plant has a treatment capacity of max. 680 m³/h and operates with the ozone bio-filtration process. Since the end of August 2014 the new plant is continuously in operation to supply potable water to the net.

Session 12. Ozone in Medicine – Part 4

12.1 Targets of medical ozone in rheumatoid arthritis. How they impact in the clinical scenery?

O. S. León Fernández, R. Viebahn-Haensler, L. Delgado Roche, B. Tamargo Santos, I. Wilkins Pérez, G. López Cabreja, I. Serrano Espinosa (Cuba, Germany, Mexico)

Rheumatoid arthritis (RA) is a common chronic inflammatory and destructive arthropathy that cannot be cured and that has substantial personal, social, and economic costs. The long-term prognosis is poor: 80 percent of affected patients are disabled after 20 years, and life expectancy is reduced by an average of 3 to 18 year. On the other hand, current slow-acting antirheumatic drugs have limited efficacy and many side effects. Moreover, they do not improve the long-term prognosis of rheumatoid arthritis. In this work is showed medical ozone efficacy in RA. Reduction of inflammatory reaction, mRNA transcripts as well as regulation of oxidative stress and autoimmunity mediators in 10S fraction of peptidoglycan–polysaccharide model were demonstrated. 30 patients with active RA methotrexate resistant were treated with medical ozone by rectal insufflation. 20 treatments of ozone achieved a reduction of Pain (49%), Reactive "C" Protein (60%), Erythrosedimentation (54%), DAS-28 (51%), and HAQ-CU (49%). Besides, after 20 treatments of medical ozone the antioxidant/prooxidant balance of patients was improved and it was in line with clinical response.

12.2 Treatment of the diseases of Temporo Mandibular Joint with ozone and PRP infiltrations

F. Pastor Loscertales (Spain)

The disorders and the degree of pain which affect the TMJ constitute the Costen Syndrome because was described by this otolaryngologist in 1934. This syndrome is manifested as a pain in one or both temporomandibular joints located before one or both of the ears and can be irradiated to head, mouth, nose, cervical region and shoulders. Is produced because an alteration or dysfunction in the normal anatomic relation between the disc, the condyle and the glenoid cavity which interferes with the usually soft movement of the TM joint and produces a progressive damage of self.

12.3 Knee osteoarthritis. Predictive factors for ozone treatment

J. Baeza Noci (Spain)

The use of ozone, intra or periarticular, for knee joint osteoarthritis (KO) is clearly justified by its anti-inflammatory and antioxidants properties, that should diminish the arthritic episodes of this disease. Presently, we lack of enough evidences about disease modification or predictive factors of evolution. This work is based on an open prospective study started in February 2002 and stopped in February 2010. Recruitment criteria were: Kellgren & Lawrence KO classification: any, one side/bilateral, no previous joint trauma, no rheumatic disorder, no previous surgery (but arthroscopic meniscectomy), NSAIDs for at least two months, promise to abandon any anti-inflammatory drugs during ozone treatment and informed consent. Clinical evaluation was done using WOMAC questionnaire, pre-treatment and 1, 3, 6, 12 months after treatment.

12.4 Correlation of plasma Interleukin 1 levels with disease activity in rheumatoid arthritis (RA) with and without ozone. A clinical study

Z. Fahmy (Germany)

Rheumatoid arthritis (RA) is the most severe destructive inflammatory joint disease, frequently accompanied by rheumatoid nodules, vasculitis, serositis, and pulmonary fibrosis. Its clinical course is characterized by involvement of the small joints of hand and foot followed by centripetal progression to larger joints (knee, hip, shoulder) and finally even to the cervical spine. Cytokins such as Il-1, IL-6, TNF-α .... are specific markers as follow up critera for treatment success.

Session 13. Advanced Oxidation: UV and ozone systems

13.1 On the reaction mechanism of DEET removal through visible light assisted photocatalytic ozonation with WO_3 catalyst

E. Mena, A. Rey, F. J. Beltrán (Spain)

This work focuses on the photocatalytic degradation of mechanism of N,N-diethyl-meta-toluamide (DEET), in aqueous WO_3 suspensions under simulated solar light and in presence of ozone. This combined process (Photocatalytic ozonation) proved to be an efficient treatment to completely remove DEET in less than 30 min. Different oxidation products, some of them with several isomers, were detected by liquid chromatography time-of-flight mass spectrometry and ion chromatography analyses, and the evolution of their relative abundances with reaction time was established. The efficiency of photocatalytic ozonation treatment was pointed out not only in the DEET depletion rate but also in the evolution of the main intermediate species. All the large intermediates detected were completely removed at 60 min reaction time and only short-chain organic acids with very low toxicity were the main remaining by-products, in concentrations in agreement with the mineralization degree achieved (up to 60% in 2 h). A reaction mechanism of photocatalytic ozonation of DEET was proposed and discussed. In general, the degradation of DEET involves steps of mono- and poly-hydroxylation and/or oxidation, de-alkylation and finally opening of the aromatic ring which evolves to the formation of short-chain organic acids and mineralization to CO_2 through further oxidation.

13.2 Removal of phenyl urea based herbicides by combination of ozone and photocatalysis under N-doped titania

R. R. Solís, F. J. Rivas, O. Gimeno, E. Mena (Spain)

The degradation of a mixture of two phenyl urea herbicides (diuron and linuron) in aqueous solution by photocatalytic ozonation with N-doped titanium dioxide has been accomplished under UVA radiation. A N-doped titania with an optimized N:Ti ratio was synthetized throughout sol-gel method, using urea as dopant agent source. The photoactivity was tested under oxygen presence, corroborating that N-doped was more active than bare TiO_2. In particular, the best N:Ti relation led to 59, 35 and 32% pseudofirst rate constants increment for diuron, linuron and TOC, respectively. Finally, photocatalytic ozonation was tested by using the best photocatalyst. A TOC conversion (after 3 h) of 88% in photocatalytic ozonation revealed the existence of a synergic effect if compared to TOC removal for photocatalytic oxidation (39%), and single ozonation (41%).

13.3 Formulation and assessment of indoor photocatalytic paints active under visible light

F. Salvadores, O. M. Alfano, M. de los Milagros Ballari (Argentina)

In the present work, different indoor photocatalytic paints were formulated employing visible light TiO_2 powders commercially available. These paints were tested for the photocatalytic degradation of acetaldehyde, a representative contaminant of indoor air. Two of the three formulations have presented activity under visible light. Also optical properties of the photocatalytic paint coatings were determined.

13.4 Caffeine degradation in WWTPs effluents for agricultural reuse by photocatalysis with titanium dioxide

S. Escuadra, L. Altabás, N. Miguel, M. P. Ormad (Spain)

The aim of this research work is to evaluate effectiveness of photocatalytic treatment with titanium dioxide by analysing Caffeine degradation and its complete mineralization (TOC measure) in different matrixes (distilled water, synthetic WWTP effluent and real WWTP effluent from Cortes, Spain). The photocatalytic treatment has been carried out in a solar chamber (Atlas Suntest CPS+ model) using a wavelength range from 320 to 800 nm, a radiation intensity of 500 W/m^2 and Evonik P25 TiO_2 (formerly known as Degussa P25, marketed in powder). The target study variables are the treatment time (0-240 minutes), TiO_2 dosage (0- 4g/l), the possibility of TiO_2 reuse and TiO_2 separation by decantation and coagulation-flocculation treatments. More than 95% Caffeine degradation and a 25% complete mineralization were achieved by UVA/Vis treatment of 120 minutes with a 1 g/l TiO_2 dose with a matrix of distilled water. The same treatment degrades only a 65% of the initial Caffeine in a matrix of synthetic WWTP effluent and 80% in a matrix of real WWTP effluent. The caffeine degradation increases when the treatment time (0-240 min) and the titanium dioxide dose (0-4 g/l) increase. TiO_2 sedimentation depends on the pH due to its isoelectric point. No significant differences were observed in the sedimentation rate between different matrixes. Coagulation-flocculation treatment without additives increases the sedimentation rate and consequently it improves the separation in order to use the photocatalytic treatment in continuous. A slight loss of photocatalytic activity of the reused TiO_2 was observed in the reusing trials (10 treatments UVA /Vis of 2 hours). In conclusion, TiO_2 photocatalysis could be a good alternative to treat WWTP effluents in order to degrade organic pollutants.

13.5 Solar radiation activation of ozone for the degradation of water pollutants

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

The decomposition of aqueous ozone by UV-visible radiation has been investigated with focus on the impact of ozone photolysis on the degradation of water pollutants during solar ozonation processes. The apparent first-order rate constants of the decomposition of ozone at various pHs in the 4-9 range and using radiation of different wavelengths in the UV-visible range have been determined at 37ºC. It was found that UVA-visible radiation (λ>320 nm) highly enhances ozone decomposition, especially at low pH. Hydrogen peroxide was identified as a main intermediate of ozone photo-decomposition at pH 4. Experiments of degradation of oxalic acid by ozone showed that solar irradiation brings about an increased generation of hydroxyl radicals and, as a result, a higher hydroxyl radical to ozone exposures ratio (R_{ct}). Finally, photo-ozonation (λ>300 nm) was shown advantageous over single ozonation in the mineralization of a selection of emerging contaminants (metoprolol, ibuprofen, N,N-diethyl-meta-toluamide and clofibric acid) in both ultrapure water and a synthetic secondary effluent.

Session 14. Advanced oxidation: Ozone systems

14.1 Photodegradation of dioxin-like compounds by pulsed xenon lamp irradiation

S. Shashkovskiy, A. Seliverstov, I. Zhelaev, V. Arkhipov, Y. Goldshteyn, B. Ershov (Russia)

The present study demonstrates the results of experimental tests on the possibility of dioxin-like compounds photodegradation with the help of high-intensity continuous spectrum UV radiation. Chlorobenzene was chosen as an imitator. The photolysis of chlorbenzene and dioxan molecules was studied in stationary conditions and in a flow-type reactor. The initial molecules concentration was 10^{-4} to 10^{-6} mol/L. A pulsed xenon lamp in sapphire enclosure was used as irradiation source.
Quantum efficiency for the direct photolysis of the chosen molecules reached 1.8. Additional ozone injection to air-vapor mixture increased the quantum efficiency up to 2.4.

14.2 Ozonation degree effect on physicochemical evaluation of four ozonated vegetal oils

P. Guerra Blanco, T. Poznyak, I. Chairez, M. Brito-Arias (Mexico)

The aim of this investigation was to evaluate physicochemical properties of four vegetal oils (grape, avocado, sunflower and olive) in ozonation, and to find the relationship between ozonation kinetics, the ozonation degree and the physicochemical structural changes. Structural characterization was done by Fourier transform infrared (FT-IR) and hydrogen nuclear magnetic resonance (^{1}H NMR) spectroscopy, with iso-ozonides being identified. Of all the oils studied, viscosity showed a significant increase during ozonation, a fact associated with

poly- peroxide formation. To define the ozonation degree, the measurement of the total unsaturation (TU) of oils was used. This TU method quantified the ozone-oxidizable substrate contained in oils. The TU of initial oils was found to obey the following order: grape seed > avocado = olive > sunflower. The distribution of by-products in ozonation was also different. In the grape seed oil, three reaction steps were observed for the double bond (>C=C<) conversion into iso-ozonides and poly- peroxides, while the same products were formed in parallel in sunflower, avocado and olive oils. These different reaction pathways justified the difference on the observed reaction rate constants obtained by a parametric algorithm based on the nonlinear least mean square method. The studies implemented in this investigation characterized the differences in the reactivity of these oils with ozone.

