INTERNATIONAL OZONE ASSOCIATION
Europe Africa Asia Australasia Group

2 - 7 July 2023, Milan, Italy

In partnership with

POLITECNICO MILANO 1863

26th World Congress & Exhibition

Ozone and Advanced Oxidation
Leading-edge science and technologies

PROGRAMME
BOOK OF ABSTRACTS

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Ozone and Advanced Oxidation

Leading-edge science and technologies

WELCOME ADDRESS

Frédéric VIOLLEAU,
IOA President

Renate VIEBAHN-HÄNSLER,
IOA-EA3G President

Following a long series of successful congresses organized every two years, it gives us great pleasure to welcome you to the IOA World Congress & Exhibition in Milan, at Politecnico di Milano.

With the ambition to repeat the success of past World Congresses held worldwide for 50 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, 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 advanced oxidation – 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 Milan city and its area.

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

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

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

THE ORGANIZER

IOA

The International Ozone Association is a non-profit organization dedicated to the development of educational and scientific activities to respond at the best to the needs of industry and research community in the field of ozone and derived oxidants.

Since its foundation in 1973, the IOA is at the forefront in connecting professionals around the globe involved and interested in ozone-related issues including scientists, researchers, engineers, system designers, technologists, equipment manufacturers, consultants, users and members of governmental agencies.

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

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

IOA-EA3G

The EA_3G group of IOA manages IOA membership in Europe, Africa, Asia and Australasia.

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

It initiated and carried out the organization of the Congress.

FOR ANY FURTHER CONTACT

INTERNATIONAL OZONE ASSOCIATION

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ioa-ea3g.org

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- Dr. Wilhelm SCHÜLER | Physician, Private clinic in Aystetten, Germany
- Dr. Matteo BONETTI | Istituto Clinico Citta di Brescia, Italy

SPECIAL ACKNOWLEDGEMENTS AND CONTRIBUTIONS

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

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

- **SIAD S.p.A.** | **Gold Sponsor** | Exhibition
- **SUEZ** | Sponsoring
- **POLIMI** | Host
- **De Nora Water Technologies** | Sponsoring | Exhibition

- **ALNITEC - OZONOMATIC** | Exhibition
- **Arrow Lake AB** | Exhibition
- **BMT Messtechnik GmbH / OSTI** | Exhibition
- **Veolia Ozonia** | Exhibition
- **Xylem** | Exhibition

- **Fini-stampa Giordanetto WWTP** | Technical tour
- **IZO, Vaxxinova Process Plant** | Technical tour
- **Lereti DWP** | Technical tour
- **Alto Seveso WWTP** | Technical tour

General sponsor

Host

GENERAL INFORMATION

Language

English will be the official language.

Congress Venue

The Congress venue will be POLIMI.

Politecnico di Milano, Edificio 3
Piazza Leonardo da Vinci, 32, Città Studi
20133 Milano, Italy

https://www.polimi.it/en

Registration categories

There are 14 categories of registration and associated as follows:

Full registration

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

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

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

One-day registration

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

Additional registration is required for

• Technical tour T1** Fini-stampa Giordanetto WWTP and IZO, Vaxxinova Process Plant	Thursday 6 July. Included bus transfer and lunch. Minimum number of 30 registrations is required per visit.
• Technical tour T2** Lereti DWP and Alto Seveso WWTP	Friday 7 July. Included lunch and entrance fees for the public visit of the aquarium. Minimum number of 30 registrations is required per visit.
• Congress dinner “Grand Hotel Villa Torretta”	Wednesday 5 July. Number of registrations is limited.
• Accompanying person registration	Covers welcome reception and lunches from 3 to 5 July
• Cultural tour C1*** Saint Ambrose Basilica . The canals district	Monday 3 July afternoon. Minimum of 10 registrations is required per visit. Covers guide and entrance fees.
• Cultural tour C2*** The Cathedral , Santa Maria presso San Satiro , The Ambrosiana Museum and Library	Tuesday 4 July morning. Minimum of 10 registrations is required per visit. Covers guide, entrance fees and lunch.
• Cultural tour C3*** The “Renaissance unveiled” tour	Wednesday 5 July afternoon. Minimum of 20 registrations is required per visit. Covers guide, entrance fees and lunch.
• Electronic proceedings for members or non-members	Additional copies available can be purchased during and after the Congress at discounted rate for IOA member.

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

Author registration

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

Cancellation policy

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

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

Liability and insurance

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

Disclaimer

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

Registration desk

It will be opened during the Congress as follows:

- Sunday, July 2 17:00 – 18:30
- Monday, July 3 7:30 – 17:00
- Tuesday, July 4 8:30 – 17:00
- Wednesday, July 5 8:30 – 17:00

Badges

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

Breaks

Each morning and afternoon complimentary coffee and drinks will be available in the exhibition area at the scheduled break time. Each day, lunch will be offered in the Congress area.

Meeting point

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

Wifi

A Wifi connexion will be available for each delegate.

Milan

Milan is the second largest city in Italy after Rome, and its urban centre has 1.3 million inhabitants with a metropolitan area of more than 7 million, one of the most populated areas in all Europe.

Milan was in the hands of Celts, Romans, Goths, Lombards, Spaniards and Austrians before becoming Italy's industrial and commercial capital as well as sharing the title of world fashion capital with Paris.

PREPARE YOUR STAY!

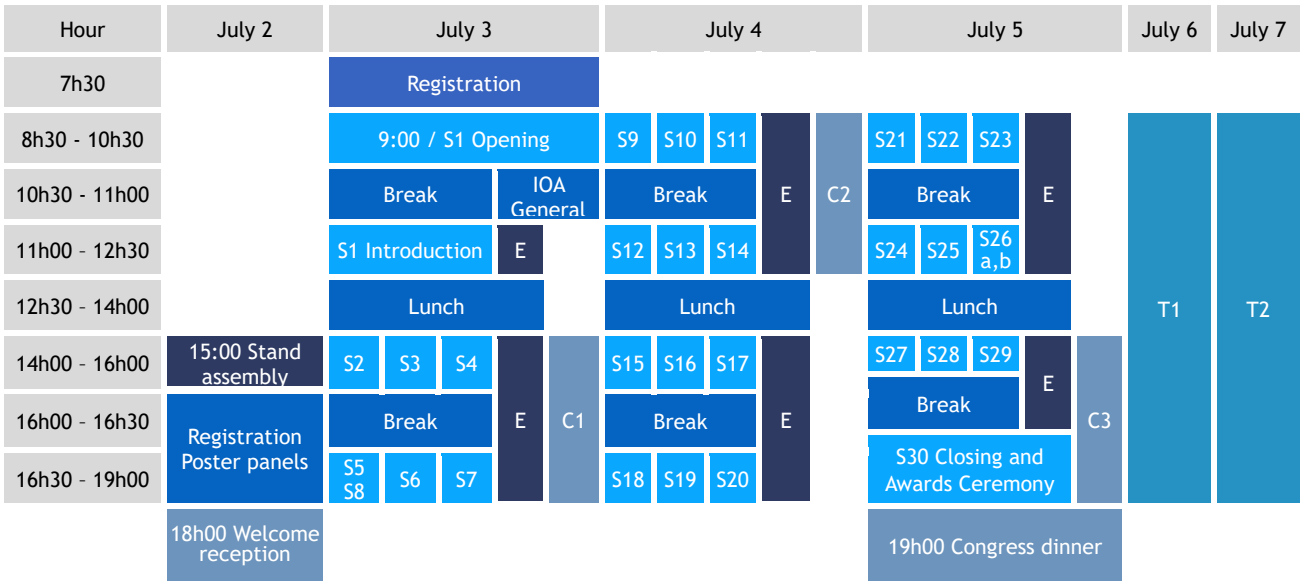
Your guide to the City: https://www.yesmilano.it/en

GENERAL PROGRAMME

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

- Attendance by top specialists and researchers from public and private organizations, all working on technologies based on ozone and advanced oxidation systems and all interested in environmental and human health protection, industrial manufacture and conditioning, medical therapy,
- 3-day Technical and Scientific Programme with more than 100 scientific presentations arranged in 30 sessions in 3 parallel tracks. All topics of current or future interest are covered,
- An Exhibition of technologies, products and services,
- 2-day exclusive plant tours to the ozone installations - Fini-stampa Giordanetto WWTP and IZO, Vaxxinova Process Plant, and Lereti DWP and Alto Seveso WWTP,
- 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 Saint Ambrose Basilica. the canals district, the Cathedral, Santa Maria Presso San Satiro, the Ambrosiana Museum and Library, the "Renaissance unveiled" tour,
- Special IOA meetings, particularly the IOA General Assembly (Monday 3 July),
- All in the Italy's world-famous environment and hospitality.

Schedule of the congress program



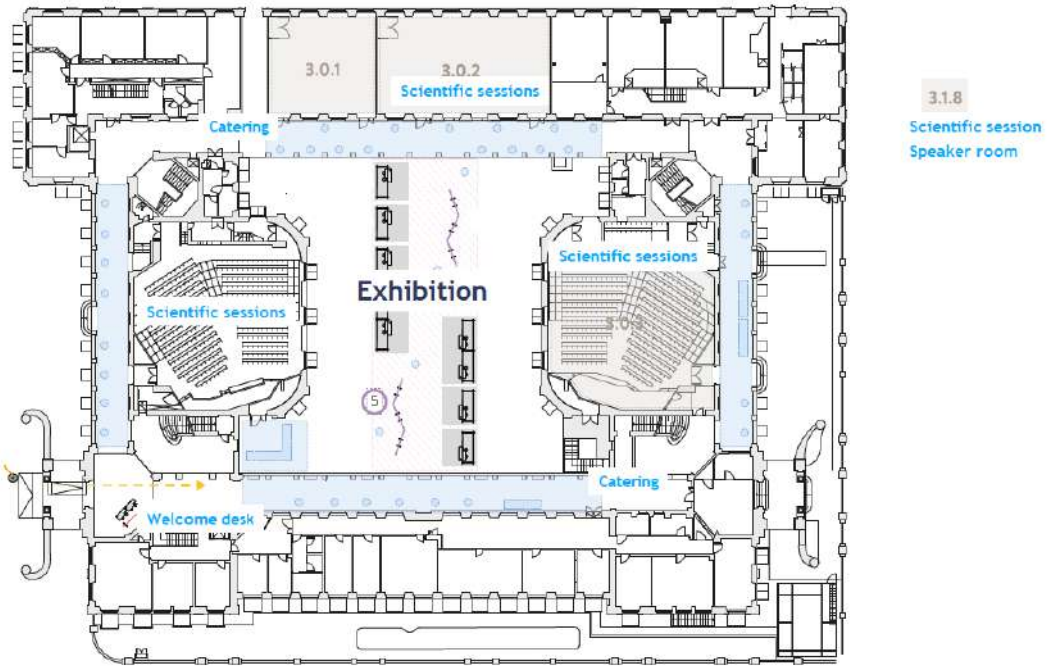
With S: Scientific Session; E: Exhibition; C: Cultural tour; T: Technical tour

S1	Opening and Introduction	S11	Ozone in Medicine - Part 1	S21	Ozone reactions - Part 4
S2	Ozone for Agrifood - Part 1	S12	Workshop / Sidestream injection of ozone	S22	Advanced treatment of wastewaters - Part 3
S3	Ozone reactions - Part 1	S13	Engineering aspects - Part 3	S23	Ozone in Medicine - Part 5 / Workshop
S4	Engineering aspects - Part 1	S14	Ozone in Medicine - Part 2	S24	Workshop / The energy vectors
S5	Ozone for Agrifood - Part 2	S15	AOPs - Part 2	S25	Advanced treatment of wastewaters - Part 4
S6	Ozone reactions - Part 2	S16	Advanced treatment of wastewaters - Part 1	S26a	Ozone in Medicine - Part 6 / Workshop
S7	Engineering aspects - Part 2	S17	Ozone in Medicine - Part 3	S26b	Workshop / Ozone for Food & Beverage
S8	Workshop / Young Ozone People	S18	AOPs - Part 3	S27	Ozone and sludge
S9	Ozone reactions - Part 3	S19	Advanced treatment of wastewaters- Part 2	S28	Advanced treatment of wastewaters - Part 5
S10	AOPs - Part 1	S20	Ozone in Medicine - Part 4	S29	Workshop / For a relevant use of ozone
				S30	Closing - Awards ceremony

EXHIBITION

Monday 3 to Wednesday 5 July

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



ALNITEC - OZONOMATIC - www.alnitec.it/en

Alnitec is a company founded in 1998 by Luigi, Alberto and Nicola Fiameni, on the basis of previous experiences in the use of ozone in different applications. In few years has estabilished itserf quickly, becoming a reference point for technology, innovation, maximum level therapeutic result, product safety, Customer service and knowledge and diffusion of the medical method at a professional level.

Alnitec collaborates with Scientific Societies, Research Centres, Universities, Ministries of Health, for the continuous improvement of products and protocols in use.

Participation in Congresses, organization of Courses, and cooperation to Scientific Studies, has consolidated the image and the international prestige of the company, known in all continents.

Our primary goal is to “Anticipate the expectations of our customers worldwide”.

Our overall goal is OZONE IN THE WORLD, i.e. the diffusion of medical and veterinary OZONE THERAPY, to facilitate the circulation of a safe procedure, with excellent results, economical, without adverse effects and without high costs for the National Health Service.

Our line OZONOMATIC has two lines of products:
OZONRELIVE: Ozonized cosmetic line
OZONOMATIC JOLLY MED: Medical device for ozonized hydrotherapy

Arrow Lake AB - https://arrowlake.se/

Arrow Lake - Much more than robust ozone technology.

Arrow Lake was founded in 2016 with a clear mission - to design and manufacture robust, industry-proofed ozone technology and decrease dependency on harmful yet, widely accepted water and air treatment practices. The company is located in Malmö, Sweden, where we manufacture our ozone technology and perform application tests.

However, what makes Arrow Lake truly unique is our team of passionate and dedicated experts covering all from Research and product development to applied ozone solutions. The team brings decades of outstanding, hands-on expertise from numerous industries, enthusiasm, and curiosity to look for new ways.

The result of the unique Arrow Lake culture is our Water Quality Management System FLO$_3$W® – an intelligent, demand-oriented system providing complete control of the process, and reliability in its efficacy, despite changing water quality parameters during the production cycle.

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

For over 35 years, BMT Messtechnik GmbH has been a recognized leader in the field of photometric ozone measurement in air, oxygen, and water. Our commitment lies in delivering measuring devices of unparalleled accuracy, durability, and longevity, setting the industry standard.

Our ozone instruments are globally renowned, finding utilization across a wide spectrum of sectors, including semiconductors, pharmaceuticals, ballast water treatment, and medical and chemical applications.

Furthermore, for comprehensive ozone treatment in water and wastewater applications, BMT offers holistic solutions covering every facet of ozone measurement within a plant. By leveraging our expertise, clients gain access to complete tools and technologies essential for implementing effective ozone treatment processes.

Moreover, BMT is providing advanced, air-cooled ozone generators designed for both experimental and small-scale ozone systems. This exemplifies our dedication to empowering ozone research and facilitating diverse applications across industries.

In summary, BMT has firmly established itself as a trusted name in the field of ozone measurement and treatment, by our focus on precision, longevity, and an extensive product portfolio positions us as the preferred partner for discerning customers seeking unparalleled ozone-related solutions.

De Nora Water Technologies - www.denora.com

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

SIAD S.p.A. - www.siad.com

SIAD is one of the most important chemical groups in Italy and supplies a full range of industrial, specialty, food and medical gases, in addition to operating in the following sectors connected with the world of gases: engineering, healthcare, LPG and Natural gas.

Founded in Bergamo in 1927, SIAD boasts a solid tradition and has acquired consolidated experience over its 90 year existence. Over time, it has succeeded in entering new geographic markets and sectors, whilst growing as a flexible and dynamic organisation and guaranteeing the utmost quality, reliability and professionalism.

Laboratory of Environmental Biology and Chemistry

The SIAD Laboratory is an applied research center in the environmental sector and gathers the experience of thirty years studies on wastewater treatment plants and groundwater remediation processes.

The feasibility study of the treatment processes is carried out through trials with laboratory, field and full-scale pilot plants and supported by chemical, biological and toxicological analysis.

The activities of the laboratory are dedicated to: wastewaters purification, remediation of contaminated sites, environmental monitoring.

Veolia Ozonia - www.watertechnologies.com

The Ozonia® ozone technology portfolio from Veolia includes products from laboratory scale units to the largest ozone systems ever built. From our company's roots in Switzerland, we have been the ozone industry pioneer for over 30 years. Veolia uses our extensive ozone technology experience to provide the industry's most reliable and robust products. Our unique ability to deliver systems with the highest operational and safety standards is why thousands of customers in every part of the world have chosen Ozonia® ozone systems.

Xylem - www.xylem.com

Xylem is a global water technology provider that helps customers solve the world's toughest water challenges across utility, industrial, commercial, and residential markets worldwide.

Over the last 100+ years, our unique combination of innovative products and services, proven expertise, and unmatched customer support have been helping to create a more water-secure and resilient world.

Across the water cycle, our innovative solutions use less energy, reduce operating expenses, and support sustainability efforts. With our solutions, we transport water, we treat it to make it clean, and we test it to ensure its quality. By working together, we can ensure water is accessible, affordable, and safe for all.

SOCIAL AND CULTURAL EVENTS

Welcome reception

On Sunday 2 July from 18:00

Place: space 8b, the "sun umbrella" space at Polimi.

Congress dinner

On Wednesday 5 July from 20:00

Overlooking the beautiful cloister of the main floor of the villa there is the famous restaurant “Il Vico della Torretta” led by the young and esteemed chef Angelo Nasta. The chef invites you to discover the delights of the best culinary traditions of Lombardy and national, with a modern twist with international quotations and exotic.

Grand Hotel Villa Torretta

Via Lucio Giunio Columella, 36

20128 Milano

Special registration will be required.

How to get to the restaurant?

Located in Milan Parco Nord. Proximity to bus stop and M5 metro station.

Awards Ceremony

Wednesday 5 July from 16:15

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

- To encourage young researchers, the Scientific Committee will select and award several prizes to the best papers presented by Doctorate Students.
- The European African Asian Australasian Group of the International Ozone Association will award the Willy Masschelein Prize for the best PhD thesis that has been issued within the past 4 years (1st April 2019 up to 31st March 2023).
- The Harvey M. Rosen Memorial Award was established in 1989 to recognise the “best paper” published in Ozone Science & Engineering [OS&E] during the two-year period between World Congresses. Dr. Harvey M. Rosen was a prime mover behind the establishment of the International Ozone Association and of OS&E, the Journal of the Association. Recipients of the Rosen Award are determined by consensus polling of the members of the Editorial Board of OS&E.
- The International Board of Directors bestows Honorary Membership in recognition of outstanding contributions towards furthering the ideals & objectives of the Association.
- Morton J. Klein Medal of Excellence, an award of excellence recognises contributions of the highest order to the International Ozone Association in commemoration of the clear vision, diplomatic proficiency, and unparalleled leadership which characterised the life of Morton J. Klein.

CULTURAL TOURS

The organizing Committee designed sightseeing tours especially for Congress participants, spouses and partners. Special registration is required. All tours will include tourist English guide, entrance tickets.

Cultural tour C1 – SAINT AMBROSE BASILICA. THE CANALS DISTRICT

Monday 3 July, afternoon, 3-hour walking tour
Meeting time and location: 9:30,am,in front of Duomo, central door

One of the most beautiful romanesque churches in Northern Italy, Saint Ambrose basilica was founded by the bishop Ambrose, patron saint of Milan, in 386.