14.3 Surfactant treatment with activated carbon adsorption, oxidation with ozone and peroxone

C. Rita Ramírez-Cortina, M. Soledad Alonso-Gutiérrez (Mexico)

The presence of surfactants in wastewaters without treatment causes diverse problems in the receiving water bodies, even in the treatment plants of biological processes with activated sludge, that is the reason why it is recommended to do research on treatment processes like adsorption and chemical oxidation. In this study the adsorption in activated carbon and the advanced oxidation processes with ozone at different pH conditions and ozone/peroxide (peroxone) at alkaline pH are tested. Results show optimum operating conditions for the surfactant removal and both advantages and disadvantages in each process are analyzed. The behavior of the adsorption process is adapted to a Freundlich isotherm. The advanced oxidation processes are adapted to a first order reaction with an oxidation rate that increases with alkaline pH, the optimum results of these ozonation tests are obtained at pH of 10 and the presence of hydrogen peroxide increases the reaction speed, which is why for the conditions of this study the ozone-peroxide process turns to be quite effective.

14.4 Removal of cyanide in the presence of solids in industrial wastewater by using hydrogen peroxide and ozone

N. Pueyo, M. P Ormad, N. Miguel, J. L. Ovelleiro (Spain)

This paper presents the results obtained from the removal of cyanide in the presence of solids in industrial wastewater by oxidation with hydrogen peroxide, ozone and hydrogen peroxide-ozone. The highest cyanide removal from industrial wastewater is obtained by ozone oxidation at pH 11 with a consumed ozone concentration of 139 $mg \cdot L^{-1}$ getting a removal of 90% of cyanide. If the wastewater is pretreated by the lime-soda ash softening process, the ozone consumption is reduced to half for the same cyanide oxidation efficiency. The cyanide oxidation efficiency by hydrogen peroxide in industrial wastewater does not exceed 50% for a hydrogen peroxide concentration of 49 $mg \cdot L^{-1}$ if the wastewater is pre-treated by the coagulation-flocculation-decantation process. Using higher concentration of hydrogen peroxide 100 or 200 $mg \cdot L^{-1}$, cyanides are not removed and they are even generated. Hydrogen peroxide addition to the ozone oxidation treatment reduces the cyanide removal efficiency to a negative value of –102% for a consumed ozone concentration of 139 $mg \cdot L^{-1}$ combined with a hydrogen peroxide concentration of 49 $mg \cdot L^{-1}$.

14.5 Treatment of municipal primary and secondary wastewater effluents by non catalytic and catalytic ozonation

M. Marce, J. Arnal Moreno, R. C. Martins, R. M. Quinta-Ferreira, S. Esplugas (Spain, Portugal)

Our society requieres high levels of water quality. Nowadays it is very known that ozonation processes are able to get this important environmental objective. Moreover, as a consequence of the interest in these oxidation technologies and in order to improve them, different studies were performed to find heterogeneous catalyst with the potential to enhance ozone action over pollutants.
The use of heterogeneous catalytic process generates in the water medium a secondary oxidant different from ozone. The secondary species are formed from the reaction between the ozone and a solid catalyst. The study of catalytic process in municipal wastewater can favor alternatives to the conventional treatment. Depending on the degree of oxidation achieve, catalytic oxidation might work coupled with classical biological treatments. The aim of this study is to improve ozone action for the degradation of soluble organic matter resistant to the conventional wastewater treatment both in the outlet of the primary effluent and in the secondary effluent outlet. The application of ozone and catalytic ozone processes in these points may upgrade the water quality in terms of filtered chemical oxygen demand (CODf), dissolved organic carbon (DOC) and UV absorbance (UV254) and it will have a positive impact in the micropollutants fate.

14.6 Advanced oxidative treatment for waste water contaminated by pharmaceutical products

C. Vreuls, A. Wilmot, M. Cludts, P. Lefèbvre, N. Gillard, B. Heinrichs, S. Lambert (Belgium)

Numerous pharmaceuticals compounds are present in urban wastewaters. Some of them are still present after the biological waste water treatment plant. A way to avoid the dispersal of pharmaceuticals into the environment could be to design dedicated sewage treatment plants capable of degrading non-biodegradable pharmaceuticals. An analytical method was first developed to simultaneously extract, detect and confirm pharmaceutical products in wastewater, including a purification /concentration step on an Oasis HLB column and analysis by UPLC-ESI-MS/MS. Samples were collected from hospitals, rest homes and urban waste water treatment plants and analyzed to identify PPs. A physic-chemical tertiary treatment was elaborated in order to degrade persistent pharmaceutical products.

Session 15. Ozone in Medicine – Part 5

15.1 Major Ozone Autohaemotherapy (AHT) in spinal degenerative pathologies

S. John, F. Jacob, A. Alexandre (Italy)

The medical societies for ozone application have set up treatment protocols as basis for standards and guidelines, revised and published as a result of the most recent research and 30 years of experience (3,4,5). They have been used in the standardization of applications, indications, concentrations, doses, and frequency of treatment as based on the mechanism of action and the pharmacology of ozone. Over the last 20 years, the low-dose ozone concept has developed into an established treatment method with a sound scientific basis. Its biochemical action and pharmacological properties have been well investigated, documented, and published in internationally recognized journals in the context of its classical indications. In the meantime, applied on a worldwide basis, ozone therapy continues to provide good and reproducible results, particularly in diabetic angiopathia, diabetic foot, chronic hepatitis, and chronic intestinal disorders.
EU.N.I (European Neurosurgical Institute) in Treviso-Italy is highly specialized in mini-invasive neurosurgical techniques, where the following Ozone applications are performed.
1- Medical Ozone AHT (Major Ozone Autohaemotherapy).
2- Lumbar , Dorsal and Cervical Paravertebral O2O3 infiltrations.
3- Epidural O2O3 treatment under the endoscope vision.
4- Intraforaminal O2O3 treatment under the X-rays fluroscopic vision.
5- Intradiscal O2O3 treatment under the X-rays fluroscopic vision.
AHT inside our activity is employed on the base of the above mentioned principles and inserted in combination with all above mentioned neurosurgical techniques used for Lumbar and Cervical disc pathology, degenerative disc pathology and spondylarthrosis.

15.2 Medical Workshop

Dr. Aziz, Dr. Habig

Session 16. Advanced Oxidation: Catalytic ozonation

16.1 Development of novel catalytic materials for removal of emerging organic pollutants by catalytic ozonation

S. S. Sable, P. P. Ghute, F. Medina, S. Contreras (Spain)

Pharmaceutical compounds are among the group of emerging pollutants as their toxic effect, even at very low concentration, has raised a big concern. Therefore, there is a crucial need for developing efficient and ecologically friendly methods to treat contaminated waters and reduce or completely eliminate these pollutants. Advanced Oxidation Processes (AOPs) are water treatment processes performed at room temperature and normal pressure based on the *in situ* generation of powerful oxidizing agents, such as hydroxyl radicals (•OH), in sufficient quantity for effective decontamination of water. AOPs can help to overcome the problem of pharmaceuticals removal.
The main aim of our work is to develop new catalytic materials for the degradation and mineralization of clofibric acid (CFA), a lipid regulator. Different families of catalysts like hydrotalcite and spinel-type, FeOOH-derived and Cu-Al oxide catalysts were synthesized and their activity and stability in catalytic ozonation was studied. Also, *in situ* attenuated total reflection (ATR-IR) spectroscopy was used to study the interaction of ozone with catalysts to investigate the catalytic mechanism.

16.2 Urban wastewater treatment by catalytic ozonation

C. Crousier, J.S. Pic, J. Albet, S. Baig, M. Roustan (France)

Advanced oxidation processes appear to be alternative solutions for obtaining high organic matter oxidation yields. Therefore, this study focuses on the catalytic ozonation of organic matter recalcitrant to usual water treatment technologies. Experiments have been carried out on urban wastewaters from secondary treatment in order to investigate the efficiency of the process TOCCATA®, that uses a granular catalyst coupled with ozonation, and to understand the mechanisms involved. Comparison was made between single ozonation, single adsorption onto catalyst and catalytic ozonation. Under the conditions applied, catalytic ozonation achieved wastewater organic matter removal yield up to 90% compared to 39% only with single ozonation. Adsorption was proven to contribute to dissolved organic carbon decrease but single adsorption only concentrated the organic matter onto the catalyst. A global apparent first order kinetic model was proposed for catalytic ozonation and a pseudo-second order sorption kinetic model was presented for single adsorption. Carbon balances showed that catalytic ozonation allows organic carbon mineralization, which was coupled with an acidification of the treated wastewater matrix. The oxidation was shown to occur under ozone mass transfer enhancement upon ozone reaction with the catalyst.

16.3 The decomposition of Humic Acid in catalytic ozonation

C.-N. Chang, L.-W. Lu, Ho-Wen Chen (Taiwan)

Magnetic $Fe_3O_4/SiO_2/Co_3O_4$, was synthesized in this study by sol-gel methods as catalysts in ozonation, which was indicated with the pH_{zpc} of 1.87. Hererogeneous catalytic ozonation can decompose refractory substance and decrease the generation of Trihalomethane by disinfection compared with sole ozonation and the decomposition rate was up to 42% by catalytic ozonation. FTIR showed that aromatic groups on humic acid from Te-Chi reservoir could be decomposed more efficiently in catalytic ozonation.
This system can generate more powerful oxidants such as hydroxyl radicals and investigate by dose coumarin scavengers. Byproduct from ozonation of coumarin: 7-hydroxycoumarin as a probe can indicate the amount of hydroxyl radicals indirectly. During the experiment, 7-hydroxycoumarin can be generated up to 4 mg/L at pH 2.

16.4 Catalytic ozonation with -Al_2O_3 to enhance the degradation of refractory organics in water

J. Vittenet, W. Aboussaoud, J. Mendret, J.-S. Pic, H. Debellefontaine, N. Lesage, K. Faucher, M.-H. Manero, F. Thibault-Starzyk, H. Leclerc, A. Galarneau, S. Brosillon (France)

Heterogeneous catalytic ozonation appears as a promising way to treat industrial wastewaters containing pollutants refractory to biological treatments. Several oxides and minerals have been used and their behavior is subject to controversy with particularly the role of Lewis acid sites and/or basic sites and the effect of salts. In this study, millimetric mesoporous γ-Al_2O_3 particles suitable for industrial processes were used for enhancing the ozonation efficiency of petrochemical effluents without pH adjustment. A phenol (2,4-dimethylphenol (2,4-DMP)) was first chosen as petrochemical refractory molecule to evaluate the influence of alumina in ozonation. Single ozonation and ozonation in the presence of γ-Al_2O_3 led to the disappearance of 2,4-DMP in 25 min and a decrease in pH from 4.5 to 2.5. No adsorption of 2,4-DMP occurred on γ-Al_2O_3. Adding γ-Al_2O_3 in the process resulted in an increase of the 2,4-DMP oxidation level. Indeed, the Total Organic Carbon (TOC) removal was 14% for a single ozonation and 46% for ozonation with γ-Al_2O_3. Similarly, Chemical Oxygen Demand (COD) removal increases from 35 to 75%, respectively. Various oxidized by-products were produced during the degradation of 2,4-DMP, but after 5 hours ozonation 90% of organic by-products were acetic acid > formic acid >> oxalic acid. Some of the carboxylic acids were adsorbed on γ-Al_2O_3. The use of radical scavenger (tert-butanol) highlighted the involvement of hydroxyl radicals during catalytic ozonation with γ-Al_2O_3 in contrary to single ozonation, which mainly involved direct ozone reaction. γ-Al_2O_3 is an amphoteric solid with Lewis acid AlOH(H^+) sites and basic Al-OH sites. After ozonation the amount of basic sites decreased due to carboxylates adsorption, while the Lewis acid sites remained constant as evidenced by FTIR. Several ozonation runs with γ-Al_2O_3 reported progressive decrease of catalytic activity due to the cumulative sorption of carboxylates on the basic sites. After 80 h ozonation, calcination at 550°C allowed recovering all Al-OH basic sites and the initial activity of γ-Al_2O_3.