The tour will continue passing by the park of the Basilicas (Saint Laurence with the 16 roman colomns of the II cent AD and Saint Eustorgio Basilica with the remains of the Wise Men).

From there we'll head to the ancient port of Milan, la Darsena, and the two Navigli (canals) entering some of the old houses' courtyards. That area is one of the favorites by the milanese for the aperitivo, and it's a great place where to end the visit and relax sitting outside enjoying the view to the waterways.

Included: entrance fees at the Saint Ambrose Basilica, headphone set, English guide.

Cultural tour C2 – THE CATHEDRAL, SANTA MARIA PRESSO SAN SATIRO, THE AMBROSIANA MUSEUM AND LIBRARY

Tuesday 4 July, morning, 3-hour walking tour
Meeting time and location: 3:30,pm,in front of Basilica Sant Ambrogio

This tour includes the visit of the cathedral inside, the Renaissance church of Santa Maria presso San Satiro, designed by Donato Bramante, one of the greatest architects of the Renaissance, and the Ambrosiana painting gallery, focusing on the main masterpieces (the basket of fruit by Caravaggio, Botticelli's Madonna of the Pavilion, Titian's Adoration of the Wise Men, Raphael's drawing of the School of Athen, Leonardo da Vinci's painting "The musician", and Da Vinci's manuscript, the Codex Atlanticus.

Included: entrance fees at the Cathedral, the Ambrosiana Museum & Library, Santa Maria Presso San Satiro, headphone set, English guide.

Cultural tour C3 – THE "RENAISSANCE UNVEILED" TOUR

Wednesday 5 July, afternoon, 2-hour walking tour
Meeting time and location: 3:30,pm,in front of San Maurizio, Monasterio Maggiore

This tour includes the visit of the church of San Maurizio al Monastero Maggiore, the "Sixtine chapel" of Milan, with one of the most beautiful cycle of Renaissance paintings in Lombardy, and the famous Da Vinci's Last Supper at Santa Maria delle Grazie church.

Included: Last Supper tickets with guided tour in the museum, entrance at San Maurizio al Monastero Maggiore, headphone set, English guide.

TECHNICAL TOURS

Upon proposals of IOA corporate members and by kind permission of the operator companies, two days of visits have been arranged for the Congress delegates. They will close the Congress on 6 and 7 July full day each. Set out from Milan to explore the area and enjoy! The tours will depart from and return to the Congress venue. Special registration will be required. The fee will include bus transfer and lunch.

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

Technical tour T1 – Fini-stampa Giordanetto WWTP and IZO, Vaxxinova Process Plant

Thursday 6 July - Full day tour

Fini-stampa Giordanetto SpA has the aim of finishing home furnishing fabric, home linen, outdoor, draperies and technical textiles. The company owns cutting-edge technologies for the green production of technical textile (solar panels, wastewater treatment plants, fume treatment plants, etc.).

Ozone is used in sewage treatment plant after aerobic biological treatment and activated carbon filtration system.

IZO, a part of Vaxxinova, is a leader in the research, production and packaging of vaccines and pharmaceuticals for veterinary use.

Vaxxinnova uses ozone in wastewater treatment plant.

Technical tour T2 – Lereti DWP and Alto Seveso WWTP

Friday 7 July - Full day tour

The Lereti drinking water plant is entirely built in a cave inside Mount Baradello and treats almost all of the water for civil use distributed in the city of Como (about 12 million cubic meters per year). Monte Baradello is surmounted by a magnificent castle and overlooks Lake Como, the deepest lake in Italy made famous by Alessandro Manzoni who set his novel “The Betrothed”.

The location in the cave guarantees a high level of protection against the risk of unwanted access to the plant which operates in a completely automatic way thanks to a remote control system. The Baradello plant of capacity 600L/s, involves preozonation, coagulation, sand filtration, main ozonation, adsorption onto granular activated carbon, disinfection using chlorine dioxide.

The Alto Seveso wastewater treatment plant is located close to the Seveso river east of the inhabitated area of Fino Mornasco in the Como area. This area is an important textile district with several small or medium textile firms. The Seveso wastewater treatment plant treats domestic and industrial wastewaters.

The textile industry is characterized by a significant environmental impact due to a significant use of chemical compounds and high water consumption that gives rise to large volumes of highly polluted wastewater, intensely coloured and containing recalcitrant and toxic compounds. Ozone treatment serves to decrease colour, to remove refractory COD, surfactants and to reduce the sludge volume.

Water treatment with SIAD, purify without pollution

Ozone to improve water and sludge quality, oxygen to control aerosol.
SIAD promotes technologies to recover resources, respecting the environment.
The Laboratory of Environmental Biology and Chemistry is dedicated to test and develop effective and sustainable purification processes.

#SIADisEverywhere

The SIAD Group.
Industrial Gases, Engineering, Healthcare, LPG and Natural Gas.

siad.com

SIAD

SCIENTIFIC AND TECHNICAL PROGRAMME

The Scientific Programme includes:

More than 100 presentations

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

Organized in 30 sessions arranged in three parallel tracks.

Sessions

S1 Opening and Introduction	S11 Ozone in Medicine - Part 1	S21 Ozone reactions - Part 4
S2 Ozone for Agrifood - Part 1	S12 Workshop / Sidestream injection of ozone	S22 Advanced treatment of wastewaters - Part 3
S3 Ozone reactions - Part 1	S13 Engineering aspects - Part 3	S23 Ozone in Medicine - Part 5 / Workshop
S4 Engineering aspects - Part 1	S14 Ozone in Medicine - Part 2	S24 Workshop / The energy vectors
S5 Ozone for Agrifood - Part 2	S15 AOPs - Part 2	S25 Advanced treatment of wastewaters - Part 4
S6 Ozone reactions - Part 2	S16 Advanced treatment of wastewaters - Part 1	S26a Ozone in Medicine - Part 6 / Workshop
S7 Engineering aspects - Part 2	S17 Ozone in Medicine - Part 3	S26b Workshop / Ozone for Food & Beverage
S8 Workshop / Young Ozone People	S18 AOPs - Part 3	S27 Ozone and sludge
S9 Ozone reactions - Part 3	S19 Advanced treatment of wastewaters- Part 2	S28 Advanced treatment of wastewaters - Part 5
S10 AOPs - Part 1	S20 Ozone in Medicine - Part 4	S29 Workshop / For a relevant use of ozone
		S30 Closing - Awards ceremony

Monday, 3 July

Session 1. Plenary session. Opening

9:00		**Opening addresses** by *Frédéric Violleau*, IOA President and *Prof. Isabella Nova*, Executive Vice Rector of Politecnico di Milano **Initial greetings** by the Commissioner *Massimo Sertori*, Councilor of the Lombardy region **Keynote lectures by:** **01.1.** *Andrea Rubini*, Director of Operations, Water Europe **01.2.** *Joachim D'Eugenio*, Policy Adviser for Zero Pollution, European Commission **01.3.** *Luca Lucentini*, Director of the Internal Water Hygiene Department of the Italian Istituto Superiore di Sanità **Exhibition**
10:30		**IOA General Assembly**
10:30		**Break**
		Congress Introduction
11:00	RT	**01.4. Round Table - Ozone in the management of the integrated water cycle** *C. Topalli (Aquaitalia), R. Drusiani (Utilitalia), G. Tartari (Cluster LE2C) (Italy)*
12:30		**Lunch**

Session 2. Ozone for Agrifood - Part 1 | Chair: Michel Roustan

Hour	Presentation	
14:00	LP	**02.1. Processing of wheat non-starch polysaccharides for the optimization of their functional and nutritional characteristics** *W. Sztupecki, L. Rhazi, F. Dépeint, T. Aussenac (France)*
14:30	LP	**02.2. Use of ozone in pasta production environments for sanitizing the air and reducing the risk of mold growth.** *D. Vallauri, C. Carboni (Italy)*
15:00	LP	**02.3. Microbial and fungal growth control and evaluation of quality parameters during ripening of Toma Piemontese PDO cheese treated with gaseous ozone** *V. Eramo, C. Carboni, M. Lembo, R. Forniti, R. Botondi (Italy)*
15:30	LP	**02.4. Effect of ozonated atmosphere on postharvest decay of plum and melon fruits in cold storage** *C. Berger, M. Pages, L. Volmerange,V. Quintard, S. Gerbaud, C. Verdier, F. Violleau (France)*
16:00		**Break**

Session 3. Ozone reactions – Part 1 | Chair: Jean-Pierre Duguet

Hour	Presentation	
14:00	LP	**03.1. Non-target screening reveals the identity of carbonous and nitrogenous carbonyl- containing oxidation byproducts formed during ozonation of various water types** *J. Houska, T. Manasfi, I. Gebhardt, U. Von Gunten (Switzerland)*
14:30	LP	**03.2. Decomposition of chlorophenols mixture by the combination of ozonation and biodegradation in continuous mode with recycling of treated water** *A. González-Suárez, P. Guerra-Blanco, T. Poznyak, I. Chairez, J. Morales, E. Albiter (Mexico)*
15:00	LP	**03.3. Mimicking realistic ozonation conditions without using dissolved organic matter: Low molecular weight compounds as surrogates** *S.A. Rath, U. Von Gunten (Switzerland)*
15:30	LP	**03.4. Pilot ozonation plant modelling for prediction of bromate formation, bromate mitigation and trace organic contaminant removal** *G. Bellandi, R.M. Pearce, I. Takács, S. Hogard, G. Salazar-Benites, U. Rehman, C. Bott, W. Audenaert (Belgium, USA, France)*
16:00		**Break**

Session 4. Engineering aspects – Part 1 | Chair: Sylvie Baig

Hour	Presentation	
14:00	LP	**04.1. Ozone Advanced Oxidation for 1,4-Dioxane Removal in Groundwater Remediation – Bench Tests to Full-scale Application and Process Control** *D. Funk, S. Giese (USA)*

14:30	LP	**04.2. Designing a full-scale ozonation plant for maximum micropollutants removal and minimal bromate formation, using Computational Fluid Dynamics simulation of chemical ozonation kinetics as optimization and validation tool** *R. Muoio, G. Bellandi, R. Schemen, P. van Horne, T.P.M. Spit, C.Y. de Jong, R. de Lepper, E. Buunk, R.J. van der Vleugel, U. Rehman, W. Audenaert (Belgium, The Netherlands)*
15:00	LP	**04.3. Developing of predictive Fuzzy Logic model in a Drinking Water Treatment Plant for controlling ozone dosing rate** *L. Ferràndez-Galceran, A. Cabrera-Codony, P. Agustí , M. Carrasco, M. Poch, H. Monclús (Spain)*
15:30	LP	**04.4. Multi-point ozone dissolution for enhanced bromate control and trace contaminant oxidation in ozonation for potable reuse** *R. Pearce, S. Hogard, E. Rosenfeldt, C. Bott (USA)*
16:00		**Break**

Session 5. Ozone for Agrifood - Part 2 | Chair: Frédéric Violleau

Hour	Presentation	
16:30	LP	**05.1. Ozone in wineries to control microbial contaminants of wooden casks and emerging need for bioindicators** *A. Del Casale, F. Fracchetti, M. Tebaldi, C. Carboni, S. Torriani (Italy)*
17:00	LP	**05.2. The ozone molecule at the service of the vines: from the nurseries to the vineyard** *A. Canado, M. Pages-Homs, C. Berger, A. Romeo Olivan, R. Pierron, C. Breton, F. Violleau (France)*
17:30		**Posters short oral presentions**
	SP	**05.3. The Use of Ozone Technology to Control Microorganism Growth, Enhance Food Safety and Extend Shelf Life: A Promising Food Decontamination Technology** *W. Xue, J. MacLeod, J. Blaxland (UK)*

Session 6. Ozone reactions – Part 2 | Chair: Jean-Pierre Duguet

Hour	Presentation	
16:30	LP	**06.1. Mechanistic investigation on nitrate formation during ozonation of organic nitrogenous compounds via stable isotope analysis** *J.W. Ra, K. Huang, J. Mohn, T.B. Hofstetter, U. Von Gunten (Switzerland)*
17:00	LP	**06.2. Alternative ozonation process as mitigation technique for bromate formation in the wastewater treatment** *K.F. Guerrero-Granados, J. Mante, M. Joy, A. Boergers, S. Schastok, C. Kube, S. Panglisch, J. Tuerk (Germany, USA)*
17:30	LP	**06.3. Ozone oxidation of a steel manufacturing wastewater** *C. Tizaoui, M. Munawa (UK)*

Session 7. Engineering aspects – Part 2 | Chair: Christopher Schulz

Hour	Presentation	
16:30	LP	**07.1. Case Studies Make A Strong Case for Ozone Sidestream Injection** *J. Lauria, A. Mazzei (USA)*
17:00	LP	**07.2. Role of the immediate ozone reaction by the application of ozone strong water for an advanced wastewater treatment** *J. Mante, K.F. Guerrero-Granados, H. Zhang, A. Boergers, S. Panglisch, J. Tuerk (Germany, China)*
17:30	LP	**07.3. In Situ Chemical Oxidation using Ozone for remediation of an aquifer impacted by hydrocarbons and ethers** *A. Crema, E. Pasinetti, M. Peroni, D. Soderino, F. Grecolini (Italy)*
18:00		**Posters: short oral presentions**
	SP	**07.4. Cutting-Edge Ozone-Technology for Water Treatment** *V.J.P. Vilar, I. Rodrigues, P.H. Marrocos, M.M. Pituco, F. Moreira, A.F.P. Ferreira, R.J. Santos, (Portugal)*
	SP	**07.5. High efficiency Plug flow Ozone Reactor including multiple dissolving function** *K.J. Kim (Republic of Korea)*
	SP	**/07.6. Use of micronanobubble aeration in wastewater treatment** *M. Mohamed, M. Kizhisseri, M. Sakr, M. Maraqa, M. Hamouda (United Arab Emirates)*

Session 8. Young Ozone People (YOP) Workshop

Hour	Presentation	
17:40	WS	**08.1 Young Ozone People Workshop** *M. Pages, T. Merle (France)*

Tuesday, 4 July

Session 9. Ozone reactions – Part 3 | Chair: Fernando Beltrán

Hour	Presentation	
8:30	LP	**09.1. Degradation of extracellular and intracellular antibiotic resistance genes in water during ozonation process** *D. Das, A. Bordoloi, D.J. Caldwell, R.P.S. Suri (USA)*
9:00	LP	**09.2. Advanced oxidation of tertiary wastewater micropollutants with nearly-zero contact time: modeling and validation studies** *D. Santoro, O. Santoro, T. Pastore, S. Mancini, T. Masi, T. Mao (Canada, Italy)*
9:30	LP	**09.3. Batch ozonation tests, combining lab experiments and CFD-kinetic simulations to improve standardization of the method** *G. Bellandi, R. Muoio, K. Guerrero-Granados, A.B. Sanchez, A. Börgers, R. Schemen, P. Vlasschaert, U. Rehman, A. Wieland, J. Türk, W. Audenaert (Belgium, Germany, The Netherlands)*
10:00		**Posters: short oral presentions**
	SP	**9.4. Aerobic stabilization with pre-ozonation of residual sludge in the dairy industry's wastewater treatment plant** *C.R. Ramírez-Cortina, A. Colín-Sánchez, M.S. Alonso-Gutiérrez (Mexico)*
10:30		**Break**

Session 10. AOPs - Part 1 / Ozone-based AOPs | Chair: Manuella Antonelli

Hour	Presentation	
8:30	LP	**10.1. Elimination of drugs mixture by catalytic ozonation with $Fe(OH)_2$/NiO and $Fe(OH)_2$ catalyst films synthesized by ultrasonic spray pyrolysis technique** *G.L. Morejón, T. Poznyak, J.L. Rodríguez Santillán, P. Guerra-Blanco (Mexico)*
9:00	LP	**10.2. Treatment of a Mixture of Micropollutants by Powdered Activated Carbon – Catalyzed Ozonation** *M. Gamal El-Din, M. Alameddine (Canada)*
9:30	LP	**10.3. Degradation of Benzoic Acid in the presence of NiO and CeO_2 films by ozone** *D. Franco-Peláez, J.L. Rodríguez Santillán, T. Poznyak, P. Guerra-Blanco (Mexico)*
10:00	LP	**10.4. Catalytic ozonation of substituted phenols and industrial application for coking wastewater treatment** *Y. Xie, H. Cao (China)*
10:30		**Break**

Session 11. Ozone in Medicine – Part 1 / Introduction. COVID prevention and convalesvence | Chairs: Olga León Fernandez, Michael Schreiber

Hour	Presentation	
8:30	LP	**11.1. The Low-Dose Ozone Concept. Is there a prominent biochemical mechanism underlying all indications of systemically administered ozone ?** *R. Viebahn-Haensler, O.S. León Fernández (Germany, Cuba)*
9:00	LP	**11.2. The Role of Ozone Therapy as Adjuvant in the Management of Covid-19 in Indonesia** *D. Chaijadi, A. Hendradiana, P. Djoko Tjahjono, E. Kusumaningsih, C. Nathan, Hariyanto, D. Surya Atmadja, R. Viebahn-Hänsler (Indonesia, Germany)*
9:30	LP	**11.3. Treatment of Long-COVID with systemic ozone therapy: Importance of the 'proper dose'** *G. Tricarico, V. Travagli (Italy)*
10:00		**Discussion**
10:30		**Break**

Session 12. Workshop - Sidestream injection of ozone

Hour	Presentation	
	WS	**12.1. Sidestream injection of ozone** **Introduction, advantages and drawbacks, case studies** *M. Roustan,S. Baig, J. Lauria, R. Pearce, E. Wert (France, USA)*

Session 13. Engineering aspects – Part 3 / DWP | Chair: Florencio Martin

Hour	Presentation	
11:00	LP	**13.1. CT Calculation Methods for Achieving Cryptosporidium Inactivation Credit with Ozone** *C. Schulz, C. Ngan, E. Wert (USA)*

11:30	LP	**13.2. Assessment of Temperature Effects on Ozonation Performance and Bromate Formation Resulting from Severe Drought Conditions** *B. Abada, E. Wert, A. Atkinson (USA)*
12:00	LP	**13.3. Emerging contaminants in drinking water treatment plants: how ozonation affects activated carbon adsorption** *B. Cantoni, J. Ianes, B. Bertolo, S. Ziccardi, F. Maffini, M. Antonelli (Italy)*
12:30		**Lunch**

Session 14. Ozone in Medicine – Part 2 / Clinical studies and pharmacological effects | Chairs: Renate Viebahn-Haensler, Tarek Tanbouli

Hour	Presentation	
11:00	LP	**14.1. Pharmacological mechanisms of medical ozone and its beneficial effects on elderly patients with oxidative etiology diseases** *O.S. León Fernández, R. Viebhan-Hänsler, G. Takon Oru (Cuba, Germany)*
11:30	LP	**14.2. Do oxygen-ozone mixtures affect cell proliferation and death? In vitro studies** *M. Malatesta, C. R. Inguscio, M. A. Lacavalla, F. Carton, B. Cisterna (Italy)*
12:00	LP	**14.3. Application of medical ozone in the complex treatment of distal forms of nonspecific ulcerative colitis** *S.N. Navruzov, A.M. Khakimov, B.S. Navruzov, S.T. Rakhmonov, E.E. Kulmiev, U.G. Vohidov, A.S. Shodiev, H.H. Choriev (Uzbekistan)*
12:30		**Lunch**

Session 15. AOPs - Part 2 / Ozone-based AOPs | Chair: Andrea Turolla

Hour	Presentation	
14:00	LP	**15.1. Application of ultrasound-assisted ozonation for micropollutant elimination in wastewater treatment plants** *J. Tuerk, K.F. Guerrero-Granados, A. Boergers, S. Panglisch, W. Neumann (Germany, Switzerland)*
14:30	LP	**15.2. Numerical simulation of hydroxyl radical production during hydrodynamic cavitation in the presence of dissolved ozone** *A. Kumar, Y. Huaccallo-Aguilar, R. Rangarajan, N. Matzke, S.F. Reinecke, W. Ding, M. Meier, U. Hampel, (Germany)*
15:00	LP	**15.3. Influence of the inlet pressure, flowrate and ozone dosage on the ozonation/cavitation for the rapid removal of succinic acid** *Y. Huaccallo-Aguilar, A. Kumar, J. Mante, M. Meier, S.F. Reinecke, U. Hampel (Germany)*
15:30		**Posters: short oral presentions**
	SP	**15.4. Novel bubble column designed for catalytic ozonation with heterogenic structural catalyst** *M. Bilińska, L. Bilińska, M. Gmurek (Poland)*
	SP	**15.5. Metronidazole degradation by ozone advanced oxidation processes** *M.A. Jiménez-López, F.J. Beltrán, F.J. Rivas, P.M. Álvarez (Spain)*
	SP	**15.6. Kinetic modelling development of photocatalytic bacterial inactivation: influence of operational conditions in the inactivation constant** *S. Moles, R. Moreno, M.P. Ormad, R. Mosteo, A. Monzón (Spain)*
	SP	**15.7. Degradation of imidazolium based ionic liquids by pulsed corona discharge and UV photolysis assisted with extrinsic oxidants** *D. Nikitin, S. Preis, N. Dulova (Estonia)*
	SP	**15.8. Peroxydisulphate Activation by Ag/TiO_2 Under Sunlight: elucidation of routes for a fluoroquinolone degradation, evolution of the antimicrobial activity, and potentialities for water disinfection.** *S.D. Jojoa-Sierra, C. Jaramillo-Páez, M.C. Hidalgo, J.A. Navío, M.P. Ormad, E.A. Serna-Galvis, R.A. Torres-Palma, R. Mosteo (Spain, Colombia)*
16:00		**Break**

Session 16. Advanced treatment of wastewaters / Part 1 | Chair: Laurent de Franceschi

Hour	Presentation	
14:00	KN	**16.1. Water Reuse to provide Sustainability and reduce impacts of Climate Change on Water Systems** *S.Y. Jasim (Canada)*
15:00	LP	**16.2. Ozonation of effluent from a wastewater treatment plant in the Netherlands, origination and current progress** *M. Hoekstra, M. Spruijt, J. Versteegh, T. Keesman, R. Van Der Neut, R. Koolen (The Netherlands)*

15:30	LP	**16.3. Feasibility assessment of ozonation at a coastal WWTP in Sweden with virtual piloting of a full-scale installation** *G. Bellandi, R. Muoio, Z. Kaleh, V. Karelid, J. Suokko, U. Rehman, W. Audenaert (Belgium, Sweden)*
16:00		**Break**

Session 17. Ozone in Medicine – Part 3 / Pain, Orthopedics | Chairs: Ziad Fahmy, Wilhelm Schüler

Hour	Presentation	
14:00	LP	**17.1. Ozone Therapy &Treatment of Fibromyalgia** *T.T. Tanbouli (Egypt)*
14:30	LP	**17.2. New Approach to Chronic Back Pain Treatment: A Case Control Study** *M. Bonetti, D. Lauritano, G.M. Ottaviani, A. Fontana, M. Frigerio, A. Zambello, L. Della Gatta, M. Muto, F. Carinci (Italy)*
15:00	LP	**17.3. Role of intra-articular Ozone gas injection in the management of internal derangement of the temporomandibular joint** *E.T. Daif (Egypt)*
15:30	LP	**17.4. Immunological Aspects of Ozone Treatment in Rheumatoid Arthritis** *Z. Fahmy (Germany)*
16:00		**Break**

Session 18. AOPs – Part 3 / Non Ozone-based AOPs | Chair: Vítor J.P. Vilar

Hour	Presentation	
16:30	LP	**18.1. Persulfate Activated by Non-Thermal Plasma for Pharmaceuticals Degradation** *D. Nikitin, E. Kattel-Salusoo, S. Preis, N. Dulova (Estonia)*
17:00	LP	**18.2. Organic Micropollutants Removal through Performic Acid-UV Photolysis: kinetics and wastewater matrix influence** *C. Nabintu Kajoka, S. Brosillon, J. Gasperi, M. Oliveira, V. Rocher, G. Chebbo, J. Le Roux (France)*
17:30	SP	**18.3. Evaluating the effects of Ozone, UV and NaClO as an Advanced Oxidation Process in surface water in a DWTP of Catalonia** *L. Ferràndez-Galceran, A. Cabrera-Codony, M. Valentí, M.J. Martín, P. Agustí, M. Carrasco, H. Monclús (Spain)*

Session 19. Advanced treatment of wastewaters- Part 2 / Reuse purpose | Chair: Chedly Tizaoui

Hour	Presentation	
16:30	LP	**19.1. The Potential of Ozonation in Advanced Wastewater Treatment for Pharmaceutical Control and WWTP Effluent Reuse in the Netherlands** *M. Spruijt, M. Hoekstra, R. Koolen, B. Martijn (The Netherlands)*
17:00	LP	**19.2. The Role of Ozone Treatment in Potable Water Reuse: Overview and Global Case Studies** *A. Vieira, D. Perrin, J. Citulski, J. Reungoat, S. Katz, L. De Franceschi (USA, France, Canada, Switzerland)*
17:30	LP	**19.3. Status Implementation of EU Reuse Regulation 2020/741 in Germany - Wastewater Reuse for agriculture** *A. Ried (Germany)*
18:00		**Posters short oral presentions**
	SP	**19.4. Disinfection via electrogenerated ozone for wastewater reuse** *M.P. Castro, I.F. Mena, M.A. Montiel, M.A. Rodrigo, J. Gäbler, L. Schäfer (Spain, Germany)*
	SP	**19.5. Urban wastewater treatment by ozonation: pathogens and microcontaminants removal, disinfection byproducts and toxicity evaluation** *K.J. Castañeda Retavizca, K. O'Dowd, S. Nahim-Granados, P. Plaza-Bolaños, S. Malato, M.I. Polo-López, S. Pillai, A. Agüera, I. Oller (Spain, Ireland)*

Session 20. Ozone in Medicine – Part 4 / Application & Safety | Chair: Matteo Bonetti

Hour	Presentation	
16:30	LP	**20.1. Safety and efficacy parameters for medical ozone equipment according to current EU legislation** *G. Tricarico, V. Travagli (Italy)*
17:00	LP	**20.2. How to assess an optimal blood ozonisation in Systemic Ozonized Autohaemotherapy: a bedside indicator** *A. De Monte, M. Buttazzoni, F. Bassi, G. Sermann, C. Gori, C. Macor, A, Ercolini, L. D'orlando (Italy)*

17:30		**Posters short oral presentions**
	SP	**20.3. Application of medical ozone in purulent surgery** *S.N. Navruzov, A.M. Khakimov, B.S. Navruzov, S.T. Rakhmonov, E.E. Kulmiev, U.G. Vohidov, A.S. Shodiev (Uzbekistan)*
	SP	**20.4. The effectiveness of ozone therapy in the prevention of purulent infection after "reduction" surgery** *S.N. Navruzov, A.M. Khakimov, B.S.Navruzov, S.T.Raxmonov (Uzbekistan)*
	SP	**20.5. Effectiveness of ozone therapy in gynaecology** *R.S. Navruzova, B.S. Navruzov, A.M. Khakimov (Uzbekistan)*
	SP	**20.6. Virucidal Efficacy of Gaseous Ozone against Type 1 Herpes Simplex Virus (HSV-1)** *E.K. Ahortor, L. Baillie, D. Lloyd, J.A. Blaxland (UK)*
18:00	RT	**Round Table**

Wednesday, 5 July

Session 21. Ozone reactions | Chair: Urs von Gunten

Hour	Presentation	
8:30	LP	**21.1. Simultaneous multi-compound ozonation competition kinetic measurements of complex cyanopeptide mixtures** *V. Rougé, E.M.-L. Janssen, U. von Gunten (Switzerland)*
9:00	LP	**21.2. Does ozonation enhance activated carbon adsorption of PFAS in textile wastewater?** *B. Cantoni, G. Bergna, E. Baldini, M. Antonelli (Italy)*
9:30	LP	**21.3. Characterization of lignin extracted from Miscanthus giganteus by ozonation in a pilot-scale reactor** *M. Ebrahimi, V. Acha, L. Rhazi, S. Bresson, L. Hoang, T. Aussenac (France, Spain)*
10:00		**Posters: short oral presentions**
	SP	**21.4. Phenol ozonation modelling. Coupling the penetration theory and mass balances** *F. Javier Rivas, F. Beltran (Spain)*
	SP	**21.5. Modelling ozone disinfection for municipal wastewater in presence of HO• scavengers using the ROH concept** *J.A. Malvestiti, R.P. Cavalcante, L.R.D. Sommaggio, R.F. Dantas (Brazil)*
	SP	**21.6. Treatment of Fluoranthene in Wastewater by Ozonation** *A. Catton, C. Tizaoui, M. Gerardo (UK)*
	SP	**21.7. Genotoxicity and pathogenic bacteria removal from Secondary Effluents after Ozonation** *J.A. Malvestiti, L.R.D. Sommaggio, D.E.C. Mazzeo, M.A. Marin-Morales, R.P. Cavalcante, F.A. Oliveira, C.E. Levy, R.F. Dantas (Brazil)*
10:30		**Break**

Session 22. Advanced treatment of wastewaters – Part 3 / Micropollutant focus | Chair: Eric Wert

Hour	Presentation	
8:30	LP	**22.1. Micropollutant Removal Combinations with Ozone for Effective and Resilient Treatment Solutions** *L. Dinkloh, L. De Franceschi, A. Murillo, G. Scaramuzzi, C. Bopp (Switzerland)*
9:00	LP	**22.2. Ozonation is an Effective Treatment Method to Degrade the Antiviral Drug Oseltamivir in Municipal Secondary Effluent** *M. Gamal El-Din, S. Jansen van Beek (Canada)*
9:30	LP	**22.3. Ozone tertiary treatment for pharmaceuticals and personal care products removal from municipal wastewater** *E. Pasinetti, M. Peroni, M. Cascio, M. Antonelli, F. Malpei, A. Turolla, L. Virtuoso, L. Guzzella, L. Marziali, L. Valsecchi, F. Cappelli, S. Tasselli, E. Valenti, D. Oliva (Italy)*
10:00	LP	**22.4. Comparative Assessment of advanced wastewater treatments for micropollutant removal** *R. Serra, E. Judenne, A. Gonzalez Ospina, S. Baig (France)*
10:30		**Break**

Session 23. Ozone in Medicine – Part 5 / Workshop

Hour	Presentation	
8:30	LP	**23.1. Role of Ozone Treatment in Disc Lesions in Diabetic Patients** *U.R. Chaudhry (Pakistan)*

9:00	LP	**23.2. Administration procedures of medical ozone by local injection in small and large joints** *G. Tabaracci (Italy)*
9:45	LP	**23.3. The importance of ozone water in holistic dentistry and the systemic ozone application for the oral microbiome and its long-distance effects** *W. Schueler (Germany)*
10:30		**Break**

Session 24. Workshop / The energy vectors

Hour	Presentation	
11:00	WS	**24.1. The energy vectors of Oxygen and enriched oxygen = Ozone** *M. Wolfs (The Netherlands)*
12:30		**Lunch**

Session 25. Advanced treatment of wastewaters – Part 4 | Chair: Bernhard Paolini

Hour	Presentation	
11:00	LP	**25.1. Removal of organic micropollutants, nutrients and suspended solids from wastewater treatment effluent using ozonation in combination with a denitrifying activated carbon filter: results of a pilot-study in The Netherlands** *T.P.M. Spit, J.P. van der Hoek, T. van den Eijnde, C.M. Morgenschweis, M. Bechger, L.T.J. van der Aa, V.M. Luimstra (The Netherlands)*
11:30	LP	**25.2. Validating ozone disinfection for indirect potable reuse** *S. Hogard, R. Pearce, R. Gonzalez, C. Bott (USA)*
12:00	LP	**25.3. Disinfection as surrogate of micropollutants removal during ozonation of secondary effluent** *R.F. Dantas, J. Cristale, C.G Canela, I. Seabra, J. Malvestiti, S. Lacorte (Brazil, Spain)*
12:30		**Lunch**

Session 26a. Ozone in Medicine – Part 6 / Workshop

Hour	Presentation	
11:00	LP	**26.1. Workshop on Medical Ozone** *M. Schreiber (Germany)*
12:00	RT	**Round Table**
12:30		**Lunch**

Session 26b. Workshop / Ozone for Food & Beverage

Hour	Presentation	
11:00	LP	**26.2. Ozone for Food & Beverage** *Issues, possible role of ozone, regulations and case studies* *Thaer Yassen, Food and Agriculture Organization of the United Nations (FAO), Frédéric Violleau (France) Sylvie Baig (France), Cristian Carboni (Italy), Camilla Khrulova (Sweden)*
12:30		**Lunch**

Session 27. Ozone and sludge | Chair: Achim Ried

Hour	Presentation	
14:00	LP	**27.1. Sludge Ozonolysis to enhance anaerobic digestion: a lab-scale and full-scale case study** *D. Soderino, M. Peroni, E. Pasinetti, D. Preda, M. Cascio, A. Catenacci, F. Malpei, M. Bernardi (Italy)*
14:30	LP	**27.2. Full scale ozonolysis in biological oxidation: a case study** *M. Peroni, E. Pasinetti, D. Soderino, R. Canziani, A. Catenacci, M. Cascio, M. Bernardi, D. Oliva (Italy)*
15:00	LP	**27.3. What are the benefits of injecting ozone in a MBR** *L. De Franceschi, B. Heiniger, A. Murillo, L. Dinkloh, K. Mende, S. Baumgarten (Switzerland, Germany)*
15:30		**Break**

Session 28. Advanced treatment of wastewaters – Part 5 | Chair: Saad Jasim

Hour	Presentation	
14:00	LP	**28.1. Examining the Challenges of Implementing Ozonation and Activated Carbon Treatment for Pharmaceutical Wastewater in Real-World Settings** *S. Hedwig, L. Loreggian, N. Furler, R. Hochstrat, F. Sacher, E. Plettig, L. Emmer, M. Langer, M. Thomann (Switzerland, Germany)*
14:30	LP	**28.2. Wastewater treatment by ozonation for reducing the wastewater toxicity** *A. Bettinardi, C. Carboni, A. Sacco (Italy, USA)*

15:00	LP	**28.3. Integration of biological and ozonation models for the Eindhoven WWTP for optimal micropollutants removal, minimal bromate formation, and improved effluent quality** *G. Bellandi, R. Muoio, S. Daneshgar, E. Torfs, R. Schemen, P. van Dijk, S. Weijers, U. Rehman, W. Audenaert (Belgium, The Netherlands)*
15:30		**Break**

Hour	Presentation	Session 29. Workshop / For a relevant use of ozone
14:00	WS	**29.1. For a relevant use of ozone** *B. Paolini, M. Rothlin, C. Carboni, M. Roustan (Switzerland, Italy, France)*
15:30		**Break**

Hour	Presentation	Session 30. Congress Closing and Awards Ceremony
16:00	KN	**30.1. Keynote lecture** **Some highlights and challenges in ozone research from my experiences in the last 30 years** *U. Von Gunten (Switzerland)*
16:40		**Awards** Harvey Rosen Prize Willy Masschelein Prize Best poster & Best paper
17:20		**Congress synthesis and conclusions**

Thursday, 6 July

Hour	Technical tour – Full day | Chair: Cristian Carboni
9:30	**Fini-stampa Giordanetto WWTP**
	Lunch
14 :30	**IZO, Vaxxinova Process Plant**

Friday, 7 July

Hour	Technical tour – Full day | Chair: Cristian Carboni
9:30	**Lereti DWP**
	Lunch
14 :30	**Alto Seveso WWTP**

KEY NOTES SPEAKERS

Andrea Rubini, Director of Operations, Water Europe.
Andrea Rubini holds a master degree in Water Resources Engineering and has over 35 years of international experience in the water and energy sectors, with a particular focus on the impacts related to climate change in urban and industrial ecosystems. In the last 25 years, he has worked within the context of European lobbying in Brussels, where he has acquired a significant knowledge of EU policies for research and innovation and funding programs. He has worked for the Italian Chambers of Commerce system as an R&I expert, for the Delegation of the Presidency of the Lombardy Region at the EU. Andrea has worked at the European Commission (DG REGIO) as a policy advisor and contributed to the completion of the Regional Strategy for Research and Innovation for Smart Specialisation (RIS3). His previous experiences as a program manager at the United Nations Development Program (UNDP), consultant for the African Development Bank, professor at the International Labour Organization (ILO) and other prestigious universities in Europe, Asia, and Africa complete his profile. Andrea is the Director of Operations of Water Europe, the European Technology Platform for Water based in Brussels, and manages the collaboration and implementation programs of the Platform. He represents Water Europe in the Water4All partnerships and in A.SPIRE/Process4Planet as a member of their respective Executive Boards.

Joachim D'Eugenio, Policy Adviser for Zero Pollution, European Commission.
As environmental engineer by training, Joachim D'Eugenio started working in the German Federal Environment Agency (UBA) in Berlin. In 1999, he moved to the European Commission working mostly in DG Environment on water (Water Framework Directive), marine, air and industry policies. In addition, he followed inter-institutional affairs in the Commission's Secretariat General from 2007-2010. In 2015, he joined the Unit on Compliance & Better Regulation of DG Environment where he was leading the Fitness Check on Environmental Reporting and led the agenda on "digitalisation and the environment". Since 16 January 2020, he is working as Policy Adviser for Zero Pollution in the DG Environment coordinating the work on the "Zero Pollution Action Plan" and contributing to many Green Deal and other initiatives.

Luca Lucentini is the Director of the National Center for Water Safety - National Institute for Health - Italy. Expert for the World Health Organization, the European Union, and the United Nations on health-related issues concerning access to water and sanitation, including the development and implementation of regulatory acts, standards and guidelines, scientific opinions, risk analysis processes, training and communication, research, surveillance, and control activities encompassing water resources, water cycle, water (re)uses, integrated and source-to-sea management. National delegate for the WHO/UNECE Protocol for water and health, he coordinates national and international initiatives in water fields, including health-related regulatory issues. Responsible for international cooperation programs and support on water and health in many countries in the European, African, and Asian regions. Author of over 100 peer-reviewed scientific publications in international journals.