16.5 Assessment of a non-woven fiber paper coated with ruthenium nanoparticles for catalytic ozonation

P.-F. Biard, B. Werghi, I. Soutrel, A. Denicourt-Nowicki, R. Orhand, A. Couvert, A. Roucoux (France)

This study focuses on the use of Ru nanoparticles as heterogeneous catalyst for ozone decomposition and radical production. The nanoparticles have been impregnated on 3 different supports: TiO_2, SiO_2 and a non-woven fiber paper composed of a mixture TiO_2/SiO_2/zeolite. The experiment confirmed the high potential of Ru nanoparticles for the ozone decomposition at pH 3 since the ozone half-life time decreases by a factor 20-25 compared to the reference experiment carried out without catalyst. The enhancement of the ozone decomposition kinetics provided an improved radical production and a higher transient radical concentration in a shorten ozone exposure duration. Consequently, lower oxidant dosage and contact time would be necessary. Thus, very significant atrazine consumption kinetics enhancements were measured. The potential of the non-woven fiber paper as a nanoparticles support is confirmed, even if lower ozone decomposition kinetics than using TiO_2 or SiO_2 are measured. This non-woven fiber paper would be an interesting alternative to TiO_2 and SiO_2 powders to avoid the catalyst recovery step and to design reactors such as tubular reactors. A new numerical procedure is presented for the evaluation of the transient HO° concentration and of the R_{ct}.

16.6 Use of a trickle bed reactor for heterogeneous catalytic ozonation of phenol

L. Briceño, E. Duran (Costa Rica)

Due to its operational advantages, mass and heat transfer characteristics, and low-pressure drop, trickle bed reactors have been successfully used in many gas-liquid-solid applications (e.g. wet air oxidation processes) [1]. On the other hand, heterogeneous catalytic ozonation has been mainly carried out in batch and semibatch stirred tank systems, although some research is reported on packed bed reactors as well. However, the use of trickle bed reactors for heterogeneous catalytic ozonation is yet to be explored as a viable technology for industrial applications. This paper presents a study on the use of a co-current down flow trickle bed reactor for heterogeneous catalytic ozonation of phenol (as a model pollutant) utilizing iron-modified diatomite pellets as catalyst. Hydrodynamic and residence time distribution (RTD)

analyses were also performed in order to characterize the reactor behavior under different flow conditions. It was found that the reactor could operate under trickle and pulsing flow regimes and that RTD data adjusted well to a N=12 n-CSTR model. The results showed that phenol conversion increases by 6.4% (from 13.3 to 19.7%, with τ = 0.098 min) when using the catalyst and the external mass transfer appears to be the controlling step in the heterogeneous catalytic reaction.

Session 17. Water Reuse Purpose

17.1 A hybrid process of ozonation and short soil aquifer treatment for water reuse

I. Zucker, H. Mamane, H. Cikurel, M. Jekel, U. Hübner, D. Avisar (Israel, Germany)

The Shafdan reclamation project facility (Tel Aviv, Israel) practices artificial recharge of groundwater with wastewater that has undergone soil aquifer treatment (SAT) as tertiary treatment. During SAT, manganese dissolves in the infiltrated effluent due to negative redox potential (anoxic conditions). An additional emerging problem is the presence of trace organic compounds (TrOCs) in wastewater that should be removed prior to effluent reuse. An innovative hybrid advanced oxidation process (AOP)-short SAT (sSAT) technology is proposed based on a multistage pretreatment for the Shafdan secondary effluents prior to the sSAT (~22 days retention time). The sSAT has a shorter effluent pathway than the conventional SAT – cSAT (retention time of 180–360 days), and reduces the treatment area. The goal of this study was to determine the potential of the proposed technology for degradation of organic contaminants, prevention of manganese dissolution and increasing infiltration capacity. The first effluent pretreatment stage included coagulation–flocculation and hydrogen peroxide addition to a high-rate biofilter (5–6 m h^{-1}). Besides efficient removal of particulate matter, biofiltration efficiently removed dissolved organic carbon (DOC, to 17–22%), ammonium and nitrite. This resulted in reduced effluent oxygen demand during infiltration and oxidant (ozone) demand during ozonation by 23 mg L^{-1} and 1.5 mg L^{-1}, respectively. Ozonation (1.0–1.2 mg O_3 mg DOC^{-1}) efficiently reduced concentrations of persistent TrOCs and supplied sufficient dissolved oxygen (>30 mg L^{-1}) for fully oxic operation of the sSAT with negligible Mn^{2+} mobilization (<50 µg L^{-1}). Overall, the examined hybrid process provided DOC reduction of 88% to a value of 1.2 mg L^{-1}, similar to cSAT, while improving the removal of TrOCs and efficiently preventing manganese dissolution.

17.2 Study of the influence of Advanced Oxidation Processes as a pretreatment of a Reverse Osmosis from an ultrafiltred water reclamation

C. Mesa, I. Martin, B. Lefèvre, O. Gibert, X. Bernat (Spain)

Fouling is the major factor limiting the widespread application of ultrafiltration (UF) and reverse osmosis (RO) technologies because it results in reduced membrane flux and the need to apply frequent membrane cleaning strategies, which in turn increases the overall operational and investment costs. The main objective of the present study is to evaluate the feasibility of Advanced Oxidation Processes (AOPs) as a pre-treatment of a RO as a mean of reducing the organic fouling potential of an ultrafiltrated water. The AOP's studied consisted of ozone, ozone + UV light, hydrogen peroxide + UV light and hydrogen peroxide + ozone between UF and RO modules in lab-scale tests. The results obtained from AOP tests applied after the ultrafiltration in comparison to a water without treatment, showed improvements in the different fouling rate of the RO membrane with the combination of O_3+UV and H_2O_2+UV and negatively affected for O_3+H_2O_2.

17.3 Treatment of nanofiltration concentrates by ozonation for wastewater reuse: optimization of operational parameters

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

The application of nanofiltration (NF) for wastewater reuse is promising solution for assuring high water quality and lower operating cost than reverse osmosis. However, one significant disadvantage is the need to dispose off the NF retentates. Studies focusing on organic micropollutants in wastewater reuse applications have raised questions concerning their concentrations in membrane concentrates limiting the possibilities of discharge and the need to treat. Ozonation was choice to degrade these trace compounds in retentates that contains high concentration of effluent organic matter and other inorganic constituents. The main purposes of the study were to evaluate the impact of retentate matrix on the degradation of four pharmaceutical pollutants during the ozonation process. Different retentate matrixes were obtained for different volume factors reduction (VRF). Pharmaceuticals reduction was significantly impacted by the increase of the VRF, especially pharmaceuticals with low ozone second apparent rate constant (degradation is mainly governed by radical attacks) due to the increase of hydroxyl radical scavenging rate. Nevertheless, ozone consumption was lowered by combining ozonation with nanofiltration instead of using direct ozonation and ozone was found to be a promising technology to mitigate common water pollutants in highly complexe matrixes as concentrates.

17.4 Combining adsorption with advanced oxidation – A case study

M. G. Conti-Ramsden, N. W. Brown, M. Khan, N. De Las Heras-Rodriguez (UK)

A technology combining adsorption with advanced oxidation based around a novel material, Nyex, is described and discussed. The material's adsorptive and conductive properties promote the removal of organics from solution and the subsequent oxidation of the organic on its surface when a current is passed. The technology has been trialled against different wastes from different industries including: pharmaceutical, utilities, land remediation and the oil & gas industry. Treatment in all cases was found to be successful and exhibited high current efficiencies with low energy consumptions order 10's of kWh/kg COD even at the low ppm organic concentration level. Further, recalcitrant and hard to treat organics such as dioxin and furan species were successfully treated with the technology demonstrating the advanced oxidation capability of the destruction of these stable species. Here the technology's performance against the treatment of the micro pollutants dioxin and furan in different waste matrices is presented alongside the technology's performance in the treatment of triclosan. The technology shows great promise for the treatment of waste streams containing low levels of recalcitrant organics cost effectively and with no secondary waste.

17.5 Wastewater disinfection by ozone: water reuse

J. A. Perdigón-Melón, A. Luminita Petre, J. Benito Carbajo, R. Rosal, E. Garcia-Calvo (Spain)

Wastewater disinfection is essential in order to protect environment and public health ensuring a safe water reuse. The disinfection degree achieved by continuous ozonation of the effluent of a secondary clarifier in a sewage treatment plant was monitored using three indicators: total coliforms, fecal coliforms and *E. coli*, which are those commonly used in different legislations. As these assays do not give information on the presence of other no targeted microorganisms (either pathogen or not), a more in depth study was performed to assess the presence of living microorganisms by means of global methods measuring aerobic microorganisms growth and the total microbial activity recorded by fluorescein diacetate hydrolysis. The main microorganism deactivation (2-3 inactivation log) took place using non-measurable concentration of dissolved ozone (<0.01 mg $O_3 \cdot L^{-1}$). Using ozone doses near 4 mg$\cdot L^{-1}$ treated wastewater accomplished the regulation for the irrigation of food and green areas. The total microbial activity and aerobic microorganism counting detected the presence of living microorganism even at very high ozone doses, 60 mg$\cdot L^{-1}$, this probably being due to the high number of total microorganisms present in raw wastewater, the presence of ozone-resistant microorganisms or the short contact time for a fraction of treated water in a CSTR arrangement.

Session 18. Water Disinfection Target

18.1 Evaluation of pulsed xenon ultraviolet irradiation of continuous spectrum for efficacy against multidrug-resistant nosocomial strains

S. Kireev, S. Shashkovskiy, T. Grenkova, Y. Goldshteyn, I. Goncharenko, E. Selkova (Russia)

The present study demonstrated the evaluation results of pulsed xenon ultraviolet irradiation of continuous spectrum for efficacy against multi-drug resistant strains with high epidemic potential and resistance against main groups of chemical disinfectants (MRSA, VRE, A. baumannii, P. aeruginosa, Proteus mirabilis, S. aureus). Microbial concentration on plastic and metal surfaces was at least 10^7 CFU/cm^2. The samples were placed horizontally and vertically at 1.2-2 meters' distance from the irradiation source and treated for 5, 10 or 20 minutes. After 5 minutes' treatment the microbial reduction was at least 4.9 lg for all the pathogens and surface materials. The presence of bioburden on samples did not affect the disinfection efficacy. The decontamination efficacy for metal plates reduced insignificantly.

18.2 Wastewater matrix effect on disinfection with LP/UV and MP/UV radiation

R. Salgado, C. Hipólito, D. Galhanas, L. Epifâneo, J.P. Noronha (Portugal)

The disinfection of the wastewater effluents is important to reduce the pathogenic microorganism impact in the environment. UV radiation is one of the technologies used for this purposed. The wastewater characteristics, such as dissolved organic compounds or the presence of suspended solids can affect the efficiency of the faecal coliform bacteria removal in the disinfection process by ultraviolet (UV) radiation technology. This study addresses to see the effect of the effluent wastewater matrix in the disinfection by the use of low pressure (LP/UV) and media pressure (MP/UV) lamps. Samples collected in different wastewater treatment plants show different transmittance emission profiles due mostly to the presence of the mixture of dissolved organic compounds with some effect on the faecal coliform bacteria removal.

18.3 Influence of hydraulics on disinfection efficiency

M. Roustan (France)

Whatever the disinfection technology, the design of reactors requires taking into account the hydraulics in the reactor. The related model for ozone disinfection incorporates the expression of disinfection kinetics, hydrodynamics and hydraulcs of the contactor. Investigation results highlight the interest to design reactors as close as possible to plug flow.

18.4 Disinfection of simulated municipal wastewater effluent by ozonation at laboratory and pilot scale

P. Valero, R. Mosteo, R. M. de Castro, M. J. Quero-Pastor, M. Hinojosa, A. Acevedo, M. P. Ormad (Spain)

Ozonation is an effective technique for drinking water and wastewater disinfection. The aim of this research work was to evaluate the efficiency of ozonation at laboratory and pilot scale on the inactivation of *Escherichia coli* present in a simulated treated municipal wastewater. Ozonation at laboratory scale was carried out in 1 L sample using an ozone generator Fischer 500 supplied with pure oxygen which led to a production of 0.9 g O_3/h. At pilot scale, 20 L of sample were treated by ozonation. The ozone generator GZ15 of the pilot plant was fed either with dry atmospheric air or with concentrated atmospheric oxygen obtained by pressure swing adsorption (PSA) technology. Different operational conditions were applied at pilot scale and, therefore, different ozone productions were obtained with air (4.8, 10.8 g O_3/h) and oxygen (39.0, 40.8 g O_3/h). In laboratory scale experiments, large amounts of the introduced ozone were released as unconsumed ozone, probably due to an insufficient contact of ozone and the water. At pilot scale, *E. coli* inactivation was faster and more efficient when ozone was produced from oxygen instead of air. Considering the introduced ozone, pilot scale ozonation was more effective than at laboratory scale. For instance, 50 mg $O_{3\ introduced}$/L removed 3 log units at laboratory scale, 4 log units with air-produced ozone and 5 log units with oxygen-produced ozone at pilot scale.

Session 19. Advanced Oxidation : Photo-Fenton systems

19.1 Photo-Fenton degradation of a herbicide with simulated solar radiation. Kinetic model using the ferrioxalate complex

O. Alfano, L. Conte, A. Schenone, E. Albizzati (Argentina)

A theoretical and experimental study of the homogeneous photo-Fenton degradation of herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) is presented. Firstly, different sources of iron in water solution were studied: sulphate, oxalate and citrate complexes. The behaviour of these complexes was evaluated by means of two parameters: (i) the photonic efficiencies of degradation and mineralization; and (ii) the quantum efficiencies of degradation and mineralization. The ferrioxalate system presented the best performance for conditions at pH = 5. From these results, a kinetic model derived from a reaction sequence is proposed using the ferrioxalate complex as iron source, for conditions of pH close to neutrality. Operating the system under simulated solar radiation, with high radiation level and the highest concentration of hydrogen peroxide, the conversion of 2,4-D after 180 min of reaction was close to 100% over the full range of working temperatures. Besides, a good agreement between the kinetic model and experimental data, for a rather wide range of the operating variables, was observed.

19.2 Assessment of Fe(III)-NTA use in photo-Fenton at neutral pH

R. F. Dantas, A. De Luca, S. Esplugas (Brazil, Spain)

The stability of ferric nitrilotriacetate chelates (Fe(III)-NTA) was studied under excitation by temperature stress, irradiation and oxidation. The knowledge of chelate stability is fundamental to correct implement the management system of wastewater treatment plant for application of chelates as catalyst in photo-Fenton process at neutral pH. Fe(III)-NTA solution stability was monitored under different temperature conditions (T=10-30°C), in presence and absence of UV-A irradiation and with the addition of three different concentrations of H_2O_2 ($[H_2O_2]_0$=20 mg L-1, 40 mg L^{-1}, 100 mg L^{-1}). The additional effect on chelate stability due to the photons transfer by different irradiation source (UV-A, UV-C and Xenon lamps) was also evaluated. From the results, it has been demonstrated as during nine days, any instability phenomena can be arisen from the only increment of temperature solution. By the way, the control of this parameter became completely necessary when the solution was stressed by irradiation and even more after addition of hydrogen peroxide. The solution was kept stable during two hours of reaction under UV-A irradiation only when temperature was set at 10-15°C while in presence of hydroxyl radicals (HO·) the temperature control could only reduce the chelates decomposition. Under irradiation and radical strain, the Fe(III)-NTA solution was weakly mineralized. Thus, the production of organic radical from free ligands was also demonstrated. Finally, just considering the stability of chelates solution, UV-C lamps appeared to be not adequate as source of photons transfer for the process application. In fact, the solution irradiated with UV-C lamps in presence of 20 mg L^{-1} of hydrogen peroxide showed a reduction on chelates content of almost 90% after only 30 minutes of irradiation.

19.3 Solar photo-fenton oxidation of levofloxacin antibiotic at near neutral pH with ferrioxalate complexes

A. A. Nogueira, M. Dezotti, R. A. R. Boaventura, V. J. P. Vilar (Portugal, Brazil)

Pharmaceutical products such as antibiotics are gaining increasing attention from the scientific community and public perception [1]. Perhaps the biggest environmental problem involving drugs is that after administration, a part is metabolized and the other one is excreted, ending up in sewerage. A large portion of these compounds are not removed by conventional wastewater treatment plants. Therefore,drugs and

metabolites may reach natural water bodies [2]. Antibiotics can cause a resistance increase of pathogens through the concentrations found in wastewaters [3, 4] and these compounds can present a significant acute toxicity even in low concentrations. Advanced oxidation processes (AOPs) constitute nowadays an alternative and efficient technology for the elimination of micropollutants from urban wastewaters [5, 6, 7]. In this study, it was evaluated the Levofloxacin degradation usinga solar photo-Fenton process at near neutral pH with ferrioxalate complexes (Fe^{3+}/H_2O_2/oxalic acid/UVA-Vis) and using iron concentrations below the discharge limits imposed by Portuguese legislation (≤2.0 mg/L).

Session 20. In relation to Activated Sludge

20.1 The reduction of the production of activated sludge with electomagnetics waves treatment

M. H. Izazy, G. Merlin, E. Gonze, E. Vallete (France)

The reduction of the production of activated sludge in the waste water treatment plants (WWTPs) is an important issue of the 21st century. In France, urban waste sludge represent 1.300.000 tons dry matters produced annually. 60 % of sewage sludge is direct applied into agricultural soil, 15 % is incinerated and 25 % is landfilled. The Increase in the productions of sludge, combined with the restrictions of the new legislation on discharge, pose a real problem of management of these sludge produced by the wastewater plants. It thus appears essential to develop integrated systems into the treatment of wastewater allowing to reduce this production of sludge.
In this study, the effects of electromagnetic waves on activity of activated sludge in wastewater treatment were investigated in a lab- scale pilot of activated sludge treatment plant containing synthetic wastewater.
The wastewater in the pilot were exposed to extremely low-frequency electromagnetic fields in the frequency range 2-50 Hz., two frequency have been tested during our study. The strength of electromagnetic waves applied in our study was very small and located in the range of some µT.
Accordingly, The possibility of an electromagnetic field (EMF) influencing the production of activated sludge, the organic compound (COD) removal from domestic wastes, and the physical effect like the sedimentation of sludge and granule of sludge was investigated. We have found that the efficacy of electromagnetic treatment is frequency dependent. The reduction of the production of sludge reached in this study was 12% without destroy the quality of treatment. (by knowing that a reduction of 5% can already be financially very interesting). The effect of electromagnetic treatment on the sedimentation of sludge is inhibitory effects or stimulatory effects, depends the frequency of electromagnetic field.

20.2 Effects of persulfate and peroxide treatment on components and dewaterability of waste urban sludge

N. Bilgin Öncü, N. Mercan, D. Aydın, I. Akmehmet Balcıoğlu (Turkey)

Waste urban sludge was treated by activated persulfate as well as activated hydrogen peroxide processes. In addition to high rates of antimicrobial degradation, remarkable solubilisation of the sludge in terms of organics, metals and nutrients was achieved with the application of microwave activated hydrogen peroxide (MW/H_2O_2) microwave activated persulfate ($MW/S_2O_8^{2}$), heat ($Heat/S_2O_8^{2-}$), and simultaneous heat and ferrous iron activated persulfate ($Heat/S_2O_8^{2-}/Fe^{2+}$) processes regardless of the type activation. Compare to hydrogen peroxide process, higher performance of persulfate for metal solubilization and antimicrobial degradation was attributed to drastic pH decline and generation of selective sulfate radical, respectively. While MW/H_2O_2 caused lower AOX values in liquid phase of the sludge $Heat/S_2O_8^{2-}/Fe^{2+}$ process provided the lower AOX values in solid phase with concomitant phosphate precipitation. Compare to other processes, $Heat/S_2O_8^{2-}/Fe^{2+}$ process also improved sludge dewaterability at higher ratio

20.3 Evaluation of excess sludge reduction and bacterial inactivation using ozone ultra-fine bubble (nanobabbles)

K. Hashimoto, T. Okuda, W. Nishijima, K. Sawai, N. Sumida (Japan)

To date, ozone dosage required for reuse of excess sludge as substrate for activated sludge in the aerobic tank could not be decided based only on decrease of biomass, and biological treatment experiment after ozonation is needed for deciding ozone dosage. In this study, the application of bacterial viability analysis as an indicator of excess sludge reuse as substrate to evaluate sludge reduction using ozone in activated sludge process was studied. The degree of cell lysis/destruction of activated sludge by ozone dose was revealed in ozone treatment. Although decreased MLSS was only about 10-15% at 50 mg-O_3/g-MLSS with milli-bubble ozonation, bacterial viability analysis showed significant living microbial cell reduction at about 80% at this dosage. Because the possibility of complete elimination of excess sludge was reported at 30-50 mg-O_3/g-SS according to a previous study, this result shows that the bacterial viability analysis is a suitable indicator for sludge reduction rather than MLSS and DOC concentration. Intracellular substances in the dead cell are solubilized in the solution, which could be readily utilized by aerobic microorganisms in the aeration basin. MLSS and DOC concentrations with milli-bubble ozonation reached saturation at 30 and 50 mg-O_3/g-MLSS, respectively. These results showed there is a time lag until the cytoplasm in the cells is eluted outside. In addition, dead ratio of bacteria was observed at about 80% at lower ozone dosage, 20 mg-O_3/g-MLSS, than milli-bubble ozonation. In addition, dead ratio of bacteria by ozone-UFB was 10-50% higher than in the dissolved ozone only. Permeability of ozone-UFB to sludge using an oxygen micro sensor was studied but acceleration of the permeability by UFB was not observed. These results confirmed that UFB ozonation give higher efficiency of sludge reduction than milli-bubble ozonation although the mechanism is still not clear.

20.4 Behavior of trace materials in ozone-added activated sludge process

F. Nishimura, Y. Okada, Y. Nakagawa, M. Masuda, H. Tsuno (Japan)

Ozone-added activated sludge process is one of the modified biological wastewater treatment processes for reduction of excess sludge production. Although ozone-added activated sludge system was originally developed in order to reduce excess sludge production, it is expected that its direct ozonation to activated sludge can also remove some biorefractory compounds by chemical oxidation, and the treatment efficiency and stability can be increased as results. In this study, phenol and endocrine disrupting chemicals (EDCs) were targeted as trace organic compounds, which exists actual sewage and oxidation by ozone as well as biological decomposition can be expected.
More developed process based on the ozone-added activated sludge process was also developed. Aiming excess sludge reduction and phosphorus recovery, "the advanced sewage treatment process with excess sludge reduction and phosphorus recovery (advanced SRPR process)" was developed. The advanced SRPR process consists of biological reaction process(AO process), ozonation process and crystallization process. The crystallization process is also incorporated in parallel in which supernatant of mixed liquor in anaerobic tank in introduced into the crystallization tank and phosphorus is crystallized by Ca cation for phosphorus recovery. Behaviors of metals and nutrients in the advanced SRPR process were also investigated in order to evaluate treatment performance of the process.