Urs von Gunten has a joint appointment between Eawag, the Swiss Federal Institute of Aquatic Science and Ecole Polytechnique Fédérale de Lausanne (EPFL) where he is a full professor. He is an internationally recognized expert on oxidation processes with a strong focus on ozonation and he has co-authored one book and more than 280 publications. He has received several international awards among them the Harvey Rosen Award 2001, 2007 and 2015, the 2022 ACS Award for Creative Advances in Environmental Science and Technology, the Outstanding Achievements in Environmental Science and Technology Award in 2023 and the distinction of being listed multiple times as a Thomson Reuters/Clarivate Highly Cited Researcher since 2014. Besides his academic activities, he collaborates regularly with practitioners from the water sector. From 2004-2008 he was the head of the trans-disciplinary project "Water supply for the 21st century" and from 2013-2016 he was the head of the trans-disciplinary project "Regional Water Supply Basel-Country", one of the Swiss cantons (states). In the last two decades he was strongly involved in the application of ozone for enhanced municipal wastewater treatment for micropollutant abatement, which is now implemented in Switzerland and in other countries.

Dr. Saad Y. Jasim, P.Eng., is President of SJ Environmental Consultants. He was formerly Manager, Utilities for Engineering and Municipal Operations, City of White Rock, British Columbia, Canada. He served as an Acting Research Director and Principal Investigator at the Qatar Environment and Energy Research Institute (QEERI). Before joining QEERI, Dr Jasim was the President of SJ Environmental Consultants (Windsor) Inc. (1993-2005 and 2013-2015) and Adjunct Research Professor at the University of Western University, Canada from 2009. He is also Adjunct Professor, University of Windsor since 1996 and serves on the Editorial Board of OS&E Journal and on the Editorial Board for Water Process Engineering. He also worked on the Editorial Board of the Desalination Journal from 2009 to 2012. Dr. Jasim served as Director of the Great Lakes Regional Office-International Joint Commission. He managed the operation of the Scientific and Technical programs, initiated strategic partnerships and alliances with the stakeholders. Served as the Founding CEO for the Walkerton Clean Water Centre, developing it to be one of the leading research and training institutes for water treatment in Canada. He was also the past president of the International Ozone Association-PAG. Saad Jasim received his masters and Ph.D. degrees on Chemical Engineering from the University of Wales in Swansea, UK, and is the recipient of several awards such as the George Warren Fuller Award (2016), the recognition award from the International Network for the Advancement of Water & Wastewater Education (2013) and the Harvey Rosen Award for Best Publication (2011) about Ozone. He is Past-President-of the International Ozone Association.

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ABSTRACTS OF PRESENTATIONS

Monday, 3 July

Session 1. Plenary session. Opening

Opening addresses by *Frédéric Violleau*, IOA President and *Prof. Isabella Nova*, Executive Vice Rector of Politecnico di Milano
Initial greetings by the Commissioner *Massimo Sertori*, Councilor of the Lombardy region
Keynote lectures by:
01.1. *Andrea Rubini*, Director of Operations, Water Europe
01.2. *Joachim D'Eugenio*, Policy Adviser for Zero Pollution, European Commission
01.3. *Luca Lucentini*, Director of the Internal Water Hygiene Department of the Italian Istituto Superiore di Sanità

01.4. Round Table - Ozone in the management of the integrated water cycle
C. Topalli (Aquaitalia), R. Drusiani (Utilitalia), G. Tartari (Cluster LE2C) (Italy)

Session 2. Ozone for Agrifood - Part 1

02.1. Processing of wheat non-starch polysaccharides for the optimization of their functional and nutritional characteristics
W. Sztupecki, L. Rhazi, F. Dépeint, T. Aussenac (France)

Ozone treatment is mostly used on cereal grains for microbial stabilization, food storage and grain processing. The effect of Ozone on wheat major constituents (i.e. starch, proteins) is well known, but its impacts on non-starch polysaccharides from wheat bran have not been widely studied. This work deals with the optimization of wheat bran functional and nutritional properties using ozone. The effect of zone on the structure, functional and physico-chemical properties of wheat bran were investigated. With increasing consumption of ozone, it was observed an increase in the carbonyl, carboxyl and dietary soluble fibers contents, as well as a decrease in the pH and molecular weight distribution of some soluble fibers. The results demonstrate that the wheat bran processed with ozone was changed in its molecular level. Further, preliminary binding analysis showed the binding capacities of wheat bran significantly changed. It was possible to demonstrate variations on antioxidant and biological activities. All these changes directly affected the modified non-starch polysaccharides properties, resulting in significant differences in terms of bread rheological qualities, proving the effectiveness of using ozone as an oxidizing agent for wheat bran modification.

02.2. Use of ozone in pasta production environments for sanitizing the air and reducing the risk of mold growth.
D. Vallauri, C. Carboni (Italy)

The study carried out at a Piedmonts fresh pasta production company (Ravioles from Val Varaita, Plin stuffed with herbs, Ravioli stuffed with meat and vegetables) involves the development of a treatment protocol with gaseous ozone in the cooling tunnel (cooler) present in the fresh pasta production line to improve its hygienic conditions and thus guarantee a positive impact on the final product in terms of microbiological characteristics and shelf-life. The cooling system could be the zone where, after the pasteurization, recontamination happens due to moulds. The use of ozone in pasta production environments can be an extraordinarily effective aid for sanitizing the air and reducing the risk of mold growth. The experimentation also evaluated the organoleptic quality of the pasta produced using the ozone-sanitized lines.

02.3. Microbial and fungal growth control and evaluation of quality parameters during ripening of Toma Piemontese PDO cheese treated with gaseous ozone
V. Eramo, C. Carboni, M. Lembo, R. Forniti, R. Botondi (Italy)

The cheese ripening phase, in which biochemical changes occur under specific temperature and humidity conditions, is crucial for making the finished product marketable. However, the food matrix can become a growth medium for developing spoilage microorganisms and fungi. In dairy factory, contamination of the crust area can be monitored with several wasteful and time-expensive methods, i.e. use of saline solutions and/or the brushing of cheese wheels. This study investigates the effectiveness of different ozone treatments in controlling microbial and fungal growth during the ripening of Toma Piemontese PDO cheese. Results showed that ozone treatments have a significant effect on spoilage microflora, preserving the overall quality.

02.4. Effect of ozonated atmosphere on postharvest decay of plum and melon fruits in cold storage
C. Berger, M. Pages, L. Volmerange,V. Quintard, S. Gerbaud, C. Verdier, F. Violleau (France)

During storage, microbial contamination of fruits and vegetables can cause serious economic losses. Industrials and fruit growers are often facing huge losses that can affect the profitability of their company and be responsible of food waste. They are therefore looking for solutions capable of effectively reducing pathogenic microorganisms and improving the fruit preservation while leaving little or no residue in the product (Aslam et al, 2020). This study investigated the effect of ozone injections during cold storage period on plums and melons as a non-persistent alternative to chemicals. Those fruits were stored during several days under various storage conditions and ozone concentrations. A reduction of both the fungal and bacterial flora has been highlighted in many cases on both species while the physicochemical properties of the fruits have not been affected. Those results are suggesting that ozone could be a promising tool for a better conservation.

Session 3. Ozone reactions – Part 1

03.1. Non-target screening reveals the identity of carbonous and nitrogenous carbonyl- containing oxidation byproducts formed during ozonation of various water types
J. Houska, T. Manasfi, I. Gebhardt, U. Von Gunten (Switzerland)

Carbonyl compounds belong to undesired oxidation byproducts formed during the ozonation of water and wastewater and their identification in complex matrices remains a bottleneck in analytical chemistry. Therefore, a workflow was developed to derivatize and detect unknown carbonyl compounds formed during ozonation of a wide range of water types. Derivatization proceeded by optimizing a method involving p-toluenesulfonylhydrazine (TSH) and detection by making use of signature fragments originating from TSH. With this method, quantitative and qualitative analysis of carbonyl compounds could be undertaken, leading to the identification of 178 unknown carbonous and nitrogenous carbonyl compounds, which were formed during ozonation of various water types. A core group of carbonyl compounds was identified among all water types, with additional structural elucidation of selected compounds.

03.2. Decomposition of chlorophenols mixture by the combination of ozonation and biodegradation in continuous mode with recycling of treated water
A. González-Suárez, P. Guerra-Blanco, T. Poznyak, I. Chairez, J. Morales, E. Albiter (Mexico)

The combination of ozonation and biodegradation in a continuous multistage system was examined to mineralize the phenols (Phs) mixture: phenol (Ph), 4-chlorophenol (4-CPh) and 2,4-dichlorophenol (2,4-DCPh), with 40 mg L−1 of each concentration in distilled water. Ozonation was performed in continuous mode at a hydraulic retention time (HRT) of 60 min. The ozonized effluent was treated in a bioreactor with a mixed microbial consortium pre-adapted to the phenols' ozonation products. The continuous biodegradation of the pre-ozonized aqueous solution was performed at a liquid flow of 0.868 mL min-1. The phenols mixture was efficiently decomposed (□ 99%) within 10-30 min by ozonation, however only 36.7% of mineralization was obtained in this step. The global mineralization obtained by means the combined treatment system of ozonation-biodegradation in continuous mode was 96%. After the combined treatment, TOC of the effluent was 3.0 mg L-1, this was returned to the ozonation column for the experimental modeling of its reuse in the system.

03.3. Mimicking realistic ozonation conditions without using dissolved organic matter: Low molecular weight compounds as surrogates
S.A. Rath, U. Von Gunten (Switzerland)

To investigate kinetics and mechanisms of micropollutant (MP) abatement and the formation of ensuing transformation products (TP) and formation of disinfection by-products (DBPs) during ozonation, both the reactions with ozone and hydroxyl radicals (.OH), and the interplay between the two oxidants need to be investigated. Due to the constraints of using real waters on high end analytical instruments, a tool is needed to accomplish realistic ozonation conditions without using dissolved organic matter (DOM). Herein, the development of a standardised protocol to mimic realistic ozonation conditions is reported using the concept of initiators, promoters and inhibitors to control the ozone decay. Low molecular weight compounds are used as model .OH scavengers to act as surrogate for DOM. Using this system, realistic ozonation conditions for surface waters and wastewaters have been accomplished. It was demonstrated, that comparable amounts of TPs of the micropollutants bezafibrate and atrazine have been obtained and similar kinetics of bromate formation have been observed demonstrating the usefulness of this tool for future identification of TPs during ozonation.

03.4. Pilot ozonation plant modelling for prediction of bromate formation, bromate mitigation and trace organic contaminant removal
G. Bellandi, R.M. Pearce, I. Takács, S. Hogard, G. Salazar-Benites, U. Rehman, C. Bott, W. Audenaert (Belgium, USA, France)

To maximize trace organic contaminants (TrOCs) and minimize bromate formation in downstream biofiltration it is important to optimally operate and design ozonation processes based on kinetic process understanding. A The Amozone kinetic ozonation model was calibrated and validated in the framework of HRSD's innovative water reuse project SWIFT (swiftva.com) on the pilot testing to reproduce operational performances and performed advanced testing. SWIFT aims to treat wastewater effluent to drinking water standards for managed aquifer recharge.

Session 4. Engineering aspects – Part 1

04.1. Ozone Advanced Oxidation for 1,4-Dioxane Removal in Groundwater Remediation – Bench Tests to Full-scale Application and Process Control
D. Funk, S. Giese (USA)

1,4-Dioxane is a contaminant that may be found in groundwaters impacted by industrial activities. As part of a plant upgrade for an existing remedial groundwater treatment facility located in the north-eastern United States, ozone-hydrogen peroxide advanced oxidation was selected to replace an existing ultraviolet (UV)-hydrogen peroxide system near the end of its service life. The selection and design criteria were established through bench scale testing to compare UV and ozone advanced oxidation removal of 1,4-dioxane in water samples collected from the existing treatment train. These results were used in an economic analysis which revealed ozone advanced oxidation had lower capital and operating costs than UV. After installation of the new system in November 2022, full-scale testing confirmed the accuracy of bench studies in terms of required ozone and hydrogen peroxide doses. The tests also revealed a correlation between 1,4-dioxane removal and improvement in UV transmittance (UVT) which can be used as a real-time surrogate of treatment performance.

04.2. Designing a full-scale ozonation plant for maximum micropollutants removal and minimal bromate formation, using Computational Fluid Dynamics simulation of chemical ozonation kinetics as optimization and validation tool
R. Muoio, G. Bellandi, R. Schemen, P. van Horne, T.P.M. Spit, C.Y. de Jong, R. de Lepper, E. Buunk, R.J. van der Vleugel, U. Rehman, W. Audenaert (Belgium, The Netherlands)

The water authority De Dommel (The Netherlands) is in the process of realizing a full-scale ozone installation at the WWTP of Hapert for demonstration purposes on the removal of organic micropollutants (OMPs). The Amozone virtual piloting, as was presented at the EA3G2022 event in Toulouse, was used as a tool to develop the technological assumptions for this ozone installation. At the design stage, the CFD-Amozone model is used to achieve an optimal and efficient design of the full-scale demonstration facility. Based on this model and considering the water matrix and gas diffuser specifications, the design and configurations are changed. A co-current configuration performed best for both maximum OOMPs removal and minimal BrO3- formation.

04.3. Developing of predictive Fuzzy Logic model in a Drinking Water Treatment Plant for controlling ozone dosing rate
L. Ferràndez-Galceran, A. Cabrera-Codony, P. Agustí , M. Carrasco, M. Poch, H. Monclús (Spain)

Drinking water treatment plants (DWTPs) must ensure that customers receive high-quality water, thus removing numerous compounds from surface waters that are under governmental regulations. The presence of natural organic matter (NOM) is the main cause for disinfection byproducts (DBP) formation, such as toxic trihalomethanes (THM), upon final chlorination. Ozonation is a technology that ensures high NOM removal in the initial stage of the DWTP. In the Figueres DWTP this operation consumes the 30% of the total electricity expenses. The objective of this work was to develop a digital tool for predict the optimum dose of ozone in the water pre-treatment to both enhancing the effluent quality, minimizing THM formation and reducing the energy expends.

04.4. Multi-point ozone dissolution for enhanced bromate control and trace contaminant oxidation in ozonation for potable reuse
R. Pearce, S. Hogard, E. Rosenfeldt, C. Bott (USA)

The removal of trace organic contaminants from wastewater effluent is of major concern for the implementation of potable reuse. Ozone can be used to directly oxidize many contaminants while hydroxyl radicals (*OH) formed in ozonation can also degrade ozone-recalcitrant compounds. Of these, 1,4-dioxane is a problematic, ozone-recalcitrant, carcinogenic compound which is often found in wastewater due to its use in household products and in industry. Removing 1,4-dioxane with ozone can be difficult due to the formation of bromate when elevated bromide is present.

Session 5. Ozone for Agrifood - Part 2

05.1. Ozone in wineries to control microbial contaminants of wooden casks and emerging need for bioindicators
A. Del Casale, F. Fracchetti, M. Tebaldi, C. Carboni, S. Torriani (Italy)

The feasibility of gaseous ozone to reduce the load of microbial contaminants presents on the inner layers of wooden casks, i.e., barrels, barriques and tonneaux, was investigated at 20 wineries located in several Italian regions. Efficient sanitizing and targeted sample preparation protocols were developed and validated for vats of different size used at least once and kept empty. Conventional and molecular analysis revealed that wooden casks were naturally colonized by heterogeneous populations of yeasts and bacteria, including microbial species unusual for wine industry, such as bacteria belonging to the family Pseudomonadaceae. Substantial differences in the initial microbial concentration were also observed, with counts ranging from absence of colonies to 106 CFU/mL (cm2). Developed sanitation protocols allowed reduction of 3-4 log units, when properly tailored based on the cask volume, initial microbial load, and degree of cleaning. The unusual psychrotrophic and biofilm-forming contaminants detected highlighting the need to develop standardized methods and bioindicators to reduce the bias due to patchy contaminations and to assess the efficacy of the ozone treatment in any environmental conditions.

05.2. The ozone molecule at the service of the vines: from the nurseries to the vineyard
A. Canado, M. Pages-Homs, C. Berger, A. Romeo Olivan, R. Pierron, C. Breton, F. Violleau (France)

The ozone molecule has proved its biocide properties over a wide range of microorganisms and applications. These biocide properties and the low remanence of the ozone molecule makes it a promising candidate to substitute controversial phytosanitary products used in agriculture. The present study aims to review several applications of the ozone molecule for its use in wine growing. From the nursery to the vineyard, different experimentations have been performed and have showed promising results: i) Ozone gas treatment for reduction of pathogens on crafted grapevines in nurseries, ii) irrigation with ozonated water for plant stimulation, iii) ozonated water for the esca treatment in nurseries and iv) ozonated water for the treatment of the downy mildew in the vineyard. For all these trials, the ozone molecule has proved its usefulness to replace or reduce the use of controversial chemicals in the wine growing.

Posters short oral presentions

05.3. The Use of Ozone Technology to Control Microorganism Growth, Enhance Food Safety and Extend Shelf Life: A Promising Food Decontamination Technology
W. Xue, J. MacLeod, J. Blaxland (UK)

The need for microorganism control in the food industry has promoted research in food processing technologies. Ozone is considered to be a promising food preserving technique and has gained great interest due to its strong oxidative properties and significant antimicrobial efficiency, and because its decomposition leaves no residues in foods. In this ozone technology review, the properties and the oxidation potential of ozone, and the intrinsic and extrinsic factors that affect the microorganism inactivation efficiency of both gaseous and aqueous ozone, are explained, as well as the mechanisms of ozone inactivation of foodborne pathogenic bacteria, fungi, mould, and biofilms. This review focuses on the latest scientific studies on the effects of ozone in controlling microorganism growth, maintaining food appearance and sensorial organoleptic qualities, assuring nutrient contents, enhancing the quality of food, and extending food shelf life, e.g., vegetables, fruits, meat, and grain products.

The multifunctionality effects of ozone in food processing, in both gaseous and aqueous form, have promoted its use in the food industries to meet the increased consumer preference for a healthy diet and ready-to-eat products, although ozone may present undesirable effects on physicochemical characteristics on certain food products at high concentrations. The combined uses of ozone and other techniques (hurdle technology) have shown a promotive future in food processing. It can be concluded from this review that the application of ozone technology upon food requires increased research; specifically, the use of treatment conditions such as concentration and humidity for food and surface decontamination.

Session 6. Ozone reactions – Part 2

06.1. Mechanistic investigation on nitrate formation during ozonation of organic nitrogenous compounds via stable isotope analysis

J.W. Ra, K. Huang, J. Mohn, T.B. Hofstetter, U. Von Gunten (Switzerland)

Organic nitrogenous compounds present in micropollutants or natural organic matter, are considered major precursors of toxic nitrogenous disinfection byproducts during water treatment processes. Once they react with ozone, nitrate is formed as a final byproduct, but the underlying formation mechanism has not been entirely elucidated. To better understand nitrate formation from organic nitrogenous compounds during ozonation, a novel approach combining continuous ozonation and stable isotope analysis has been applied. Results from apparent NO3– formation rates, δ15N, and δ18O in nitrate showed two different reaction pathways for the screened model compounds. High second-order nitrate formation rate constants (kNO3–) with high enrichment factor (εN) and high δ15N/δ18O ratios were observed for ozonation of free or combined amino acids, but low kNO3– with low εN and low δ15N/δ18O ratios were observed for simple primary amine, nitroalkane, and gaba-type compounds. This is because two different intermediates (e.g., nitroalkane and oxime) with different reaction kinetics and mechanisms are anticipated for the reactions with ozone.