Session 21. Micropollutants control – Part 1. At full scale

21.1 First full-scale application of ozonation for wastewater treatment in Switzerland: elimination of micropollutants and formation of oxidation products

M. Bourgin, M. Boehler, E. Borowska, J. Fleiner, J. Hollender, C. Kienle, R. Teichler, A. Wittmer, H. Siegrist, M. Schachtler, M. Thomann, M. Blunschi, C. S. McArdell (Switzerland)

The pollution in the Swiss surface waters is usually relatively low compared to other countries. However some micropollutants are found at concentrations above the environmental quality standards, so that local aquatic ecosystems could be affected. Therefore, to reduce this pollution, the Swiss Federal Office for the Environment (FOEn) initiated the project "strategy MicroPoll" in 2006 to assess the situation of Swiss surface waters quality and identify potential actions to minimize the load of micropollutants from urban areas. Since a reduction at the source (production and consumption) appears to be very complicated or even impossible for e.g. pharmaceuticals, a new water protection act

focusing on the end of pipe micropollutants elimination was decided in 2009. Therefore, the wastewater treatment plants, which strongly impact Swiss surface waters after discharge have to be upgraded with advanced treatment. Ozonation and activated carbon adsorption are proposed as the two alternatives for this additional treatment step. Ozonation has already been shown to remove micropollutants efficiently, robustly and with a moderate cost during water and wastewater treatments. However, ozonation treatment induces the formation of transformation products (TPs) from the oxidation of the micropollutants. So far, this new category of compounds has not been systematically investigated in treated waters and wastewaters. The aims of this work are (i) to demonstrate the efficiency of ozonation to remove a wide range of micropollutants usually present in Swiss wastewaters and (ii) to monitor the formation and the concentration of the TPs.

21.2 Optimisation of full-scale ozonation tertiary treatment for micropollutants removal

Y. Penru, C. Miège, A. Roussel-Galle, L. Dherret, A. Guillon, M. Esperanza, S. Baig, S. Martin Ruel, M. Coquery, J. M. Choubert (France)

Dissemination of chemical substances in the environment is becoming a major issue and wastewater effluents are one of the main point sources. The goal of the present work was to determine the performances on micropollutants removal of a recently developed process consisting in ozone contactor followed by a post-denitrification submerged biofilter. A full-scale tertiary treatment line (600 m^3/h) built at Sophia-Antipolis WWTP was studied under various operating conditions (ozone and methanol dosage). The groups of micropollutants monitored include pharmaceuticals, hormones pesticides (domestic uses) and also compounds listed in the WFD such as metals. Presented results show that with an ozone dosage of 5 g/m^3, the tertiary treatment was able to eliminate pharmaceutical compounds, such as antibiotics and betablockers, achieving removal efficiencies higher than 70%. Regarding pesticides, only diuron and AMPA were quantified in the secondary effluent and both were greatly removed by the tertiary treatment (60 and 80%). Majority of the studied substances were removed by ozonation stage. This study also permits to highlight the positive effect of this tertiary treatment (especially the ozonation stage) for the removal of refractory micropollutants usually remaining in the effluent released by conventional physical and biological treatments.

21.3 Application of ultraviolet absorption measurement for closed-loop control of tertiary ozonation

M. Stapf, U. Miehe (Germany)

To cope with the occurrence of organic micropollutants (OMPs) in the urban water cycle, different technologies have been tested to upgrade wastewater treatment plants for OMP removal. Measures are either based on adsorption onto activated carbon or ozonation. To ensure an economic and effective operation of the OMP removal, an automatic control system, which adapts the dosage to the varying water quality of the secondary effluent, is necessary. An online OMP measurement is not possible because of the high analytical afford, thus other surrogates have to be used for control purposes instead. One promising surrogate is the reduction of the ultraviolet absorption at 254 nm (ΔUVA_{254}) at the ozonation stage, which correlates very well with the OMP removal. In this study, the results of the successful application of the ΔUVA_{254} for a closed-loop control at an ozonation pilot plant for OMP removal are presented with a focus on implementation issues like coping with delay time and the choice of measurement points. OMP removal was assessed for three different ΔUVA_{254} setpoints, of which two of them also were performed as an advanced ozone process. It could be shown that changes of the ozone demand, e.g. by a varying concentration of the dissolved organic carbon (DOC) or nitrite, can be detected and countered by an adaption of the applied ozone dose.

21.4 Determination of estrogenic activity at a waste water treatment plant with full scale ozonation using *Arxula adeninivorans* yeast estrogen screen assay

F. Itzel, L. Gehrmann, C. Portner, H. Herbst, G. Kunze, T. C. Schmidt, J. Tuerk (Germany)

The extensive use of pharmaceuticals & personal care products (PPCP) and industrial chemicals as well as their biological (active) transformation products have become ubiquitously detectable in the aquatic environment. In the last decades fish and other aquatic organisms show symptoms like feminization of males and a decrease in population. These effects could be traced back to endocrine disrupting chemicals (EDCs) like estrogenes or industrial chemicals that were detected at the effluent of waste water treatment plants (WWTP) and surface waters in several studies. Therewith the observation of the fate of the EDCs is of growing concern. The application of ozone is a promising technique for the removal of these EDCs from WWTP effluents. In this study estrogenic effects at a WWTP with a full scale ozonation were observed.
Beside the classical instrumental analysis, which is not sensitive enough for the analysis of the emerging contaminant 17α-Ethinylestradiol, effect based methods extend the analytical information and were used for the evaluation of the treatment efficiency in this work. Therefore, the more sensitive A-YES Assay (*Arxula adeninivorans* yeast estrogen screen), was used to analyse the samples for estrogenic effects.
The detected concentrations by the A-YES assay varied in the range of 0.10 to 0.18 ng 17ß-Estradiol equivalents per liter (EEQ/L) with limits of detection between 0.03 and 0.1 ng EEQ/L. The removal rates in terms of estrogenic effects were >98% for the whole WWTP. An additional removal of >84% by ozone and a biological post-treatment could be achieved.

Wednesday, 1st July

Session 22. Design and Engineering aspects – Part 1

22.1 Effects of cavitating water jets on advanced oxidation processes in an annular photolytic reactor

M. Čehovin, J. Scheideler, A. Ried, J. Mielcke, H. Stapel, A. Žgajnar Gotvajn, A. Medic, B. Kompare (Slovenia, Germany)

Advanced oxidation processes (AOPs) can be applied as an adequate technology for treatment of drinking water that contains natural organic matter. Hydrodynamic cavitation (HC) was experimentally investigated in this research as a complementary method of H_2O_2/UV and O_3/UV AOPs, as it is can also enhance efficiency of contact between oxidants and promote production of oxidative radicals, typical of AOPs. In this case, humic acid was used as a source of dissolved organic carbon (DOC) in the range 1 to 3 mg L^{-1}. At the same time it provided precursors of oxidation/disinfection by-products (DBPs): trihalomethanes (THM), halogenated acetic acids (HAA), adsorbable organic halogens (AOX). When HC was applied together with H_2O_2/UV AOPs, improvements of dissolved organic carbon oxidation (10-15 %) were observed compared to H_2O_2/UV AOPs alone, increasing with the higher UV adsorption of the matrix, but with an increase of the formation potential of all considered DBPs (21-34 %). Combination of HC and O_3/UV impeded the reactions compared to O_3/UV AOPs alone. Lower DOC removal (18-30 %) was observed in this case as well as lower DBPs formation potential of the same range and approximately 15 % higher concentrations of non-reacted ozone. An increase in energy input to drive HC generators (additional 10-40 % to AOPs alone), dependent on geometry, flow and pressure regimes, along with their sensitivity to material wear need to be addressed for overall efficiency evaluation on case-by-case basis.

22.2 Implementation of ozonated water pulverization: characterization of the ozone desorption

M. Tournois, M. Pages, M. Roustan, D. Kleiber, F. Violleau, G. Hébrard (France)

The use of Ozonated Water (OW), known for its high disinfecting power, is an interesting alternative to polluting disinfectants. The present work focuses on the ozone transfer during OW spraying, in order to highlight the parameters affecting the Dissolved Ozone Concentration (DOC) and its stripping at the spray target. An experimental study on tap water spray by different nozzle types was conducted using a high-speed camera (APX Photron®) combined with an image processing method. Droplets diameter and velocity were measured to provide the interfacial area. Coupling these results with the modelling of the ozone transferred to the air by the spray, allowed the estimation of DOC along trajectories of droplets. Therefore, a model was established to quantify the ozone desorption rate during OW spraying. According to the results, the ozone desorption can be minimized by spraying close to the target and using nozzles that produce larger droplets. Furthermore,

the consistency and accuracy of this model were challenged. This has been done through additional experimentations consisting in the pulverization of ozonated water and by following the remaining DOC at the spray target.

22.3 Retrofit of ozone contact basins with Sidestream Venturi gas injection

J. R Jackson, S. S. Pathapati (USA)

The changing global economic climate has had a significant impact on the manner in which utilities operate their water and wastewater treatment facilities. Community job losses have reduced revenue, resulting in limited staffing as the most senior utility employees are enticed to retire early while the hiring of new employees is discouraged. Yet regulatory law continues to increase the burden of monitoring required to insure full compliance with the current and the anticipated future statutes which regulate the plants' water product quality. Utilities using ozone as part of their treatment process face additional complexity in plant operation and maintenance. Utilities using ozone today as well as those adding ozone to their treatment process have responded to the need to operate with less revenue and staffing by modifying plant equipment and design. Outdated, high maintenance equipment is being replaced by more reliable equipment that provides a sustained level of performance without requiring difficult and time consuming maintenance procedures, thus saving utility man hours and reducing the cost of plant operation. In recent years, modifications made to many existing ozone utility designs as well as proposed new plants in construction have included the use of sidestream venturi injection (SVI) to replace or in preference to their existing ozone contacting system. This paper reviews three Public Utility ozone treatment plants that operate at a combined water flow of 5,000 MLD at a peak ozone production capacity of 459 kg/h. Each utility has replaced their original contacting system design with SVI and a basin nozzle manifold (BNM) or have selected the SVI-BNM contacting system in preference to alternative contacting methods.

22.4 Ozone concentrations exceeding 15wt% on an industrial scale?

N. Brüggemann, M. Salvermoser, T. Pühmeier, R. Fiekens, R. Fietzek (Germany)

Ozone can be produced more efficiently at ever-increasing concentrations. The most notable benefits of high ozone concentrations are directly related to the decrease of feed gas flow necessary to produce a defined amount of ozone per time. This directly leads to operational expense savings since less feed gas must prepared. Moreover, capital expenses decrease since smaller feed gas preparation system can be used. On the other hand it is known from literature that at about 15 wt% spontaneous decomposition of ozone can occur. Above this threshold special care for safety management is necessary. Nowadays semiconductor industry desires very high ozone concentrations (> 15 wt%) confined within small volumes. With increasing gas volume at atmospheric pressures the danger of accidents increases since the amount of energy stored in the ozone/oxygen mixture is proportional to ozone concentration, volume and pressure. The intention of this paper is to initiate the discussion within the ozone industry in order to establish a consensus about the maximum ozone concentration used in field applications that still can be safely operated. Does it make sense to create an international standard?

22.5 The influence of sample tubing material on accuracy of low ozone concentration measurement

A. Scholz, F. Wallner (Germany)

The aim of this study was to investigate the applicability of different sample tubing materials for low ozone concentration measurement. Ozone is a very unstable gas. The materials used in a measurement system have to be selected carefully. Otherwise ozone decomposition could occur on the surface of the materials, especially inside the tubing. Due to the toxicity of ozone, workplace concentration monitoring is mandatory in many countries. Any destruction of ozone on its way from the point of sample to the ozone monitor has to be prevented. Otherwise the safety monitoring system fails. Two stainless steel (SS) tubing materials were compared with a sample gas tubing made of FEP (fluorinated ethylene propylene). The FEP tubing showed no measurable ozone decomposition and thus is the material of choice for low ozone concentration measurement. On the other hand the measurements showed alarming results for the stainless steel tubing. Inside the tubing up to 100% (!) of the ozone was destroyed. For safety monitoring this is a catastrophe. The paper gives recommendations for a proper installation.