06.2. Alternative ozonation process as mitigation technique for bromate formation in the wastewater treatment

K.F. Guerrero-Granados, J. Mante, M. Joy, A. Boergers, S. Schastok, C. Kube, S. Panglisch, J. Tuerk (Germany, USA)

Ecotoxicological impact, due to the action of micropollutants (MPs), is nowadays an important issue of social and political concern. Wastewater treatment plants (WWTPs) play a highly relevant role in this field since the main contaminated effluents are being conducted and treated there. Nevertheless, WWTPs are not primary focused on the elimination of MPs and therefore, a conventional treatment must be extended by applying either adsorptive or oxidative advanced treatment steps. Regarding the oxidation techniques, the direct dosage of ozone is the most common procedure to MPs elimination. Ozonation involve selective reactions with ozone and non-selective, but highly reactive hydroxyl radicals (•OH).
The formation of transformation products (TPs) by oxidative processes represents a drawback especially for the case of bromate (BrO3-). However, possible solutions for this issue can be provided through process parameter optimization or the development of alternative set-ups. A new ozone injection mechanism (dosage of ozone strong water (OSW) in the liquid phase) developed by Air Liquide was operated and analyzed in pilot and full-scale at the WWTP of Duisburg-Vierlinden, Germany. Laboratory experiments were conducted to assess the bromate formation potential of the standard laboratory approach with wastewater from this and other WWTPs, and to establish a comparison with pilot and full-scale applications. The aim of this study is to evaluate the performance of this alternative ozone injection, with a special focus on a reduced bromate formation. Beside micropollutant removal also further parameters such as toxicological aspects and elimination of pathogens were considered as secondary aspects.

06.3. Ozone oxidation of a steel manufacturing wastewater

C. Tizaoui, M. Munawa (UK)

Production of steel through the coke making process results in the generation of highly contaminated wastewater. Traditionally, the steel coke oven's wastewater is treated using biological treatment, which has become an inefficient strategy to manage this wastewater. This project evaluated other treatment techniques including ozone-based oxidation. The results show that ozone was effective to reduce the chemical oxygen demand of the wastewater but significantly reduced its biodegradability possibly due to the formation of toxic substances during ozonation, or removal of key nutrients required for bacterial growth.

Session 7. Engineering aspects – Part 2

07.1. Case Studies Make A Strong Case for Ozone Sidestream Injection

J. Lauria, A. Mazzei (USA)

Mazzei Injector Company executives conducted an in-depth analysis of the International Ozone Association (IOA) installation database, water media reports, presentations at IOA conferences, and the company's own files on customer and competitor installations to assess trends in ozone dissolution in North American drinking water and wastewater ozone facilities over the last 30 years. Driven by improvements in transfer efficiency, reduced energy demand, environmental footprint, maintenance costs, worker safety, and other factors, much of the industry shifted from fine bubble diffusers to sidestream injection for ozone transfer. Using data from case studies presented at the August 2022 IOA-Pan American Group Conference, as well as computational fluid dynamics (CFD) modelling to validate system designs and compare in-field performance, this presentation will explore the factors that have led to the increased adoption of sidestream injection.

07.2. Role of the immediate ozone reaction by the application of ozone strong water for an advanced wastewater treatment

J. Mante, K.F. Guerrero-Granados, H. Zhang, A. Boergers, S. Panglisch, J. Tuerk (Germany, China)

Ozonation processes can be applied as advanced treatment step at wastewater treatment plants (WWTPs) to remove micropollutants (MPs). Nevertheless, the formation of toxic transformation products (TPs) such as bromate (BrO3-) is still a limitation for their wide application.

Process parameter optimization can play an important role in the reduction of TPs formation as well as ozone and energy consumption. One of the key factors for the improvement of ozonation processes lies in the ozone injection mechanism.
In standard ozonation technologies, wastewater is treated by injecting gaseous ozone using diffusers or pump injector systems. In these cases, the three process steps, i.e., mass transfer, mixing and reaction, are generally carried out simultaneously in the same reaction basin. An alternative ozone dosage system, ozone strong water (OSW), was installed and operated for nine months in full-scale at the wastewater treatment plant of Duisburg-Vierlinden, Germany. The main distinction of an OSW system to standard ozonation technologies consists in the separation of the main process steps into three delimited process units that can be optimized independently. This could lead to an ozonation process where a reduction in reactor size and reaction time is expected.

07.3. In Situ Chemical Oxidation using Ozone for remediation of an aquifer impacted by hydrocarbons and ethers
A. Crema, E. Pasinetti, M. Peroni, D. Soderino, F. Grecolini (Italy)

Among contaminated site remediation technologies In-Situ Chemical Oxidation (ISCO) using ozone involves the injection of a mixture of oxygen and ozone directly into the subsurface, both in vadose zone and in the saturated zone, to degrade organic contaminants of concern. ISCO ozonation is the only in-situ technology that involves the use of a gaseous chemical, thus posing different design, operational and treatment considerations than those of other liquid oxidants (e.g. hydrogen peroxide, persulfate, permanganate). This study reports the results obtained in a ISCO field test using ozone to remediate an aquifer impacted by hydrocarbons and ethers in a former gas station in Northern Italy. At the end of the field test, an 82% removal efficiency of all organic contaminants of interest has been obtained, consequently ISCO technology using ozone has been proposed to and accepted by the Authorities for the new Site Remediation Project including periodic ozone injections to treat residual contaminants.

7.4. Cutting-Edge Ozone-Technology for Water Treatment
V.J.P. Vilar, I. Rodrigues, P.H. Marrocos, M.M. Pituco, F. Moreira, A.F.P. Ferreira, R.J. Santos, (Portugal)

The reactive nature of O_3 typically limits the capability of O_3 generators to produce O_3 in concentrations greater than 15%, resulting in low yield and high O_3 production costs. High O_3 supply demands, the extended contacting time required in the reaction chamber, and the bulky size of the equipment also constitutes a major impediment to the mass penetration of ozone technology in the water treatment sector. OZONE4WATER project is addressing these issues by developing a disruptive ozone-technology for water treatment including: (i) functionalized membranes for O_3/O_2 separation to obtain an O_3-enriched gas stream, allowing for O_3 generation at lower concentration utilizing a lower specific power; simultaneously the O_2 from the mixture of O_2/O_3 can be recovered and recycled back to the O_3 generator, thereby saving costs for the energy to produce O_2 and reduce the O_2 consumption and (ii) the development of a low footprint ozone side stream contacting train for water treatment through the integration of the O_3/O_2 separation unit with a static micro/meso-structured mixer (NETmix), thus enhancing the O_3 mass transfer to the liquid phase to almost 100%, leading to an O_3 enriched water stream, resulting in a downstream compact reaction chamber.

7.5. High efficiency Plug flow Ozone Reactor including multiple dissolving function
K.J. Kim (Republic of Korea)

The plug-flow type ozone dissolution reactor(Ozone Dynamic Reactor, ODR™) with a multiple dissolution function shows higher ozone dissolution efficiency and organic matter removal ability than conventional ozone dissolving facility. This ozone dissolving reactor has holding zone that temporarily hold undissolved ozone gas in the several vertical zones, and the remain ozone gas is dissolved again with water turbulence caused by mixing velocity changes. As the test result of the ozone dissolution rate for tap water, the ozone dissolution rate is more than 99% at the ozone dosage 8mgO_3/L(Case 1). In addition, due to the fast reaction rate of ODR™, the TOC removal rate was 16.1% higher than that of the conventional CSTR ozone dissolution (Case 2, ozone dosage 100mgO_3/L). Also It has been demonstrated that the organic matters removal rate was increased by 27.1% after installation ODR™ in the performance test of livestock wastewater treatment plant.

7.6. Use of micronanobubble aeration in wastewater treatment
M. Mohamed, M. Kizhisseri, M. Sakr, M. Maraqa, M. Hamouda (United Arab Emirates)

Activated sludge process (ASP) is the most commonly used method for treating municipal wastewater. The oxygen level in the aeration tanks is critical for improving the removal of organic matter. Micro and nano bubbles have the potential to increase oxygen levels more effectively than conventional macro bubbles. This study aims to investigate whether micronanobubbles of air can replace macro bubbles for aeration in an ASP system. A hybrid MNB aeration method was used, involving a nanobubble generator and ultrafine diffusers with compressed air, to generate micronanobubbles. Two identical ASP systems were used, one with MNB aeration and the other with macro bubble aeration, and both were tested at bench scale level. Treatment efficiency was determined by measuring the COD of influent and effluent samples. The results showed that the method was successful in generating nanobubbles with good concentration in wastewater, indicating that nanobubble aeration has great potential to improve the efficiency of ASP wastewater treatment plants.

Session 8. Young Ozone People (YOP) Workshop

08.1 Young Ozone People Workshop
M. Pages, T. Merle (France)

Tuesday, 4 July

Session 9. Ozone reactions – Part 3

09.1. Degradation of extracellular and intracellular antibiotic resistance genes in water during ozonation process
D. Das, A. Bordoloi, D.J. Caldwell, R.P.S. Suri (USA)

Municipal and industrial wastewater can be a significant source of antimicrobial resistance genes (ARGs) and lead to their proliferation in the aquatic environment. Ozonation process may be used for wastewater disinfection and for the removal of emerging contaminants such as pharmaceutical compounds. This study examines the ozonation process for the degradation of resistance genes from three antibiotics, namely ciprofloxacin (gyrAR), levofloxacin (qnrsR), tetracycline (tetAR). The fate of extracellular ARGs (e-ARGs), intracellular ARGs (i-ARGs), free (f-ARGs) and mobile genetic elements (intl-1, plasmids) will be discussed.

09.2. Advanced oxidation of tertiary wastewater micropollutants with nearly-zero contact time: modeling and validation studies
D. Santoro, O. Santoro, T. Pastore, S. Mancini, T. Masi, T. Mao (Canada, Italy)

A novel intensified technology, MITO3X®, has been tested and validated for oxidizing recalcitrant micropollutants in tertiary municipal wastewater using different advanced oxidation processes: (a) ozonation alone, and (b) ozone/hydrogen peroxide. Suspect screening techniques based on high-resolution mass spectrometry (operated in both positive and negative modes) were applied to characterize the concentrations of a wide spectrum of micropollutants, from pharmaceuticals to PFAS, initially present in the BAC-treated tertiary wastewater used as influent to the MITO3X® pilot. The technology was further analysed using computational fluid dynamics (CFD), which, after calibration against pilot data, confirmed the considerable intensification achieved as indicated by the enhanced mass-transfer observed numerically. In the pilot test, operated at a 6 m3/h flow rate, different ozone concentrations (2-6 mg/L) were tested, alone and in combination with hydrogen peroxide (4 mg/L). Results indicated that ozone at a relatively low dose (3 mg/L) could achieve 41% micropollutant oxidation calculated as an average of 25 micropollutants. Such removal increased to 50% when the ozone dose was raised to 6 mg/L. When 4 mg/L of hydrogen peroxide was added to 6 mg/L of ozone, 80% removal for all micropollutants was achieved with nearly zero contact time (<2 sec). CFD modelling and analysis allowed for detailed quantification of mass-transfer coefficients, which were found to be enhanced by 1000 and 100 times relative to fine bubble diffuser and venturi injection (with static mixers), respectively.

09.3. Batch ozonation tests, combining lab experiments and CFD-kinetic simulations to improve standardization of the method
G. Bellandi, R. Muoio, K. Guerrero-Granados, A.B. Sanchez, A. Börgers, R. Schemen, P. Vlasschaert, U. Rehman, A. Wieland, J. Türk, W. Audenaert (Belgium, Germany, The Netherlands)

Ozonation and its combination with other advanced oxidation processes is an effective solution to remove micropollutants and pathogens in many areas of the water treatment sector. Batch ozonation experiments are widely used to evaluate the ozone demand of a given water matrix and to assess the suitability of ozone technology. However, to date, the lack of sufficient standardization in this methodology can mislead the decision to build or not an ozone installation due to the variability in bromate formation. This work wants to highlight the root causes of these variability in bromate results among different labs and replicas showing some important aspects of the batch ozonation test waiting for standardization. This was possible by combining lab experiments and simulations.

9.4. Aerobic stabilization with pre-ozonation of residual sludge in the dairy industry's wastewater treatment plant
C.R. Ramírez-Cortina, A. Colín-Sánchez, M.S. Alonso-Gutiérrez (Mexico)

In dairy industries, the volume of wastewater effluents and their content in terms of pollutants are highly variable, depending on the nature of the manufacturing, the work technique implemented and how the factory is made up, among others. The water used in large quantities by the dairy industry ranges from 2 to 10 liters of water for each liter of milk. This water is largely restored, entering the manufacturing process for specific needs, such as feeding the boiler condensers or washing materials mainly.
The wastewater from these industries is mainly made up of milk residues, diluted dairy products and cleaning products. The main organic constituents present in milk residues are its natural solids: emulsified milk fat, lactose and proteins such as casein, salts and trace elements, it also contains sucrose. The cleaning products used in the dairy industry are mainly alkalis (caustic soda, sodium carbonate and silicate) and acids (nitric, hydrochloric, and sulfuric) in combination with detergents and disinfectant chemicals such as sodium hypochlorite and other iodinated compounds. The organic substances in the effluents of dairy industries come from discarded products and, to a lesser extent, from cleaning products and sanitary sewage (CAR/PL, 2002).

Session 10. AOPs - Part 1 / Ozone-based AOPs

10.1. Elimination of drugs mixture by catalytic ozonation with $Fe(OH)_2$/NiO and $Fe(OH)_2$ catalyst films synthesized by ultrasonic spray pyrolysis technique
G.L. Morejón, T. Poznyak, J.L. Rodríguez Santillán, P. Guerra-Blanco (Mexico)

In the present study, the degradation of pharmaceuticals compounds model mixture of carbamazepine (CB), naproxen (NP), and sulfamethoxazole (SX) was carried out by ozone in the presence of iron-based catalysts films synthesized using the Ultrasonic Spray Pyrolytic technique (USP) at a deposition temperature of 450oC. The UV-vis spectroscopy results showed a total removal of the initial compounds by direct reaction with molecular ozone, while the catalysts effect shows in the decomposition of the ozonation intermediates. The catalysts selectivity and activity depend on the chemical structure of ozonation products. The catalyst films of Fe(OH)2:NiO/ (50:50 v/v) with a precursors concentration of 0.01% mmol were more effective in ozonation.

10.2. Treatment of a Mixture of Micropollutants by Powdered Activated Carbon – Catalyzed Ozonation
M. Gamal El-Din, M. Alameddine (Canada)

In order to improve the performance of ozonation in the degradation of micropollutants (MPs), catalysts are added to accelerate the rate of ozone reactions, boost the removal and mineralization, as well as reduce toxicity. As such, powdered activated carbon (PAC) has been used to catalyze the ozonation process by virtue of its ability to act as adsorbent material, or reaction support, or radical initiator or promoter. The objective of this study was to examine the efficiency of PAC-catalyzed ozonation for the removal of a mixture of 17 MPs, including pharmaceuticals and personal care products, herbicides and perfluorinated compounds. The results indicated that MPs with limited reactivity with ozone were removed by at least 68% within 10 minutes by PAC-catalyzed ozonation with 10 mg/L ozone and 100 mg/L PAC. In most cases, the parent compound degraded within the first minute. Singlet oxygen and superoxide radicals were the main reactive species that dictated the mechanism of oxidation.

10.3. Degradation of Benzoic Acid in the presence of NiO and CeO_2 films by ozone
D. Franco-Peláez, J.L. Rodríguez Santillán, T. Poznyak, P. Guerra-Blanco (Mexico)

In this research, cerium oxide (CeO_2) and nickel oxide (NiO) thin films were synthesized by ultrasonic pyrolytic spray (UPS) to degrade benzoic acid (BA) in aqueous solution using ozone as oxidant agent. The results of X-ray diffraction confirmed that both films (CeO_2 and NiO) are polycrystalline with cubic crystal structure. The effect of nozzle-to-substrate distance (NSD) on morphology and physicochemical features of the thin films was studied. Complete BA degradation was obtained for conventional and catalytic ozonation at 20 min of reaction, without affect the concentration profiles of BA due to nozzle-to-substrate distance during the synthesis of films. Oxalic acid (OA) was the main product generated in the BA removal by catalytic ozonation, which was partially decomposed due to the formation of reactive oxygen species (ROS), such as hydroxyl radical ($^{\bullet}OH$). Total Organic Carbon (TOC) results indicated 84% and 58% of mineralization degree were achieved with CeO_2 and NiO films, respectively, in contrast 53% obtained conventional ozonation at 2 hours of treatment.

10.4. Catalytic ozonation of substituted phenols and industrial application for coking wastewater treatment
Y. Xie, H. Cao (China)

Ozone is very promising in aqueous organic pollutants removal, but the efficiency is not high enough for practical wastewater treatment, and high active catalysts are urgently required. In this work, we like to introduce our work for decades on reaction mechanism of ozone decomposition, active sites on catalyst surface, and integrated technology for organic wastewater treatment. The technology developed has now been applied in dozens of projects in China.

Session 11. Ozone in Medicine – Part 1 / Introduction. COVID prevention and convalesvence

11.1. The Low-Dose Ozone Concept. Is there a prominent biochemical mechanism underlying all indications of systemically administered ozone ?
R. Viebahn-Haensler, O.S. León Fernández (Germany, Cuba)

In chronic inflammatory conditions and diseases accompanied by inflammation, the main indication range of systemically administered ozone, one basic mechanism of action has emerged following the low-dose ozone concept:
Interference in the diverse biological redox processes and its regulation at low concentrations. It starts with the oxidation of GSH (active form of glutathione) by “ozone peroxides” and, after a considerable number of regulatory processes and mechanisms, finally leads to the regulation of the glutathione balance GSH ⇋ GSSG itself, the most important intracellular antioxidant system. Typically, the upregulation of GSH is demonstrated in aging processes, in rheumatoid arthritis and the protection of liver intoxication.

11.2. The Role of Ozone Therapy as Adjuvant in the Management of Covid-19 in Indonesia
D. Chaijadi, A. Hendradiana, P. Djoko Tjahjono, E. Kusumaningsih, C. Nathan, Hariyanto, D. Surya Atmadja, R. Viebahn-Hänsler (Indonesia, Germany)

Covid-19 Pandemic, since the first March 2020 had attacked Indonesia, caused increasing number of morbidity as well as mortality among Indonesian people. The pandemy had caused the collapsed of many hospitals in Indonesia, due to too many patients, lack of oxygen supply, drugs and health workers because many health workers were exposed and died due to covid-19. *Indonesian Medical Ozone Association* (IMOA/PERTOZI) proposed two Programs to help Indonesian Police Central Hospital (Hospital of Bhayangkara Tk.1 R. Said Sukanto) to strengthen medical staff and to support the management of Covid-19 patients. Based on the roles of ozone therapy to kill the viruses, to reduce the inflammation and to enhance the blood oxygen concentration, we proposed two Programs to enhance doctors and paramedics immunity and to give adjuvant therapy to Covid-19 patients.

11.3. Treatment of Long-COVID with systemic ozone therapy: Importance of the 'proper dose'
G. Tricarico, V. Travagli (Italy)

Systemic therapy with medical ozone has proved since the beginning of the pandemic to be a good adjuvant therapeutic approach to the other therapies proposed for the treatment of COVID-19. The joint action of effector molecules generated as a result of the appropriate mixing of the patient's blood with a gaseous oxygen-ozone mixture on capillary and pre-capillary vascular endothelial cells favours the restoration of the coating known as glycocalyx. This action enables greater defence and self-healing of patients against the most dangerous consequence of viral infection, namely endotheliitis at the microcirculatory level.
Indeed, the damage that the cytokines induced by the viral pathology produce at the level of the glycocalyx, especially when this is already damaged by pre-existing pathologies, is such as to generate thrombotic phenomena at a local level, with consequent pre-capillary arterial haemolysis and increased perivascular and intraparenchymal lymphocyte migration, to mention only the most relevant consequences. These same phenomena, then, in some subjects remain for a very long time due to the poor ability of endothelial cells to repair the damage. An adequate therapeutic treatment with ozone is able to increase the repair processes at the endothelial level, demonstrating efficacy in the therapy of the so-called Long-Covid.

Session 12. Workshop - Sidestream injection of ozone

12.1. Sidestream injection of ozone
Introduction, advantages and drawbacks, case studies
M. Roustan,S. Baig, J. Lauria, R. Pearce, E. Wert (France, USA)

Session 13. Engineering aspects – Part 3 / DWP

13.1. CT Calculation Methods for Achieving Cryptosporidium Inactivation Credit with Ozone
C. Schulz, C. Ngan, E. Wert (USA)

Concentration-time (CT) tables have been developed by the United States Environmental Protection Agency (EPA) to determine inactivation credits for cryptosporidium and other regulated microbial pathogens. This paper will introduce different CT calculation methods approved by EPA for achieving disinfection credit using ozone. These methods were applied to two large water treatment plants (2,300 ML/day and 1,380 ML/day) owned and operated by the Southern Nevada Water Authority to determine design and operational impacts of meeting cryptosporidium- based disinfection goals.

13.2. Assessment of Temperature Effects on Ozonation Performance and Bromate Formation Resulting from Severe Drought Conditions
B. Abada, E. Wert, A. Atkinson (USA)

The Southern Nevada Water Authority (SNWA) oxygen and ozone systems at their two water treatment facilities are currently being assessed for upgrades after reaching a 20-year lifespan. The renovated ozone system will be designed for a 1.5 *Cryptosporidium* log reduction value (LRV) –up from the current 0.5 LRV– to account for potential climatic-driven changes in raw water temperature and quality. Hence, ozone CT, decay, initial demand, and bromate formation/control were evaluated in this pilot study at LRV targets of 0.5-1.5 and temperatures between 15-29 ºC. Although CT requirements varied, a similar transferred ozone dose of 2.3-2.8 mg/L was needed to achieve the targeted 1.5 LRV for all temperatures tested.

13.3. Emerging contaminants in drinking water treatment plants: how ozonation affects activated carbon adsorption
B. Cantoni, J. Ianes, B. Bertolo, S. Ziccardi, F. Maffini, M. Antonelli (Italy)

Contaminants of Emerging Concern (CECs) in drinking water are a growing concern for potential negative effects on human health. This study combines full-scale monitoring campaigns in a drinking water treatment plant (DWTP) and lab-scale experiments using real water matrices without CECs spike. Monitoring campaigns were performed over one year and over 116 monitored CECs, a maximum of 22 compounds have been detected at the DWTP inlet. The analyses show that ozonation and adsorption on activated carbon (AC) have the main impact in reducing a wide variety of CECs, with performances influenced by their characteristics. At lab-scale adsorption isotherms were performed on 4 different water matrices, before and after ozonation, the evaluate the effect of ozonation on the adsorption process. Ozonation is less effective than AC adsorption in CECs removal, but the combination of the two processes allows to reduce the variability of the removal efficiencies, providing a highest performance for the removal of all the investigated CECs.

Session 14. Ozone in Medicine – Part 2 / Clinical studies and pharmacological effects

14.1. Pharmacological mechanisms of medical ozone and its beneficial effects on elderly patients with oxidative etiology diseases
O.S. León Fernández, R. Viebhan-Hänsler, G. Takon Oru (Cuba, Germany)

Medical ozone reestablishes cellular redox balance so that it may be a valid therapeutic approach in the prevention and management of age-related diseases with oxidative etiology in elderly people. The aim of this study is to evaluate oxidative stress and some vasoactive substances in older (60-70 years) rheumatoid arthritis (AR) patients with diabetes and hypertension as well as another group subject with bronchial asthma in order to demonstrate the beneficial effects of medical ozone in the prevention and therapy of these age groups. A randomized clinical study with 45 elderly patients (60-70 years) was performed. Medical ozone arrested the progression of oxidative damage and modulated those endogenous mechanisms that promote a suitable redox status and TXA_2/PGI_2 balance. Medical ozone may become a standard approach in the prevention and management of age-related oxidative diseases.

14.2. Do oxygen-ozone mixtures affect cell proliferation and death? In vitro studies
M. Malatesta, C. R. Inguscio, M. A. Lacavalla, F. Carton, B. Cisterna (Italy)

Our research aims at identifying the basic mechanisms accounting for the beneficial effects of medical ozone by studying the structural, functional and kinetic changes that occur at the cellular level after treatment with low ozone concentrations. We used in vitro systems, which allow analysing the cell features under strictly controlled and standardized experimental conditions suitable for the application of refined multimodal imaging and biomolecular analyses. The first question to answer concerns the effect of oxygen-ozone mixtures on cell proliferation and death. Our studies demonstrated that the low ozone concentrations usually applied in the clinical practice are generally safe because they do not markedly alter cell proliferation or viability. However, different cell types under different functional states may present various degrees of tolerance to ozone, which may induce alteration in proliferation rate or increase in cell death.

14.3. Application of medical ozone in the complex treatment of distal forms of nonspecific ulcerative colitis
S.N. Navruzov, A.M. Khakimov, B.S. Navruzov, S.T. Rakhmonov, E.E. Kulmiev, U.G. Vohidov, A.S. Shodiev, H.H. Choriev (Uzbekistan)

Non-specific ulcerative colitis (NUC) is a severe pathology which, with all its manifestations, dramatically worsens the patient's quality of life. Treatment of ulcerative colitis is an urgent, unresolved problem of coloproctology.
Distal ulcerative colitis is a term that includes 3 main forms of the disease: proctitis, an inflammatory process extending up to 20 cm from the anus margin, proctosigmoiditis (20-40 cm) and left-sided colitis (40-80 cm). These together account for 60-70% of all cases of non-specific ulcerative colitis. The accessibility of the inflammatory zone to rectally administered drugs, the high concentration they create in the intestinal wall and the low concentration in the systemic bloodstream are prerequisites for a predominantly local treatment of distal ulcerative colitis. Ozone due to its unique physiological activity has versatile therapeutic effects on the body including effects on tissue transport and oxygen release, immunomodilatory, haemostatic, bactericidal, detoxifying effects.
The aim of the study was to evaluate the effect of medical ozone in the treatment of distal forms of NSCLC.

Session 15. AOPs - Part 2 / Ozone-based AOPs

15.1. Application of ultrasound-assisted ozonation for micropollutant elimination in wastewater treatment plants
J. Tuerk, K.F. Guerrero-Granados, A. Boergers, S. Panglisch, W. Neumann (Germany, Switzerland)

Organic micropollutants (MPs) are an integral part of everyday life and are used in many areas of the human activity. Through the daily use of e.g. household chemicals or pharmaceuticals, these enter municipal wastewater treatment plants, in which these substances cannot be removed adequately. Municipal wastewater treatment plants represent important point sources for the discharge of MPs in surface waters. To ensure high water quality, political action is needed to reduce inputs of trace substances to water bodies. Across Europe, environmental quality standards (EQS) are currently being discussed for various micropollutants, e.g. from the groups of estrogenically active substances or active pharmaceutical ingredients for surface waters (EU Proposal 2022). For the elimination of these MPs, ozonation and adsorption on activated carbon have proven to be efficient and economical.
As part of this project, the innovative ozonation technology USONiQ, consisting of a special ozone injection (OptimiXer®) and ultrasound treatment, was integrated and evaluated at the wastewater treatment plant (WWTP) of the city Hamminkeln, Germany with 48.500 population equivalents. The receiving water is the Issel River. The optimal operating parameters were determined to achieve an 80% MPs elimination. Extensive tests were carried out to evaluate the formation of transformation products. Further experiments were conducted to assess the effect of weather conditions, and the bromate formation potential at high specific ozone doses.

15.2. Numerical simulation of hydroxyl radical production during hydrodynamic cavitation in the presence of dissolved ozone
A. Kumar, Y. Huaccallo-Aguilar, R. Rangarajan, N. Matzke, S.F. Reinecke, W. Ding, M. Meier, U. Hampel, (Germany)

The hydroxyl radical (HO•) is a strong non-selective oxidant generated in advanced oxidation processes (AOPs) to remove organic micropollutants (OMPs) from polluted water. Hydrodynamic cavitation is an emerging AOP that has received a lot of attention recently and has shown promising potential for the treatment of complex OMPs. In this study, we attempted to simulate the production of HO• by using multiphase computational fluid dynamics (CFD) model at various conditions during cavitation of water containing dissolved ozone (O_3). Validation experiments were carried out to examine the presence of HO• in the reaction chamber via the degradation of succinic acid (which is reactive with strong oxidants such as HO•) using a hydrodynamic cavitation combination with dissolved O_3. The simulation results are qualitatively comparable to the experimental results.

15.3. Influence of the inlet pressure, flowrate and ozone dosage on the ozonation/cavitation for the rapid removal of succinic acid
Y. Huaccallo-Aguilar, A. Kumar, J. Mante, M. Meier, S.F. Reinecke, U. Hampel (Germany)

Water cavitation with dissolved ozone (O_3) is a powerful advanced oxidation technique to remove micropollutants. However, further understanding is required before being applied at the industrial scale. In this sense, our work is to evaluate the effect of the dissolved ozone dosage, inlet flow rate, and inlet pressure in the cavitation/ozonation process for the rapid removal of succinic acid (SA) from an aqueous solution and give an insight into the production of hydroxyl radicals (HO•) in terms of removal values of SA. Constant variables in the reaction were 106.3±6.8 mg L^{-1} of SA concentration and a feed flow rate of 18±0.4 L h^{-1}. After the performance, the high SA removal efficiency (41.3%) was observed at the high inlet pressure (48 bar), high inlet flow rate (15 L h^{-1}), and low O_3 concentration (7.4 mg L^{-1}) after 60 s. This fast SA removal at the higher inlet pressure could be related to more bubble formation and implosion, which leads to high HO• generation. Therefore, cavitation/ozonation is a promising combination for the rapid removal of emerging pollutants.

15.4. Novel bubble column designed for catalytic ozonation with heterogenic structural catalyst
M. Bilińska, L. Bilińska, M. Gmurek (Poland)

The objective of the study was to find the efficiency of the newly constructed bubble column by determining hydrodynamic and kinetic parameters. This novel column reactor was designed for catalytic ozonation. A key innovation was catalytic baffles placement through the column. The ozone gas contacted catalyst while moving through the column. However, every change in the geometry of the absorption column results in changing the mass transfer resistance. The experiment proved the volumetric mass transfer coefficient was not worse for ozonation whit catalytic baffles than it take place for classical ozonation with out catalyst, and it can be higher (k_{La}, was between 0.007 and 0.01 1/s for the column without baffles, when the baffles were in, k_{La} was between 0.007 and 0.018 1/s). At the same time, the overall interphase surface was increased from 21.61±3.3 1/m to 49.05±6.4 1/m when the baffles were used. A kinetic study of dye removal showed a higher rate of decolorization after using catalytic baffles. Moreover, the Hatta number increased from 2.25 to 4.28 then.

15.5. Metronidazole degradation by ozone advanced oxidation processes
M.A. Jiménez-López, F.J. Beltrán, F.J. Rivas, P.M. Álvarez (Spain)

Several metronidazole (MTZ) elimination tests were carried out using ozonation, catalytic ozonation and photocatalytic ozonation processes, with TiO_2-P25 as a heterogeneous photocatalyst to check their influence on MTZ degradation and the degree of synergy among the different processes. Also, a mathematical model based on mass balances of species present in water was used to predict experimental concentrations.

15.6. Kinetic modelling development of photocatalytic bacterial inactivation: influence of operational conditions in the inactivation constant
S. Moles, R. Moreno, M.P. Ormad, R. Mosteo, A. Monzón (Spain)

Heterogeneous photocatalysis utilizing TiO2-based catalysts has been extensively studied for its efficacy in removing pollutants from water and inactivating pathogenic coliform bacteria. Despite being a readily available and low-cost option, the development of suitable industrial-scale photoreactors has proven challenging due to the complexity of modelling the process in real wastewater, particularly when dealing with bacteria that possess significant structural differences. Consequently, TiO2-based photocatalysis is still regarded as an effective yet energetically inefficient process. This study focused on Escherichia coli (gram-positive) and Enterococcus sp (gram-negative) to investigate their kinetics. Since first-order kinetics cannot accurately represent the bacterial inactivation process, various mathematical models were applied to fit the experimental data, including the Gompertz model, which has demonstrated sufficient accuracy in describing the process. Moreover, the effect of catalyst concentration, matrix and UV-A dose has included in the proposed equation.

15.7. Degradation of imidazolium based ionic liquids by pulsed corona discharge and UV photolysis assisted with extrinsic oxidants
D. Nikitin, S. Preis, N. Dulova (Estonia)

Ionic liquids are salts with exceptional properties; however, they can pose a threat to humans or aquatic life due to the high aqueous solubility and potential toxicity. The biodegradation of ionic liquids depends on the nature of their anion and cation components, and many ionic liquids are not readily degraded in conventional wastewater treatment plants, therefore cost-effective solutions to treat these pollutants are required. Advanced oxidation processes demonstrate the ability to degrade recalcitrant pollutants. The aim of this work is to study the degradation of imidazolium ionic liquids in water by pulsed corona discharge and UV photolysis combined with extrinsic oxidants. The effects of various factors including pH, alkyl chain length, type of anion, type, and concentrations of extrinsic oxidant on the degradation efficiency was examined. Pulsed corona discharge in contrast to direct UV photolysis demonstrated the ability to degrade imidazolium based ionic liquids. In turn, the introduction of extrinsic oxidants substantially enhanced the efficiency of target compounds degradation in UV-based systems.

15.8. Peroxydisulphate Activation by Ag/TiO_2 Under Sunlight: elucidation of routes for a fluoroquinolone degradation, evolution of the antimicrobial activity, and potentialities for water disinfection.
S.D. Jojoa-Sierra, C. Jaramillo-Páez, M.C. Hidalgo, J.A. Navío, M.P. Ormad, E.A. Serna-Galvis, R.A. Torres-Palma, R. Mosteo (Spain, Colombia)

The degradation and elimination of antibiotic activity (AA) of the fluoroquinolone Levofloxacin (LEV) using TiO_2 and (Ag/TiO_2) catalysts were evaluated in the presence and absence of sunlight and peroxydisulphate (PDS). Characterization of materials allowed to understand the contribution of the processes observed during the elimination of AA, since it persisted after 80% of LEV elimination. This could be ascribed to the combined effects of solar light, formation, and attacks of sulfate radicals by PDS cleavage, plus the photocatalytic behavior of Ag/TiO_2. The degradation pathways were elucidated. In addition, the combined system was tested for effective *E.coli* water disinfection.

Session 16. Advanced treatment of wastewaters / Part 1

16.1. Water Reuse to provide Sustainability and reduce impacts of Climate Change on Water Systems
S.Y. Jasim (Canada)

Climate change affects global water resources and water systems in different ways and magnitudes, there is a complicated and unpredictable pattern for some of the significant impacts, that could cause serious impacts on the ecosystem and eventually on human health.
These effects will add challenges to the sustainable management of water resources, which are already under severe pressure globally. The availability of water for basic human needs, with the quality and quantity recommended for safe drinking water and sanitation could be under serious threats. The effects of climate change can be highly idiosyncratic at the local scale current trends and future projections indicate major shifts in climate, and more extreme weather events in many parts of the world. It is therefore paramount that decision makers involved consider the potential impacts of a changing climate when managing water as a resource for society that is fundamental to sustainable development.

16.2. Ozonation of effluent from a wastewater treatment plant in the Netherlands, origination and current progress
M. Hoekstra, M. Spruijt, J. Versteegh, T. Keesman, R. Van Der Neut, R. Koolen (The Netherlands)

All the uses of water are connected in the water cycle. Indirect reuse of treated wastewater might be an important possibility to shorten the water cycle and it will help reaching a resilient water future. But the presence of micro pollutants and emerging compounds in the wastewater treatment plant (WWTP) effluent are a limiting factor for the indirect reuse. Water authority HHNK, in collaboration with water technology supplier PWNt and drinking water company PWN, has been investigating the potential of ozonation for the degradation of organic micropollutants in WWTP effluent at Wervershoof, for the last 7 years. On WWTP Wervershoof a full scale ozonation installation of 700 m3/hr was built in 2022, treating the effluent of the WWTP before emitting the water to the surface water system. The installation contains three different ozonation systems: two conventional systems (diffusers

and venturi) and an innovative system (roturi). In the last seven years' experience is obtained on ozonation of the effluent of WWTP Wervershoof and on the collaboration with the different stakeholders. For the coming years the newly built full scale installation will be used to gain knowledge on removal rates, bromate formation and energy consumption. Being the first installation for ozonation on wastewater effluent in the Netherlands, these experiences will be shared with all other water authorities. A detailed research program is drafted for related research; into (indirect) reuse and the and the implementation of a digital twin of the installation.

16.3. Feasibility assessment of ozonation at a coastal WWTP in Sweden with virtual piloting of a full-scale installation
G. Bellandi, R. Muoio, Z. Kaleh, V. Karelid, J. Suokko, U. Rehman, W. Audenaert (Belgium, Sweden)

With the increasing water scarcity and stringent legislation, releasing safe and stable quality water into the environment is essential for entire communities. Ozonation is a valuable technology to remove contaminants that are recalcitrant to biological treatment processes, but its application should be engineered and tailored to the local water characteristics to assure minimal bromate formation while removing micropollutants. In view of assessing the feasibility of ozonation at a municipal WWTP on the west coast of Sweden (50,000 P.E.) for micropollutants removal and minimal bromate formation, Sweco made use of the Amozone kinetic model. The virtual full-scale experiments revealed the extent of production of bromate which could be maintained below 1 ug/L by working at a limited ozone dosage injected in multiple locations, yet allowing more than 70% overall micropollutants removal.

Session 17. Ozone in Medicine – Part 3 / Pain, Orthopedics

17.1. Ozone Therapy &Treatment of Fibromyalgia
T.T. Tanbouli (Egypt)

Fibromyalgia is a chronic disorder causing pain and tenderness throughout the body with fatigue , trouble sleep , memory and mood affection. Other symptoms may present as (Muscle and joint stiffness.,Tenderness to touch. Numbness or tingling in the arms and legs.Problems with concentrating, thinking clearly, and memory (sometimes called “fibro fog”) sensistivity to light, noise, odors, and temperature Digestive issues, such as bloating or constipation.fog”).

17.2. New Approach to Chronic Back Pain Treatment: A Case Control Study
M. Bonetti, D. Lauritano, G.M. Ottaviani, A. Fontana, M. Frigerio, A. Zambello, L. Della Gatta, M. Muto, F. Carinci (Italy)

Our study compares the clinical outcome of chronic low back pain present for over six months treated with alpha-lipoic acid (ALA) + palmitoylethanolamide (PEA) and myrrh and periradicular infiltrations of oxygen-ozone under CT guide to periradicular steroidal infiltrations in a short (one week), medium (three months) and long-term period (six months). We enrolled 246 patients (Group A) with low back pain treated with periradicular infil- trations of oxygen-ozone under CT guide combined with 800 mg/day of ALA + 600 mg/day of PEA + 200 mg/day of myrrh orally. Group B consisted of 176 patients with low back pain treated with periradicular infiltrations of steroids. The results highlight how the treatment associated with ozone therapy and oral administration of alpha-lipoic acid + palmitoylethanolamide and myrrh can be considered a valid alternative to common therapeutic approaches in the treatment of chronic low back pain.