Session 23. Industrial waters

23.1 Removal of Hard COD in industrial wastewater – comparison of different treatment solutions based on Chemical Coagulation, DAF, Ozone and Bio Filter

A. Ried, I. Zhu, T. Getting (Germany, USA)

New regulations are requiring lower COD levels in the effluent of industrial waste treatment plants. Typical wastewater treatment including biology treatment as the main step, can achieve a certain effluent level of COD. The non-biodegradable COD (hard COD) will stay in the effluent and may not reach the given COD limit. In this case a further treatment step is needed. Perhaps, the most commonly used process train is the usage of chemical coagulation, flocculation and sedimentation/filtration or flotation to reduce the COD. Alternative solutions using ozone are getting more and more attention. One process combination using ozonation and bio-filtration to achieve low COD levels is completely reducing the use of chemicals and the production of chemical related sludge. Alternatively the usage of ozone in front of the common chemical flocculation process can reduce significantly the amount of used chemicals and the produced sludge. Ozone can be used to partly oxidize the hard COD and transform the COD into more biodegradable matter (BOD). The overall cost of this process depends on the amount of ozone that is needed to produce a significant amount of BOD. Key figures to describe the process are the ratio of ozone dosed/ COD reduced and BOD/COD before and after oxidation. An attractive treatment concept for this process can be achieved with 0.8 to 1.5 g ozone/1 g COD reduced and increased BOD/COD ratios from < 0.05 before oxidation to > 0.20 after oxidation. The capex of the oxidation solution is higher than for the chemical/flocculation. But lower opex cost for the oxidation solution can result in a payback time of 2 to 3 years. The process of O3 + DAF + Filtration has the advantage to reduce the amount of flocculation chemicals and results in a lower amount of produced sludge to handle. A recent pilot trial with waste water from the pulp and paper industry showed significant advantages combining the treatment steps of ozone and chemical coagulation and dissolved air flotation (DAF). The usage of low doses of ozone (20 ppm) led to reduced amount of chemicals used in the chemical coagulation and DAF process (up to 50% less).

23.2 Ozonation of landfill leachate: cost effectiveness and insights on conversions of organic matter

M. Chys, W. T.M. Audenaert, V. Oloibiri, K. Demeestere, S. W.H. Van Hulle (Belgium)

Ozonation was investigated as a potential post-treatment step for biologically treated landfill leachate to enhance the runtime of a final activated carbon (AC) filtration step before discharge. Additionally, the changes of the organic matrix due to an increased ozone dosing were investigated using full spectrum UV-VIS analyses. Based on estimated operational expenses, applying an ozonation step before AC filtration could reduce the AC cost from 1.32 € m^{-3} of treated leachate to 1.21 € m^{-3}. taking into account the cost for ozonation itself. However, the efficiency of the AC was not increased as the enhanced runtime of the columns was mainly due to an additional removal of COD. Secondly, more insights into the reaction mechanism were obtained by spectral calculations as e.g. differential absorbance. It could be hypothesized that during an initial period, ozone will selectively oxidize some species. However, further dosing led to a more unselective reaction mechanisms, indicating the significant present of an unselective oxidant ($HO^{\bullet}$ radicals) dominating the ozone reaction mechanism.

23.3 Evaluation of UV, UV/H_2O_2 and UV/$Na_2S_2O_8$ systems for the treatment of industrial waters - organics degradation and disinfection

Š. Bártová, P. Kůs, V. Šmejdová, K. Vonková, H. Šveda, J. Říhová Ambrožová (Czech Republic)

Organic molecules (measured as Total Organic Carbon – TOC) present in cooling water can cause severe problems in consequent technology, therefore cooling water treatment is necessary. One of possible methods of water treatment, particularly effective in TOC decrease, utilizes UV light or UV light in combination with oxidizing agents (eg. H_2O_2, $Na_2S_2O_8$). We experimentally tested UV, UV/H_2O_2 and UV/$Na_2S_2O_8$ systems with various industrial samples of cooling water: (i) primary coolant of nuclear power plants containing boric acid and (ii) cooling water from cooling tower of coal-fired thermal power plant. Water samples were analyzed to determine TOC and microbiological indicators of water quality. The experimental results showed that the UV light efficiency is strongly dependent on type of organic compounds as well as microorganisms present in treated water.

23.4 The new concept of catalytic ozonation process, OCS: example of waste from the power sector containing nitrogen organic compound

F. Pontlevoy, E. Azokpota, F. Leroux (France)

This communication presents the possible treatment lines and his organization by companies Technavox and Serep for the putting in conformity of industrial effluent releases concentrate in hard DCO. After three years of research and development, Serep and Technavox designed a second generation Catalytic Ozonation process, the Catalytic Ozonation Supported process, The advantages of this new concept allow a simple and economic use of this process for the treatment of nitrogen organic compound, Persistent Organic Pollutants,…, in waters.
In this publication a focus will be more specifically made on the conditions of implementation of an installation of Catalytic Ozonation Supported, OCS, installed as a supplement to a primary treatment to clean up waters of wash of cooling circuit of a power industry.
A feasibility study was realized by experiment plan on three effluents resulting of this branch of industry and having different chemical nature and concentrations. The tests were realized in a reactor laboratory in functioning in semi-batch mode and in continuous mode. The studied factors are, the production of ozone, the catalyst concentration, the contact time, the recycling rate on the catalyst. The answers of the experiments plan, i.e. parameters of follow-up of the tests, are the global parameters COD, DOC and the pH. A nitrogen balance sheet is also made on waste at the end of the treatment.
The optimization by experiment plan allowed finding effective process conditions to treat the effluent in the expected objectives. All these laboratory works resulted in a phase of industrialized pilot tested, and in finally to the design of a OCS completely mobile unit.

23.5 Ozonation and UV radiation as alternatives to chemical biocides for cooling water

S. Chéret, S. Baig (France)

Controlling the biocontamination in the cooling water circuit with alternative solutions to biocide has become a new issue. Due to large quantity of water involved in its production processes, petrochemical industry is strongly interested for field-test and demonstration of technologies and related water treatment lines for the development of an alternative to chemical treatment in the cooling water loop. Ozone and UV radiation were successfully tested for application in cooling water treatment by investigating their biocidal activity, the impact on the water quality variation and the corrosion behaviour of the system material.
Findings based on ATP, *Legionella* and aerobic bacteria indicators, indicate that microorganisms in a circulating water system are effectively inactivated provided the use of UV at 350 mJ/cm^2 or of ozone at dose as low as 0.5 mg/L. The circulating water disinfection takes place while biofilm growth is controlled according to the stabilization of the *Legionella spp* count on the surface of the system material. Under these conditions found optimal within a rather restricted range of variation, the quality of the circulating water is improved when expressed by COD. UV irradiation and ozonation induce changes in the organic content according to their oxidation power in favour of ozonation. Of interest, both disinfection processes do not promote noticeable changes in corrosion behaviour of the materials used. The results support the conclusion that UV light disinfection and ozonation of cooling systems may be appropriate alternatives or supplements to chemical biocides when properly applied and installed.

Session 24. Micropollutants control – Part 2

24.1 The contribution of analytical and chemometric tools for the performance assessment of several wastewater treatment technologies

A. Kiss, A. Gonzalez Ospina, S. Baig, E. Vulliet (France)

This work illustrates the contribution of both high resolution mass spectrometry (HRMS) and chemometric tools to the comprehensive chemical characterization of wastewater samples. The results presented here are issued from the study of an integrated wastewater treatment system combining biological oxidation followed by chemical (ozone) oxidation for the removal of micro-pollutants. The main aims of our study are to annotate the largest number of micro-pollutants and to contribute to the assessment of several wastewater treatment technologies by using molecular prints.

24.2 Determination of transformation products from the ozonation of pharmaceuticals and their detection in treated wastewaters

M. Bourgin, E. Borowska, J. Hollender, C. S. Mcardell, U. Von Gunten, (Switzerland)

Ozone is widely used in water and wastewater treatment for disinfection and chemical oxidation of inorganic and organic compounds. Environmental samples are often contaminated by micropollutants like pharmaceuticals and personal care products, pesticides, industrial chemicals. Among them, cetirizine (antihistamine), fexofenadine (antihistamine) and hydrochlorothiazide (diuretic) are commonly detected in Swiss surface waters and wastewaters. Due to their occurrence in environmental samples and the lack of information concerning their fate through wastewater treatment, they are considered as emerging contaminants. Since their reactivity with ozone has not been investigated yet, the present study aims at (i) describing the ozonation kinetics of these compounds, (ii) identifying the transformation products (TPs) produced during the oxidation of the parent compounds in ultrapure water, and (iii) detecting parent compounds and their TPs in real environmental samples.

24.3 Ozonation for degradation of pharmaceutical of hospital wastewater

K. M. S. Hansen, A. Spiliotopoulou, R. Kumar Chhetri, M. Escolà Casas, K. Bester, H. R. Andersen (Denmark)

Effluents from an experimental pilot system using staged Moving Bed Biofilm Reactor (MBBR) tanks for optimal biological treatment of wastewater from a medical care unit of Aarhus university hospital was monitored for dissolved organic carbon (DOC) and pH and samples were collected for ozonation experiments. The effect of these two parameters on ozone efficiency in removing pharmaceuticals was determined. The pH in the effluent varied from 5.0 to 9.0 resulting in approximately a doubling of the required ozone dose at the highest pH for each pharmaceutical. DOC varied from 6 to 20 mg-DOC/L. Required ozone dose for 90% removal of pharmaceuticals varied linearly with DOC and thus ozone doses normalised to DOC agreed between water samples, typically within 15%. At neutral pH the specific ozone dose required to remove the easiest degradable pharmaceutical, sulfadiazine, was 0.50±0.04 mg O_3/mg DOC and the most recalcitrant, diatrizoic acid, required 4.7±0.6 mg O_3/mg DOC. The lifetime of ozone in the higher end of the indicated required doses increased drastically. At the lowest observed pH of 5, lifetime was quadrupled to 20 min compared to neutral pH which influences the design of the reaction tank. The addition of 10% w/w H_2O_2/O_3 mitigated the reaction time without influencing the pharmaceutical removal efficiency of ozone.

24.4 Pharmaceuticals removal in wastewater by biological treatment and tertiary ozonation

B. Domenjoud, A. Gonzalez Ospina, E. Vulliet, S. Baig (France)

The reduction of micropollutants dissemination into the environment should go through a technological solution. Tertiary ozonation applied to urban wastewater has already demonstrated its efficiency for a broad range of contaminants of concern, notably for pharmaceuticals. The present article reports the results obtained from a pilot experimentation consisting in a biological treatment achieving full nitrification followed by a tertiary ozonation treatment applied to a mixed domestic and hospital effluent. 10 pharmaceuticals and 1 hormone were systematically searched and the whole treatment chain was characterized. Moreover, impact of the ozone contact time and transferred ozone dose was investigated. As main findings, it has been observed that a slight increase of the ozonation contact time from 4 to 6 min as well as increasing the ozone dose from 5 to 13 mgO_3/L favors the removal of low-reactive substances towards ozone. Higher ozone dosage did not significantly improve the oxidation of the pharmaceuticals targeted. Characterization of the full treatment chain shows that for an ozone dose of 5 mgO_3/L and a contact time of 5 min, the concentration of selected compounds could be reduced by a factor 2 with respect to the biotreatment alone. For such conditions, the biotreatment plus the tertiary ozonation achieved an average removal of 91 % of the pharmaceuticals targeted. Moreover, for these experimental conditions, immediate ozone demand was not satisfied and ozone transfer rate was 100 %.