17.3. Role of intra-articular Ozone gas injection in the management of internal derangement of the temporomandibular joint
E.T. Daif (Egypt)

The current study was carried out to compare the intra-articular Ozone gas injection versus drug therapy as conservative treatment modalities for internal derangement of the temporomandibular joint (TMJ).

17.4. Immunological Aspects of Ozone Treatment in Rheumatoid Arthritis
Z. Fahmy (Germany)

The treatment of rheumatoid arthritis RA patients (n=50) with basic treatment (n=25) and a complementary concept: basic + MAH (major auto hemotherapy) leads to better results than the basic therapy on its own:
1. Rapid and significant decrease in CRP (C-reactive protein) and ESR (Erythrocyte sedimentation rate).
2. Acute-phase protein is reduced significantly in the ozone group compared to the control group (basic treatment only). 3. ESR is reduced significantly in the ozone group compared to the control group. The ozone effect on cytokines could be explained by inhibition of cytokine production or inhibition of the response to cytokines.

Session 18. AOPs – Part 3 / Non Ozone-based AOPs

18.1. Persulfate Activated by Non-Thermal Plasma for Pharmaceuticals Degradation
D. Nikitin, E. Kattel-Salusoo, S. Preis, N. Dulova (Estonia)

The oxidation of anti-inflammatory dexamethasone (DEX), antidiabetic metformin (MET) and antibiotic vancomycin (VAN) was studied using gas-phase pulsed corona discharge (PCD) in combination with persulfate (PS). The effect of the dose of PS on the degradation rate, the degree of mineralization, and the energy efficiency of the target compounds oxidation was evaluated. Regardless of the pharmaceutical compound studied, the addition of moderate persulfate doses resulted in a noticeable improvement in oxidation efficiency compared to non-assisted PCD process. For all pharmaceuticals studied, with minor exception for DEX showing negligible improvement, an increase of the dose of PS in the PCD/PS system resulted in a substantial increase in the observed degradation rate. The results of this study contribute to the possible application of the combined PCD/PS process for the efficient oxidation of aqueous pharmaceuticals.

18.2. Organic Micropollutants Removal through Performic Acid-UV Photolysis: kinetics and wastewater matrix influence
C. Nabintu Kajoka, S. Brosillon, J. Gasperi, M. Oliveira, V. Rocher, G. Chebbo, J. Le Roux (France)

Performic acid (PFA) is an emerging disinfection oxidant increasingly used in wastewater treatment. This study investigated the effectiveness of PFA activated by UV-C photolysis for the removal of 6 pharmaceutical compounds.

Compared to PFA alone, PFA/UV was found to be more efficient, with pseudo-first-order rate constants of the pharmaceutical compounds varying between 4.76 ± 0.32 x10^{-3} and 1.14 ± 0.46 min^{-1}, with CBZ being the least reactive and DCF the most reactive compound. Comparison between PFA/UV and H_2O_2/UV processes revealed that the PFA/UV process was more efficient in removing pharmaceutical compounds due to the production of specific reactive radicals during the process and not only OH° radicals. In addition, the reactivity of furosemide was found to be highly influenced by these specific radicals, rather than OH° radicals, as demonstrated by its rate constant being 15 times higher in the PFA/UV process compared to H_2O_2/UV. The removal of pharmaceuticals in treated wastewater effluent resulted in a removal rate ranging from 30% to 60%, with DCF being the most effectively removed compound, as expected due to its high pseudo-first-order rate constant in phosphate buffer solution.

18.3. Evaluating the effects of Ozone, UV and NaClO as an Advanced Oxidation Process in surface water in a DWTP of Catalonia

L. Ferràndez-Galceran, A. Cabrera-Codony, M. Valentí, M.J. Martín, P. Agustí, M. Carrasco, H. Monclús (Spain)

The presence of natural organic matter (NOM) is the main cause for disinfection byproducts (DBP) formation, upon final chlorination. In this context, drinking water managers must maximize NOM removal and optimize chlorine dosage. In this study, post filtrated water from surface reservoir was combined with UV-LP and UV-MP irradiation and aqueous chlorine solution (sodium hypochlorite) in various Advanced Oxidation Processes (AOPs) combinations. The impact of the experiments on the structure of the Natural Organic Matter (NOM) was evaluated as well as the formation of biodegradable compounds and the disinfection by-products (DBP) formation.

Session 19. Advanced treatment of wastewaters- Part 2 / Reuse purpose

19.1. The Potential of Ozonation in Advanced Wastewater Treatment for Pharmaceutical Control and WWTP Effluent Reuse in the Netherlands

M. Spruijt, M. Hoekstra, R. Koolen, B. Martijn (The Netherlands)

In response to the recent European and Dutch policies aimed at controlling pharmaceuticals in WWTP effluent discharge, PWNT, in collaboration with water authority HHNK and drinking water company PWN, has been investigating the potential of ozonation for the degradation of organic micropollutants in WWTP effluent at Wervershoof, located in the province of North-Holland, the Netherlands. Furthermore, efforts were being made to explore the possibility of WWTP effluent reuse. The pilot-scale bubble column and venturi ozonation studies conducted in this research effort have demonstrated the potential of ozonation in advanced wastewater treatment to address both present and future challenges related to micropollutants in surface waters and water scarcity in the Netherlands. Ozonation has been shown to be effective in pharmaceutical control while limiting bromate formation, as well as enhancing ceramic microfiltration flux in a multibarrier reuse scheme, thus making it a suitable option for advanced wastewater treatment. As a result of this research project, a full-scale ozonation plant with a capacity of 700 m^3/h and three ozonation dispersion systems (bubble column diffusion, venturi and roturi) has been established.

19.2. The Role of Ozone Treatment in Potable Water Reuse: Overview and Global Case Studies

A. Vieira, D. Perrin, J. Citulski, J. Reungoat, S. Katz, L. De Franceschi (USA, France, Canada, Switzerland)

Several factors are accelerating the implementation of potable water reuse (indirect potable reuse - IPR and direct potable reuse - DPR) in a multitude of locations across the globe. The design of safe and reliable potable water reuse treatment systems (IPR/DPR) requires a robust multi-barrier approach. Ozone combined with biologically activated filter plays a crucial role in this multi-barrier flowsheet approach. In this presentation, an overview of the types of potable reuse and regulations development for IPR/DPR in the USA will be discussed. Moreover, ozone design parameters will be placed in context with regards to organics removal and disinfection credits, per specific requirements in each project. Finally, case studies depicting pilot demonstrations and full-scale operations will be presented for several sites across the globe.

19.3. Status Implementation of EU Reuse Regulation 2020/741 in Germany - Wastewater Reuse for agriculture

A. Ried (Germany)

The German Federal Ministry of Education and Research (BMBF) initiated a program to develop flexible and reliable concepts for sustainable water reuse in agriculture. This program is supporting the implementation of the Regulation (EU) 2020/741 of the European Parliament and of the Council on minimum requirements for water reuse (the Water Reuse Regulation). Which shall apply from 26 June 2023 in the member states.
Under the topic area “Reuse of Municipal Wastewater” there are 4 active projects: Flextreat; HypoWave+; Nutzwasser and PU2R. The program started in 2021 and ends in 2024.
All 4 projects are focusing on the topic reuse of municipal wastewater but have specific objectives and goals. PU2R is developing decentralized systems for domestic wastewater. FlexTreat and Nutzwasser investigate at centralized wastewater treatment plants. HypoWave+ is implementing a hydroponic system as sustainable solution for resource efficient agricultural reuse. The results from the projects give an overview of different investigated treatment technologies and solutions. The investigated technologies include e.g. membranes, oxidation- and disinfection technologies and media filtration. To achieve the requested treatment goals single treatment steps and treatment trains are investigated. Beside the technology evaluation the project objectives also focusing on risk management, disinfection validation, digital solutions and implementation of regional regulatory aspects. The overall goal is to generate experiences and knowledge to support the implementation of the EU Regulation in Germany.

19.4. Disinfection via electrogenerated ozone for wastewater reuse

M.P. Castro, I.F. Mena, M.A. Montiel, M.A. Rodrigo, J. Gäbler, L. Schäfer (Spain, Germany)

Contaminants of emerging concern (CEC) including antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARG) hinder the reuse of treated wastewater e.g. for irrigation. The SERPIC project develops a new process combination to achieve safe water free from CECs to be discharged into the aquatic system or to use in agriculture for irrigation of crops. First, the CECs from wastewater treatment plant effluent are separated via nanofiltration.

Afterwards, the concentrate stream is treated with electrogenerated persulfate to oxidise the organic CECs, ARB and ARG. The permeate stream is already free from these pollutants and is additionally disinfected to be safely used for irrigation.

Ozone is used as disinfectant. It is in-situ produced from the water molecules electrochemically in cells with boron-doped diamond electrodes. Results are shown about electrode and cell design, ozone production rate and energy efficiency of the disinfection cell.

19.5. Urban wastewater treatment by ozonation: pathogens and microcontaminants removal, disinfection byproducts and toxicity evaluation
K.J. Castañeda Retavizca, K. O'Dowd, S. Nahim-Granados, P. Plaza-Bolaños, S. Malato, M.I. Polo-López, S. Pillai, A. Agüera, I. Oller (Spain, Ireland)

This study investigates the degradation of organic microcontaminants (OMCs) and the inactivation of bacteria naturally present in the secondary effluent of an urban wastewater treatment plant, through the ozonation process using different ozone doses. In addition, different disinfection by-products (DBPs) and toxicity using different bioassays (cytotoxicity, phytotoxicity and ecotoxicity) have been also evaluated. The ozonation set-up consists of an oxygen generator, an ozone generator, non-dispersive UV analysers, a 10 L bubbling tank and a thermocatalytic ozone destructor. Degradation of 80% of the OMCs proceeded rapidly in the first minutes jointly with bacteria inactivation, being directly proportional to the ozone dose. Monitoring of bromate and bromoform formation was also carried out. Toxicity tests did not show significant changes.

Session 20. Ozone in Medicine – Part 4 / Application & Safety

20.1. Safety and efficacy parameters for medical ozone equipment according to current EU legislation
G. Tricarico, V. Travagli (Italy)

The Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices obliges electro-medical machine manufacturers to certify machines according to updated safety and efficacy parameters compared to what was previously in force. Ultimately, the regulatory bodies have identified the certification companies that, according to the regulations in force, authorise the sale following the issue of a certificate. A periodic inspection (annual or biannual) will then be carried out to verify the safety and effectiveness of the equipment and the proposed treatment. Once an ozone generator has passed the checks, obtained the certification and its user manual has been properly explained to the purchaser, it is then the latter who will decide whether those specifications are sufficient for his or her way of therapy. Therefore, for the end user, the fundamental document is the user manual, which thus becomes the guide with which to operate that device. The purpose of this contribution is to highlight, by means of some specific patterns, the fundamental topics that should be observed by medical personnel using ozone for therapeutic purposes.

20.2. How to assess an optimal blood ozonisation in Systemic Ozonized Autohaemotherapy: a bedside indicator
A. De Monte, M. Buttazzoni, F. Bassi, G. Sermann, C. Gori, C. Macor, A, Ercolini, L. D'orlando (Italy)

The application of Systemic ozonized autohaemotherapy (SOA) is progressively expanding in the clinical field, and great efforts of scientific Societies is devoted to the search for standardization of modalities of blood ozonisation. Several therapeutic protocols are described concerning amount of blood, type of container, O_2/O_3 concentration, and O_3 generator. Curiously, no such attention is dedicate to assess the ratio between nominal concentration and accuracy of homogenisation between gaseous mixture and blood. In this presentation, we argue the topic and suggest the use of partial pressure of oxygen (PaO_2) value as an indirect indicator to confirm and adequate mixing. Accordingly, we demonstrate that the simple use of a swinging blood collection scale does not guarantee an accurate blood homogenisation and it has to be integrated by manual intervention from the clinician.

20.3. Application of medical ozone in purulent surgery
S.N. Navruzov, A.M. Khakimov, B.S. Navruzov, S.T. Rakhmonov, E.E. Kulmiev, U.G. Vohidov, A.S. Shodiev (Uzbekistan)

The treatment of purulent wounds is one of the most difficult and urgent problems of modern surgery. The high rate of infectious complications in patients is probably due to the resistance of microorganisms to the used drugs, decrease of general and local immune reactivity of the organism that requires further study and improvement of treatment methods.
Aim of the research: to improve and improve methods of the complex treatment of acute purulent surgical infection.

20.4. The effectiveness of ozone therapy in the prevention of purulent infection after "reduction" surgery
S.N. Navruzov, A.M. Khakimov, B.S.Navruzov, S.T.Raxmonov (Uzbekistan)

In many diseases of the rectum and colon, the necessary to perform an abdomino-anal resection of the rectum with the reduction of the proximal of colon into the anal canal (operation "reduction") appears.
In the clinic "Yangi Hayot" from 2017 to 2022, 121 patients underwent abdomino-anal resection of the rectum with the relegation of the proximal parts of the colon into the anal canal (operation"reduction"). The patients were aged from 14 to 70 years. Mean age of patients was 39.5 years. Of them, men - 70 (57.85%) and women - 51 (42.15%).

20.5. Effectiveness of ozone therapy in gynaecology
R.S. Navruzova, B.S. Navruzov, A.M. Khakimov (Uzbekistan)

Approximately 13 million premature infants are born in the world each year; they account for 60-70% of early neonatal mortality and 65-75% of infant mortality. Recently, ozone has been widely used in surgery and other areas of medicine, but so far there have been only sporadic reports of its use for the treatment of obstetric pathology.
Aim of the research:. to study the efficacy of ozone therapy in the treatment of prematurity.

20.6. Virucidal Efficacy of Gaseous Ozone against Type 1 Herpes Simplex Virus (HSV-1)
E.K. Ahortor, L. Baillie, D. Lloyd, J.A. Blaxland (UK)

Viruses represent a major threat to human health and are capable of spreading either via direct exposure or contamination of inanimate surfaces. Certain viruses have been shown to remain viable on surfaces of dental implants and devices, fabrics and on

plastics for hours, days and weeks representing a source of continuous viral transmission which must be mitigated. In this study the virucidal activity of various concentrations of gaseous ozone at 40, 20, 10, 5 and 1 ppm was evaluated for its efficacy against Herpes Simplex Virus (HSV-1) following 1.5, 3, 6 and 8 hours exposure. Viral viability following ozone exposure was determined using Vero cells and the viral titre was quantified using the Sperman-Karber's method. Overall, inactivation of HSV-1 was dependent on ozone concentration and the duration of exposure. At 20 and 40 ppm, ozone rapidly depleted virus viability after 6 hours. At 5 and 10 ppm a time dependent reduction in viral infectivity was observed. At 10 ppm, viral titre decreased from approximately 5.2 pfu/mL at T=0 to 3.5 and 2.1 pfu/mL after 1.5 and 6 hours exposure on plastic surfaces. Similarly, viral titre decreased from approximately 5.6 pfu/mL at T=0 t 3.0 to 2.0 pfu/mL at same time frame on steel surfaces. This study builds on earlier research in the field and demonstrates the ability of gaseous ozone to inactivate HSV-1 on two surfaces commonly found in food, medical and dental settings. This study recommends that further work is completed to identify optimum ozone, humidity, and temperature combinations to inactivate such viruses on surfaces found within these environments.

Wednesday, 5 July

Session 21. Ozone reactions

21.1. Simultaneous multi-compound ozonation competition kinetic measurements of complex cyanopeptide mixtures
V. Rougé, E.M.-L. Janssen, U. von Gunten (Switzerland)

Cyanobacterial blooms occur at increasing frequency and intensity, notably in freshwaters leading to the introduction of complex mixtures of their metabolites, i.e., cyanopeptides, to drinking water treatment plants. To better understand the fate of cyanopeptides in treatment trains, ozonation kinetics of their mixtures obtained from cyanobacteria were determined using competition kinetics. 15 competitors were used to simultaneously cover a wide range of O_3 reactivity. The abatement of the competitors agreed well with their known reactivity, although some discrepancies were observed. The abatement of cyanopeptides against competitors showed good correlations when their apparent second-order rate constants (k_{app}) were within an order of magnitude of each other. In addition, the determined k_{app} for cyanopeptides agreed well with the expected reactivity of their functional groups. These correlations validate the kinetic determination using competitors in a complex matrix and allow a high-throughput screening of ozonation kinetics.

21.2. Does ozonation enhance activated carbon adsorption of PFAS in textile wastewater?
B. Cantoni, G. Bergna, E. Baldini, M. Antonelli (Italy)

Per- and polyfluoroalkyl substances (PFAS) are used in numerous industrial applications, such as in textile manufacturing, because of their special chemical properties. To avoid PFAS spread in the environment, removal strategies need to be implemented at the wastewater treatment plants (WWTP) to reduce their environmental risk on receiving water bodies. The fate of 14 PFAS in a full-scale WWTP treating textile and civil wastewater (WW) was investigated. The addition of an adsorption step before or after the ozonation process was studied through adsorption isotherms tested on the WW collected before and after the full-scale ozonation step. Ozonation is not aimed at PFAS removing, but it lowers organic matter competition towards long-chain PFAS in the following adsorption step. The removal of UVA_{254} seems to be a good proxy variable for PFAS adsorption, with relationships not dependent on the presence of ozonation step.

21.3. Characterization of lignin extracted from Miscanthus giganteus by ozonation in a pilot-scale reactor
M. Ebrahimi, V. Acha, L. Rhazi, S. Bresson, L. Hoang, T. Aussenac (France, Spain)

Lignin was extracted from *Miscanthus giganteus* by ozonation in a pilot-scale reactor under dry conditions for characterising the structure of lignin fractions. The yield of extracted fractions at the end of ozonation was determined to be 24.5%. A severe drop in pH from 6.32 to 2.04 was observed as a result of acidic compound generation during the ozonation process. 48% of lignin was extracted from *Miscanthus giganteus* at the end of ozonation. The structural modification of the fractions extracted during the ozonation was followed by ATR-FTIR which made it possible to highlight the ring opening of the aromatic structure of lignin and the generation of carbonyl and carboxyl groups. The average molecular weight of extracted lignin fractions decreased from 11000 to 1500 $g.mol^{-1}$, showing lignin oligomeric fractions generation. In addition, the phenolic monomers 4-hydroxybenzaldehyde, 4-hydroxybenzoic acid, hydroquinone, and vanillin were released from lignin; and organic acids including oxalic acid, glycolic acid, and acetic acid were produced from further oxidation.

21.4. Phenol ozonation modelling. Coupling the penetration theory and mass balances
F. Javier Rivas, F. Beltran (Spain)

Modelling of phenol ozonation has been carried out by coupling the equations derived from the renewal penetration theory and mass balances in water bulk. Up to 6 intermediates have been considered in the mechanism which are generated in reactions occurring in series. The effect of pH has been analysed at pH 3 and pH 7 by keeping constant the rest of parameters affecting the system reaction rate. Results reveal the positive influence of increasing pH values due to the corresponding increase in the ozonation direct reaction constants. Results are compared to experimental data taken from bibliography.