Session 25. Workshop –Access to ozone mass transfer parameters

J-S Pic

Overview of mass transfer modelling - Review and discussions on experimental methods

Session 26. Workshop – Young Ozone People

B. Domenjoud

Spot presentations by Young Ozone People, by experienced Ozone People - Discussion

Session 27. Workshop – IOA highlights

S. Baig

27.1 Ozone as active substance under the Biocidal Products Regulation

B. Paolini, T. Pühmeier, J. Mielcke, M. Rothe, M. Hoffmann, J. Ryckeboer (Switzerland, Germany)

Ozone is declared an active substance under the EU Biocidal Products Regulation No 528/2012 (BPR) starting as of September 1st, 2013. In effect the BPR is considerably extending scope compared with the prior existing directive. Due to this, the active substance ozone and the ozone generating equipment need to be authorized. WEDECO, OZONIA, ProMinent and BWT jointly, as the "*Ozone Registration Group*" (ORG), are writing an active substance dossier for ozone covering applications defined under biocidal product-types (PT) 2, 4, 5 and 11. The intention of this group is to submit the active substance dossier for ozone by spring 2015. This is a key step for anyone intending to bring ozone in the EU market. In case no such dossier is filed nobody will be able to comply with the new legislation and will be withheld from using ozone in Europe. Hence it is the main target of the "Ozone Registration Group" to achieve that ozone is approved as active substance and listed in the EU "List of approved active substances". Secondly, it is then required to apply also for the product authorization of ozone, a biocidal product which is generated on-site. This allows the further use of ozone in treatment processes in agreement with the EU law. The second step can possibly most effectively be done by the actual manufacturer of such ozone equipment. In order to do so an approved active substance dossier must be owned or legally accessed by a letter of access (LoA). The Ozone Registration Group (ORG) will make Letters of Access (LoA) available to everyone who needs it through a non-commercial organization under foundation named $EurO_3zon$. Some details for in-situ generated active substances (AS) are still under discussion at the level of the European Commission and thus not fixed at the date of writing this paper. This is especially true for the active substance "*Ozone*".

Review of industry and technical news

IOA Ozone engineering group

Session 28. Design and Engineering aspects – Part 2

28.1 Ozone Generation System Performance Testing Considerations

K. L. Rakness (USA)

Public and private organizations often purchase ozone systems using competitive bids. Design engineers prepare plans and specifications that outline requirements for ozone production and sometimes also for energy consumption performance criteria. Following installation, system components are tested to validate equipment operability and performance. Operability testing includes starting and stopping the ozone generators, cooling water supply pumps, off-gas destruct units, and other. After component testing is completed, the entire ozone system is tested to confirm integrated system operation. These equipment component and system operational tests are termed, "functional testing". Basic or advanced "performance testing" also might be conducted, depending on specification requirements. Basic testing is defined as production-only tests using readings from installed gas flow and ozone concentration instrumentation, without field verification of instrumentation accuracy. Advanced testing examines ozone generator power demand at multiple ozone production settings, and, in addition, requires in-field quality assurance testing of installed instrumentation. Different performance testing styles are described in this paper, including when each test might be applicable and considerations for testing approach. Data are presented based on experience. Details include but are not limited to:Testing set-up and schedule, including how to deal with the design ozone production rate when operating the water plant at less than design flow and dose. Data accuracy and quality control checks for power demand; gas flow; ozone concentration; cooling water flow and cooling water temperature. Meeting specified test conditions, such as cooling water temperature. Testing issues and considerations, including acceptance of final results.

28.2 Upgrading an Older Ozone System to Achieve Optimal Treatment Performance

C. Schulz, M. Bayan (USA)

The City of Arlington, Texas (City) owns and operates the 97.5-million-gallons-per-day (mgd) John Kubala Water Treatment Plant (JKWTP) and the 75-mgd Pierce-Burch Water Treatment Plant (PBWTP). Both plants were originally designed with conventional treatment processes and were upgraded 15 years ago with a two-stage ozonation process, followed by biological filtration. This paper presents the results of an ozone engineering assessment for the JKWTP, specifically how historical water quality and treatment performance trends, bench-scale testing, and automated control strategies were used to upgrade the ozone system at that plant to achieve optimal treatment performance.

28.3 The synergistic effects of designing ozone with a biologically active filter

I. Zhu, T. Getting, A. Ried, A. Wieland (USA, Germany)

Municipalities and industry are now faced with the prospect of further treating, or deep polishing water and wastewater prior to use as potable water, direct or indirect reuse water or for effluent discharge to sensitive surface waters. Prior research has shown that there are few inexpensive methods that can remove or destroy all of the required Chemicals of Concern (CEC) such as Endocrine Disrupting Compounds (EDC), Pharmaceutical and Personal Care Products (PPCP), and industrial recalcitrant Chemical Oxygen Demand (COD) that must be deep polished. Reverse Osmosis has commonly been used but is expensive and concentrates these micro- pollutants into a side stream that must be further treated. Designers are now turning to both physical-chemical and biological systems to provide treatment that can destroy the micro-pollutants before further use. In most cases, ozone alone can destroy most of the micro-pollutants. However, the ozone dosing rates can sometimes be very high increasing both the capital and operating costs while also possibly forming by-products such as assimilable organic carbon (AOC), bromate, and Nitrosodimethylamine (NDMA). Designers have found that reducing the ozone dose, followed by a biologically active filter can reduce capital and operating costs and reduce by-products with bio-filtration, while producing a minimal non-toxic biological side stream that can be easily treated or returned to the headworks. Ozonation followed with biologically active filtration (BAF) has synergistic effects of reduced operating cost in terms of performance, media replacement, and ozone dosage, and that potentially the combined ozone and BAF can be used to replace reverse osmosis membrane process which was usually applied for indirect or direct water reuse.

28.4 Research and development, implementation and operation of industrial experience systems for ventilation and decomposition of ozone

I. Tkachenko, S. Tkachenko, V. Lunin (Russia)

The paper presents the experience of developing, systems implementation, disposal and destruction of ozone at the municipal industrial water treatment plant where ozone - sorption technology is being used. There were examined the kinetics of ozone decomposition, aerodynamic properties of the system, the activity of the catalyst for the decomposition of ozone. The characteristics of the chemical reactor for the decomposition of ozone and the power consumption of the system were calculated. Based on this R&D, the system for ventilation and decomposition of ozone was designed and launched at the West water treatment plant in Moscow in 2011. Ozone is an environmentally friendly oxidant and it is widely used in modern technological processes at water treatment stations, including Moscow city. Despite the widespread use of ozone, it should be noted that ozone is very toxic. Maximum allowable concentration (MAC) is 0.1 mg/m^3 in Russia. Therefore, residual quantity of ozone must be disposed after its practical use.

28.5 Control Strategies for Wastewater Applications of Ozone

M. Oneby (USA)

Treatment of wastewater with ozone presents unique challenges in developing a reliable and robust full-scale system. Several potential control parameters have been tested in a number of bench-scale and pilot-scale studies. The use of parameters measured at the end of the ozone contactor requires feedback control of the ozone generating system. The infrequent full-scale ozone applications that use feedback control as one of several modes of operation have experienced difficulty in maintaining adequate control and application of ozone. Effective control strategies employ a variety of techniques to create a stable and robust process that meets treatment objectives in all operating conditions. Setpoint (feed-forward) control is an effective, stable and widely used control strategy for virtually all ozone applications. Whether the ozone system is fully automated or not, setpoint control may result in substantially higher ozone doses than are necessary when the variability in ozone demand is high, which are typical of wastewater applications. Feedback control uses a parameter measured at the end of the ozone process to establish or trim the applied ozone dose. The parameter is typically measured on-line with an analyzer to provide the a steady stream of values to control ozone production. The availability and reliability of on-line analyzers limits the number of parameters than can be utilized. Examples include the dissolved ozone residual and UV_{254} absorbance. Due to the elapsed time between ozone production and measurement, in particular the ozone contactor hydraulic detention time, the signal cannot be directly used in feedback control and must be processed. Economics is a key factor in the desire for feedback control of ozone dose. Traditionally, ozone is applied in excess to insure treatment objectives are realized. In addition, the ozone demand of wastewater is typically higher and more variable than for most applications. Simple setpoint control, where a target ozone dose is established by the operator, may lead to significant overdosing at average constituent loadings. A control system that minimizes the amount of excess ozone applied can have a significant impact on the cost of ozone treatment. Feedback control of ozone generating systems requires additional consideration to result in a stable and effective process. Techniques include a proportional-integral-derivative (PID) controller and signal dampening using step, band and delay.

Session 29. Applications in Industrial Processes

29.1 Ozone as an interesting oxidizer for green chemistry processes: pre-industrial pilot experimentations on various samples

L. V. Hoang, C. Coste, C. Druon, J.-P. Bonhoure, T. Aussenac (France)

Institut Polytechnique LaSalle Beauvais, in its pre-industrial pilot plant (LaSalleO3), has developed some new processes, aiming to intensify use of ozone in oxidative synthesis. All these processes are organic solvent-free, catalyst-free, and give yields at least as high as those obtained with current processes. They were tested in pre-industrial conditions, i.e. for productions of around 10 kg per batch, in dimensionless reactors, which allow an easier extrapolation. The two processes briefly described in this article are patented, and currently used for industrial production at a reduced scale.

29.2 Ozone delignification of lignocellulosic waste for sugar availability

P. Arenas-Cárdenas, A. López-López, E. León-Becerril (Mexico)

Lignocellulosic residues can be used for bioethanol production for which is necessary to modify the cell wall composed of lignin, cellulose and hemicellulose forming a strong recalcitrant network difficult to hydrolyze. The applied pre-treatment should keep the carbohydrates in cellulose and hemicellulose as glucose and xylose, respectively and modify mainly lignin for that reason using molecular ozone as a pre-treatment is attractive for its strong affinity to the phenolic characteristics of lignin. Sugarcane bagasse was pre-treated with molecular ozone at three different concentrations and three different particle sizes, the initial amount of carbohydrates and after the pre-treatment was determined and the percentage decrease of lignin in the material as well proving that molecular ozone is effective against lignin degradation and maintaining carbohydrates intact, reaching glucose and xylose recovery, after enzymatic hydrolysis, of 69.5% and 51.3%, respectively, these reducing sugars can be used in bioethanol production.

29.3 Advanced oxidation processes for the regeneration of siloxane-exhausted adsorbents

A. Cabrera-Codony, R. Gonzalez-Olmos, M. J. Martín (Spain)

In a context of rising concerns on a future global energy crisis combined with climate change mitigation efforts, developing technologies capable of efficiently transforming waste into energy has become a fundamental social and research challenge. In this sense, the production of biogas from municipal solid waste and wastewater sludge has increased and many sewage treatment plants are collecting and using their biogas mixture to obtain energy. However, in order to be used as a high-quality fuel, biogas needs to undertake a process of upgrading, to

remove the undesirable volatile compounds such as siloxanes. A well-known and widespread technology that can perform this purification process is adsorption onto porous materials, such as activated carbon, which has been extensively investigated as adsorbent for the siloxane removal [3], or zeolites whose performance is included in some publications. Inherent to the adsorption process, there is the problem of the regeneration of the spent materials in order to avoid them becoming a residue. Siloxane-exhausted adsorbents are not usually regenerated [2], therefore the adsorbent beds have to be replaced regularly, which constitutes the predominant part of the operational costs for the removal of siloxanes by adsorption. In the same sense, Ajhar *et al.* indicated that future research trends should be focused on regenerative systems to reduce costs for adsorbents renewal. In this context, the aim of our work is to study the regenerability of the AC. Although thermal treatment of the adsorbents is one of the most common regeneration techniques, in the case of siloxanes, it may be hampered by the presence or the formation of non-volatile siloxane polymers of higher molecular weight in the AC surface. In this perspective, advanced oxidation processes constitute important technologies for treating this hardly biodegradable contaminants.

29.4 Effect of different UV lamp configurations and reactor geometries in a bench scale UV and ozone system for VOC abatement in air streams

F. Montecchio, J. Delin, J. Mills, K. Engvall, R. Lanza (Sweden, UK)

The decomposition of hexanal at trace concentration (10 – 50 ppm) was investigated using a bench – scale system composed by ozone and UV lamps. First of all, the overall efficiency of the system for VOCs abatement were investigated and the conversion was increased for a longer residence time and for a lower VOC inlet concentration. Different configuration for the UV lamp were investigated and the unsleeved amalgam lamp proved to have the highest conversion. Different reactor geometries were tested and a higher reactor diameter slightly increases both the conversion and the ozone net production by the UV lamp. An external ozone generator was used to add external ozone into the system and further increase the VOC conversion.

29.5 Preparation and characterization of modified PVDF membrane by gamma-ray irradiation for water reuse

S. J. Lim, T.-H. Kim, I. H. Shin (Republic of Korea)

It is well-known that the physicochemical properties of fluoropolymers including a poly(vinylidene fluorine) (PVDF) membrane are chemical and thermal stability, low dielectric constant and low surface energy. However, the PVDF membrane is subjected to be fouled when exposed by hydrophobic substances such as non-ionic matters and/or proteins in an aqueous phase. The surface modification of the PVDF membrane can be achieved either by chemical, by etching, or by high energy irradiation. Although the surface modification by chemicals causes the environmental concerns and the difficulties in control, the chemical modification is the most favour method. The surface modification of a membrane by high energy irradiation such as plasma, X-ray, gamma-ray and E-beam is a relatively cleaner method because it is possible to modify the surface of the membrane without generating by-products at room temperature. The objectives of this study were to characterize the modified PVDF membranes by gamma-ray irradiation using the data of FT-IR, XPS and contact angle were to evaluate the feasibility of the modified PVDF membranes for non-potable water reuse. In this study, how to evaluate if permeate quality satisfied non-potable water reuse guidelines in the Republic of Korea, the modified PVDF membranes were applied to treat grey wastewater. As shown by FT-IR and XPS, the PVDF membrane was successfully grafted by gamma-ray irradiation and was sulfonated by sodium sulphite. The contact angle of the modified PVDF membranes sharply decreased. To conclude, hydrophilic PVDF membranes can be efficiently used for non-potable water reuse with its enhanced anti-fouling performance and chemical/thermal resistance characteristics.

Session 30. Micropollutants control – Part 3

30.1 Removal of a recalcitrant anticancer drug from water with ozone based technologies

R. Gonzalez-Olmos, L. Ferrando-Climent, A. Anfruns, S. Rodriguez-Mozaz, D. Barceló (Spain)

Tamoxifen is a non-steroidal antiestrogen, which belongs to a large list of anticancer drugs, that is frequently used to treat breast cancer as well as a prophylactic agent in women considered at significant risk of developing the disease .This compound has been detected in hospital effluents, sewage (input and output) and surface waters in different range of concentrations (51 - 200 ng/L). Tamoxifen is being released in the urban collectors and it is well-known for being a non-biodegradable compound during conventional wastewater treatments. Also it is suspected to provoke endocrine disruption effects as well as to have a high bioaccumulation potential. Tertiary treatment after the biological treatment in wastewater treatment plants might be a solution for avoiding the discharge of Tamoxifen into the natural environment. However, few studies have evaluated the potential removal of Tamoxifen by non-biological treatments. This work has the goal of studying the degradation of Tamoxifen using ozone-based technologies paying attention on the formation of transformation products (TPs) and the evolution of effluent toxicity.

30.2 Investigation of ozone based processes for removal of benzothiazoles

J. Derco, M. Melicher, J. Dudas, J. Kecskes (Slovakia)

Realistic achievement of the safety value of 2-MBT concentration suggests potential of ozonation process for toxicity decrease of the real wastewater before biological treatment of wastewater containing BT derivatives. Significantly lower 2-MBT impact on oxygen uptake rate (OUR) by ozonation was observed. Ozonation resulted also in significant reduction of inhibition effect of BT wastewater on nitrification bacteria and reduction in toxicity for *Vibrio fisheri*. However, better detoxification results both, with regard to nitrification process and *Vibrio fisheri* were observed with (O_3/GAC) process. Experimental results show that ozonation process significantly improved when combined with granular activated carbon (O_3/GAC), both in terms of BT derivatives and COD/DOC content. Combination of ozone with zeolite (O_3/ZEO) resulted in less significant increase in BT removal efficiency. Combined ozonation with UV at high pH did not lead to more efficient removal of 2-MBT.

30.3 Robust fluorescence and UV-vis correlation models for real-time control and assessment of micropollutant removal from secondary effluent using ozonation

M. Chys, S. W.H. Van Hulle, E. Deniere, L. Vergeynst, H. Van Langenhove, I. Nopens, K. Demeestere, W. T.M. Audenaert (Belgium)

Ozonation is an effective technology to remove contaminants of emerging concern (CECs, e.g. pharmaceuticals) from municipal wastewater effluent. Developing reliable, user friendly and real-time monitoring strategies to facilitate process control was the aim of this research. Detailed empirical models for real-time prediction of CEC removal were developed at lab-scale based on selected spectroscopic techniques (UV-VIS and Fluorescence) as they can provide real-time information on the effluent composition. PARAllel Factor Analysis (PARAFAC) was used to decompose complex excitation-emission matrices into 5 distinct fluorescence compounds (FCs). The removal of the 9 pharmaceuticals with different ozone affinity was strongly correlated to both the reduction of UV-VIS and fluorescence compounds. For every compound, a clear relationship could be obtained that was consistent throughout the sampling campaign. The 5 FCs (FC1-5) reacted differently as each FC was differently influenced by the applied ozone dosages. The shape of the models for both techniques was hence related to the reactivity towards ozone which is promising for further use in full-scale operations.

30.4 UV photolysis and UV/H_2O_2 photolysis processes for estrogens removal in water

B. Cédat, C. de Brauer, H. Métivier, J. N. Levrard (France)

This study aimed at investigating the degradation of a mixture of estrogenic hormones (Estrone (E1), ß-Estradiol (E2), and 17α-Ethinyl Estradiol (EE2)) in water by UV photolysis and UV/H_2O_2 photolysis. Firstly, the effects of water matrices (drinking water and treated wastewater) and H_2O_2 concentrations (10, 40, and 90 mg/L) were determined. The hormones were added in a UVC (λ=254 nm) pilot system running in semi-batch. Hormones degradation rates were measured by HPLC-UV. Secondly, a single concentration of H_2O_2 (20 mg/L) was tested in order to optimize oxidant cost. Hormones degradation rates as well as changes in estrogenic activity, measured by Yeast Estrogen Screen (YES), were followed at the same time. First results showed negligible degradation of E2 and EE2 by UV photolysis in both matrices. High UV fluences were needed to degrade 80% of E1 in drinking water (1300 mJ/cm²) and treated wastewater (1800 mJ/cm²). All hormones degradation rates were significantly improved in both water matrices at H_2O_2 concentration as low as 10mg/L. UV fluence of 400 mJ/cm² and 90mg/L of H_2O_2 would enable to remove 80% of all hormones in treated wastewater. Water quality could highly influence the treatment efficiency as shown by higher UV fluences required to reach the same result in treated wastewater than in drinking water. Estogenic activity, measured by YES bioassay, could not be removed by UV photolysis whereas it decreased in the same trend than E2 and EE2 removal rate when combining UV and 20 mg/L of H_2O_2. No high estrogenic by-products were formed. These results pointed out that estrogens removal can be highly enhanced by UV/H_2O_2 photolysis in drinking water and treated wastewater. By combining the approriate concentration of H_2O_2 and UV fluence, it would be possible to design a cost effective treatment for small and midlle sized WTPs.

30.5 Proposal to optimize ecotoxicological evaluation of wastewater treated by conventional biological and ozonation processes. A summary

A. Wigh, S. Bony, A. Devaux, A. Gonzalez-Ospina, B. Domenjoud, S. Aït-Aïssa, N. Creusot, C. Bazin (France)

The main objective of this study was to combine normalized bioassays with newly developed *in vivo* and *in vitro* tests in order to assess alteration of embryo development, growth and reproduction as well as genotoxic effects in aquatic organisms exposed to effluents (50% v/v of hospital and urban effluents) before any treatment, after biological treatment alone and after biological treatment followed by a tertiary ozonation (15 mg O_3/L). Toxicity was not detected with normalized bioassays but a residual toxicity was observed in the effluent after biological treatment and also in the effluent after tertiary ozonation treatment by measuring mortality, developmental abnormalities and genotoxicity on zebrafish embryos. However the ozonation step resulted in a diminished endocrine disrupting potential (<LOQ). This study shows that normalized bioassays lack in sensitivity for the ecotoxicological evaluation of wastewaters and that there is a great need for the development of suitable sensitive bioassays in order to characterize properly the possible residual toxicity of treated effluents.

Plenary session

Awards Ceremony

Harvey Rosen Award - Process control for ozonation systems: A novel real-time approach

H.-P. Kaiser, O. Köster, M. Gresch, P.M.J. Périsset, P. Jäggi, E. Salhi, U. von Gunten (Switzerland)

Ozone: Science and Engineering Journal 35 (2013): 168-185

For real-time control of ozonation processes in water works, a sequencing batch reactor was constructed to measure the ozone decay rate constant (k_{O3}) in short time intervals of about 15 min. The batch reactor is filled during the production process, immediately after dissolving ozone in water by a static mixer. On the basis of k_{O3} and the initial ozone concentration ($[O_3]_0$), and the experimentally determined ratio of the concentrations of •OH radicals to ozone (R_{ct}), the degradation of micropollutants in ozone reactors (modeled as Continuously Stirred Tank Reactors - CSTRs) were calculated for compounds with known reaction rate constants with ozone and •OH radicals. Calculated degradation of atrazine, iopromide, benzotriazole and acesulfame are in good agreement with measured data. For acesulfame the following rate constants were determined in this study at 20 °C: reaction rate constant with ozone = 88 $M^{-1}s^{-1}$, reaction rate constant with •OH radical = 4.55×10^9 $M^{-1}s^{-1}$. For the ozone reaction an activation energy of 35 kJ/mol was determined. Similarly to micropollutants, the relative inactivation of microorganisms (N/N_0) can be calculated based on the inactivation rate constant for ozone and if applicable the lag phase. The pI-value ($= -\log N/N_0$) was introduced and implemented in the process management system to calculate online the log inactivation of reference microorganisms such as *B. subtilis* spores. The system was tested for variation of pH (6.5–8.5), DOC (1.2–4.2 mg/L) flowrate 3.2–12 m^3/h and temperature (5.7–9 °C). Furthermore, a given pI-value, e.g. 1 for a 1-log inactivation of *B. subtilis* spores, can be set as control parameter in the process management system. The ozone gas flow is then adjusted until the set pI-value is reached. The process control concept was validated with *B. subtilis* spores. Generally, a good agreement was found between calculated and measured inactivation data. It was also demonstrated, that a constant ozone residual may lead to insufficient disinfection or overdosing of ozone. The new process control concept for ozonations based on onsite measurement of the ozone decay rate constant and the pI-value allows to assess disinfection and degradation processes quantitatively in real-time.

Synthesis and Conclusions

Announcements

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