21.5. Modelling ozone disinfection for municipal wastewater in presence of HO• scavengers using the ROH concept
J.A. Malvestiti, R.P. Cavalcante, L.R.D. Sommaggio, R.F. Dantas (Brazil)

The variation in the matrix composition can lead to the use of inadequate oxidant/radiation dose and disturb a correct treatment. The aim of this study was to model the ozone disinfection process of secondary wastewater in presence of carbonate, nitrate and metals using as biological indicator the *Escherichia coli*. The $R_{OH,O3}$ was applied to quantify and compare the *E. coli* inactivation by the radical pathway. The metals Cu, Fe and Zn caused an improvement while carbonate and nitrate caused a decrease on R_{OH} values for both stages of O_3. The modelling results based on R_{OH} values demonstrate that *E. coli* inactivation can be predicted satisfactory (R^2> 0.98), being a useful tool for the generalized prediction of disinfection by ozone.

21.6. Treatment of Fluoranthene in Wastewater by Ozonation
A. Catton, C. Tizaoui, M. Gerardo (UK)

This study evaluated the effectiveness of ozonation for the degradation of a main emerging contaminant (EC) in wastewater; fluoranthene (FLT). The effects of key semi-batch ozonation parameters related to gas-liquid mass transfer and reaction kinetics were identified.

Ozone mass transfer was first studied using pure water revealing that the volumetric mass transfer varied between 0.10 min^{-1} and 0.24 min^{-1} depending on temperature and pH. The degradation rates were evaluated using concentration changes of ozone and FLT versus time. The fluoranthene reaction was found rapid giving a degradation of 75 % in less than one-minute at an ozone gas concentration of 20 g/m^3 NTP.

21.7. Genotoxicity and pathogenic bacteria removal from Secondary Effluents after Ozonation
J.A. Malvestiti, L.R.D. Sommaggio, D.E.C. Mazzeo, M.A. Marin-Morales, R.P. Cavalcante, F.A. Oliveira, C.E. Levy, R.F. Dantas (Brazil)

In this study, secondary effluents from two wastewater treatment plants (WWTPs) with different physicochemical properties were submitted to O_3 treatment and evaluated by BD Phoenix™ 100 (Becton Dickinson, USA) and MALDI-TOF to perform the characterization of the indigenous microorganisms present in the effluents, before and after ozonation. The genotoxic potential of these effluents (before and after ozonation) was also evaluated by micronucleus (MN) and comet assays in cell culture (HepG2/C3A) and, finally, the efficiency of removal of emerging contaminants by ozone was evaluated. The results showed that the highest ozone dose was effective in removing *Escherichia coli* (*E. coli*). *Bacillus* sp. was the most resistant microorganism and was found after the treatment. The genotoxic potential of these effluents after the treatment was not statistically significant.

Session 22. Advanced treatment of wastewaters – Part 3 / Micropollutant focus

22.1. Micropollutant Removal Combinations with Ozone for Effective and Resilient Treatment Solutions
L. Dinkloh, L. De Franceschi, A. Murillo, G. Scaramuzzi, C. Bopp (Switzerland)

The oxidation of specific contaminants in wastewater had always been an important application for an ozone treatment stage. At the same time, synergetic effects with other treatment steps (namely down-stream biological active filtration = BAF) were observed, analyzed and thus resulted in further design aspects for combinations of treatment technologies. Ozone should therefore not be seen solely as a stand-alone process but typically in combination with up- and downstream processes.

22.2. Ozonation is an Effective Treatment Method to Degrade the Antiviral Drug Oseltamivir in Municipal Secondary Effluent
M. Gamal El-Din, S. Jansen van Beek (Canada)

Antiviral drugs are a class of micropollutants that have become a concern due to their increased use and potential negative impacts on the environment. Bench-scale studies were conducted to assess the efficiency of ozonation to degrade oseltamivir phosphate. The results of batch experiments indicated that ozone was effective for the removal of oseltamivir in buffered water with >99% removal of oseltamivir. The ozonation of oseltamivir in secondary effluent was able to remove >98% of the oseltamivir within 30 seconds with a 10:1 molar ratio of ozone to oseltamivir. Thirteen byproducts resulting from the ozonation of oseltamivir were monitored with respect to time. Finally, the acute toxicity towards *V. fischeri* and the genotoxicity of both untreated and treated oseltamivir samples showed that ozonated oseltamivir samples in buffered and real wastewater matrices did not result in an increase in toxicity.

22.3. Ozone tertiary treatment for pharmaceuticals and personal care products removal from municipal wastewater
E. Pasinetti, M. Peroni, M. Cascio, M. Antonelli, F. Malpei, A. Turolla, L. Virtuoso, L. Guzzella, L. Marziali, L. Valsecchi, F. Cappelli, S. Tasselli, E. Valenti, D. Oliva (Italy)

An ozone pilot plant was installed at a conventional WWTP to evaluate the removal rate of emerging contaminants, drugs, and fragrances, as tertiary treatment. The filtered secondary effluent flow rate ranged between 1.3÷1.9 m^3/h with a retention time of 10÷30 minutes and the plant operated with an ozone dose of 2-4 mgO_3/l. The results evidenced a high removal rate of 80-100% for most of the organic targeted compounds: Amisulpride, Azithromycin, Carbamazepine, Diclofenac, Clarithromycin and Ofloxacin. Lower removal rates from 20% to 80%, were observed for some substances e.g. Gabapentin Lactam, Galaxolidone, Irbesartan, Lamotrigine, and Tonalide. Advanced Oxidation Process (AOP) treatment with O_3/H_2O_2, (0.5–1.0–2 $molH_2O_2/molO_3$) allowed improved results for almost all these latter. In addition, ozone determined up to 42% removal of the absorbance at 254 nm and 20% of COD, wastewater disinfection, a decrease of the GC-MS chromatographic area, and no acute toxicity effect nor estrogenic and mutagen effects have been detected.

22.4. Comparative assessment of advanced wastewater treatments for micropollutant removal
R. Serra, E. Judenne, A. Gonzalez Ospina, S. Baig (France)

As more and more citizens get concerned about environment issues, the subject of micropollutants contained in waters arises. Not only water that feeds wastewater treatment plants but also water that flows back to the natural environment after treatment. Micropollutants generated by human activity represent a potential threat to human health and the aquatic environment. The technical solutions likely to reduce micropollutants in a WWTP are pretty well known: ozonation and activated carbon treatment and possible combination thereof. The choice between these technologies depends on numerous factors including the wastewater quality and treatment objectives, the related capital and operating costs and finally their impact on the environment. A comparative assessment was carried out, based on several treatment options.

Session 23. Ozone in Medicine – Part 5 / Workshop

23.1. Role of Ozone Treatment in Disc Lesions in Diabetic Patients
U.R. Chaudhry (Pakistan)

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

23.2. Administration procedures of medical ozone by local injection in small and large joints
G. Tabaracci (Italy)

Oxygen-ozone therapy is a medical practice consisting in the administration of a gas mixture composed of pure oxygen and ozone. The scientific literature recognizes the effectiveness of oxygen-ozone therapy and points out the very low rate of side effects due to the gas action and of complications linked to the administration procedures, provided that these are carried out using suitable materials, following appropriate methodology and in accordance with the guidelines. In this report, I describe the procedures for the administration of medical ozone by local injection in small and large joints, I set up during my long experience as ozone therapist. These methods lead to a high success rate in the treatment of a large number of disorders of the upper and lower limbs and spine.

23.3. The importance of ozone water in holistic dentistry and the systemic ozone application for the oral microbiome and its long-distance effects
W. Schueler (Germany)

Chronic inflammation disrupts immune tolerance:
The Human microbiome project (HMP) distinguishes 9 different microbial habitates in the oral cavity
Different types and varying numbers of bacteria have been found in people with different oral diseases.
Oral microbes affect the process of systemic diseases by the inflammatory response caused by an oral infection or ectopic colonization of oral microorganisms in other organs or tissues of the human body, such as tumor, intestine, heart, blood, brain, joint, placenta.

Session 24. Workshop / The energy vectors

24.1. The energy vectors of Oxygen and enriched oxygen = Ozone
M. Wolfs (The Netherlands)

Before ozone was discovered by Schoenbein, it was already given the name the odour of electricity in experiments via static electricity and splitting of water van Marum (1750-1837) Cruickshank 1801.Via the electrolysis of a gas in 1857. Werner von Siemens predicted that this instrument has a very great future. Because it is able to store Energy in a gas! In 1949, the electrolysis cell of H Boer produced 17 wt % almost flammable ozone and hydrogen There is a new route to make liquid enriched oxygen gas LO3. Ozone is still known to be unstable and explosive. That is incorrect. Increasing safety. has different routes. The role of the oxygen molecule in the energy transition seems to have been forgotten: Via Oxygen/ozone, simple sustainable large and small-scale energy storage can be built via Power2molecules as Solarfuel at any places in the world.

Session 25. Advanced treatment of wastewaters – Part 4

25.1. Removal of organic micropollutants, nutrients and suspended solids from wastewater treatment effluent using ozonation in combination with a denitrifying activated carbon filter: results of a pilot-study in The Netherlands
T.P.M. Spit, J.P. van der Hoek, T. van den Eijnde, C.M. Morgenschweis, M. Bechger, L.T.J. van der Aa, V.M. Luimstra (The Netherlands)

Ozonation prior to granular activated carbon (GAC) filtration has been shown to strongly increase activated carbon lifetime and improve organic micropollutant removal. This has been demonstrated by a recently concluded pilot study at a Dutch wastewater treatment plant (WWTP). The specific type of denitrifying GAC filter (1-STEP® filter) has already proven to be successful in nutrient, suspended solids and micropollutant removal from wastewater effluent. The addition of a preceding ozonation step at least doubled the lifetime, during which >80% of micropollutants were removed. The increased lifetime resulted in lower carbon reactivation frequency, hence lower costs and CO_2 footprint, while the addition of ozone extended the range of removed organic micropollutants. In addition, concentrations of nitrogen, phosphorous and suspended solids strongly decreased during the complete pilot period. Furthermore, bromate appeared to decrease in the 1-STEP® filter, reducing one of the risks of ozonation. As an integrated effluent polishing technique, this so-called O3-STEP filter is added to existing WWTPs. Due to the successful results, several filters are currently being designed for Dutch WWTPs.

25.2. Validating ozone disinfection for indirect potable reuse
S. Hogard, R. Pearce, R. Gonzalez, C. Bott (USA)

Ozone has been applied for decades for disinfection in water treatment in the United States and worldwide. In water recycling applications, ozone presents several other ancillary benefits including trace organic contaminant of emerging concern (CEC) oxidation, and removal of taste and odor compounds. The US Environmental Protection Agency (EPA) established ozone CT (concentration*time) tables for achieving virus disinfection credit with ozone in water treatment applications. These tables have been shown to be overly conservative when they are applied to a wastewater matrix with elevated ozone demand and high disinfection byproduct (DBP) precursor concentrations. The Hampton Roads Sanitation District (HRSD) in southeast Virginia, USA has implemented ozone/biofiltration based water reuse in order to recharge the depleted Potomac Aquifer via managed aquifer recharge

(Hogard et al., 2021; Martinez et al., 2022). Given the relatively high bromide concentration in the region, the development of non-CT frameworks is essential in order to limit bromate formation while ensuring disinfection goals are met (Hogard et al., 2023; Morrison et al., 2022).

25.3. Disinfection as surrogate of micropollutants removal during ozonation of secondary effluent
R.F. Dantas, J. Cristale, C.G Canela, I. Seabra, J. Malvestiti, S. Lacorte (Brazil, Spain)

This study attempted to increase the micropollutants removal evaluation by developing an index that relates the inactivation of common and worldwide used bacteria as disinfection indicators (total coliforms and *Escherichia coli*) with the removal of micropollutants during an ozonation of secondary effluent. The developed index, named Microlog, was tested in three different WWTP samples as well as compared to literature data. Good correlations were obtained between the numbers of log10 of bacteria removal with a percentage of a specific micropollutant removal, independently of the quality of the effluent. The Microlog concept can be easily used as an additional tool to assess the final micropollutants removals when the ozone disinfection of the effluent was measured.

Session 26a. Ozone in Medicine – Part 6 / Workshop

26.1. Workshop on Medical Ozone
M. Schreiber (Germany)

Medical ozone has proven a valuable technique in the treatment of gastroenterological disease, especially in chronic disease. We use Major Auto Hemotherapy MAH as well as Rectal Insufflation RI of ozone in our day to day treatment of patients, and combine it with microbiological probiotic therapy.
In the treatment of gastroenterological disease, especially when we are faced with chronic illness, medical ozone has proven a very valuable technique in a busy physician's clinic. We use Major Auto Hemotherapy MAH as well as Rectal Insufflation RI of ozone in our day to day treatment of patients, and we combine it with microbiological probiotic therapy, orthomolecular therapy and phytotherapy. Cases of patients are used to illustrate the clinical approach.

Session 26b. Workshop / Ozone for Food & Beverage

26.2. Ozone for Food & Beverage
Issues, possible role of ozone, regulations and case studies
Thaer Yassen, Food and Agriculture Organization of the United Nations (FAO), Frédéric Violleau (France)
Sylvie Baig (France), Cristian Carboni (Italy), Camilla Khrulova (Sweden)

Session 27. Ozone and sludge

27.1. Sludge Ozonolysis to enhance anaerobic digestion: a lab-scale and full-scale case study
D. Soderino, M. Peroni, E. Pasinetti, D. Preda, M. Cascio, A. Catenacci, F. Malpei, M. Bernardi (Italy)

Sludge pre-treatment is a crucial step in the Anaerobic Digestion (AD) process to enhance biodegradability and hence improve the energetic balance of the digester. Ozone can play various roles in a Wastewater Treatment Plant (WWTP), including sludge pre-treatment to increase the anaerobic degradability. As part of the PerFORM WATER 2030 project, funded by the Lombardy Region, the application of ozonolysis to anaerobic digestion has been studied at a 30.000 PE WWTP in northern Italy. Full-scale ozonolysis plant led to an increase in biogas production of 20% for ozone dosages of about 25 gO_3/kgVS on about 30% of the sludge flow and an improvement of its quality with the abatement of about 50% of the H_2S content. Laboratory-scale tests showed the effectiveness of ozonolysis in increasing the residual methane capacity of the digested sludge, from 100% to 500% for dosages of 130-300 gO_3/kgVS and the increase in fresh sludge methane capacity from 38% to 74% for dosages of 20-140 gO_3/kgVS.

27.2. Full scale ozonolysis in biological oxidation: a case study
M. Peroni, E. Pasinetti, D. Soderino, R. Canziani, A. Catenacci, M. Cascio, M. Bernardi, D. Oliva (Italy)

As part of the PerFORM WATER 2030 project, funded by the Lombardy Region, a full-scale study was carried out for the application of the ozonolysis process in biological oxidation to minimize the production of waste activated sludge. The study, conducted at a 30,000 PE WWTP (Population Equivalent, Wastewater Treatment Plant) in Northern Italy, involved the ozone dosage in an activated sludge tank with an effective volume of 450 m3, fed with pure oxygen, with hydraulic retention times of the order of 6-8 hours and an organic loading rate of 0.05-0.1 $gBOD_5$/gVSS/d. The data collected highlighted an average reduction of the sludge to be disposed of about 39% using an average tested ozone dosage of 5-8 gO_3/kgTSS with a corresponding dosage of 90 $gO_3/gTSS_{avoided}$ and a reduction in specific sludge production (Yobs) from 0.67 to 0.42 gTSS/gCODremoved. Any inhibitory effect on autotrophic biomass was observed.

27.3. What are the benefits of injecting ozone in a MBR
L. De Franceschi, B. Heiniger, A. Murillo, L. Dinkloh, K. Mende, S. Baumgarten (Switzerland, Germany)

Membrane bioreactors and ozonation are two technologies commonly found in advanced wastewater treatment schemes, e.g. when targeting wastewater reuse. There is clear trend towards high quality water production, specifically including the advanced removal of antibiotic resistant bacteria, recalcitrant pollutants (pharmaceuticals, chemicals), nano particles et cetera.
Even if the combination of both technologies does not emerge as being obvious at first glance, there is a series of benefits for the overall treatment process.
The present paper, result of successful pilot-scale experimental work at Leverkusen (Germany), exploring ozone benefits when directly injected into an MBR.

Session 28. Advanced treatment of wastewaters – Part 5

28.1. Examining the Challenges of Implementing Ozonation and Activated Carbon Treatment for Pharmaceutical Wastewater in Real-World Settings

S. Hedwig, L. Loreggian, N. Furler, R. Hochstrat, F. Sacher, E. Plettig, L. Emmer, M. Langer, M. Thomann (Switzerland, Germany)

Complex industrial wastewaters, such as from pharmaceutical production sites, pose a challenge for municipal wastewater treatment plants. To alleviate the burden on end-of-pipe service providers, effective on-site pollutant removal strategies are essential. Conventional evaporation and incineration approaches are becoming less economically efficient due to rising energy costs.
Here, we have investigated the efficacy of alternatives, such as ozonation and activated carbon treatment for wastewater from a pharmaceutical production site. Our study highlights the benefits and limitations of these approaches, emphasizing the need for further biological on-site treatment stages. We also evaluated their ecotoxicological impact (marine bacteria *Allivibrio fischeri* luminescence inhibition, *daphnia magna* immobility, algae growth inhibition, and Ames-test for detecting mutagenicity) of these wastewaters, providing effect-based information about the risk and removal efficiencies. Ultimately, we used a life-cycle assessment and costing approach to benchmark evaporation against our process, promising ecological and economic benefits.

28.2. Wastewater treatment by ozonation for reducing the wastewater toxicity

A. Bettinardi, C. Carboni, A. Sacco (Italy, USA)

Effluents from biological wastewater treatment plants (WWTPs) may contain various pollutants with potential toxic effects. Ozonation is widely applied to purify wastewater, which may influence the toxicity index. This study's main goal was to reveal the influence of ozonation on the toxicity of WWTP effluents from chemical plant.
The goal was to achieve the reduction of at least 50% of the toxicity value of the effluent. Pilot studies were conducted followed by toxicity tests with wastewater samples and sentinel aquatic organisms (*Ceriodaphnia dubia Richard* and *Pimephales promelas Rafinesque*). Ozonation significantly eliminated toxicity of WWTP effluents, with reduction rates of 50% on *Pimephales promelas* survival, 100% on *Pimephales promelas* growth, 100% on *Ceriodaphnia dubia* survival and 50% on *Ceriodaphnia dubia* reproduction. When the pilot system was operated on the industrial site, the effluent met the toxicity requirements of the regulator. the results showed a significant reduction in toxicity with reduction rates of 75% on *Pimephales promelas* survival, 100% on *Pimephales promelas* growth, 100% on *Ceriodaphnia dubia* survival and 100% on *Ceriodaphnia dubia* reproduction.
The values of DOC and BOD were also verified during the on-site tests. Ozonization did not substantially affect the values of the BOD, but showed a 13% reduction in the COD.

28.3. Integration of biological and ozonation models for the Eindhoven WWTP for optimal micropollutants removal, minimal bromate formation, and improved effluent quality

G. Bellandi, R. Muoio, S. Daneshgar, E. Torfs, R. Schemen, P. van Dijk, S. Weijers, U. Rehman, W. Audenaert (Belgium, The Netherlands)

Treating municipal wastewater and releasing safe and stable quality water into the environment is essential for entire communities giving a relentless water crisis and the crescent need for reuse. In this view, the integration of conventional (e.g. biological activated sludge for N and P removal) and advanced treatment systems (e.g. ozonation for pharmaceuticals removal), are nowadays essentials to achieve increasingly stringent effluent quality standards. This work shows the importance of considering the biological and ozonation plants as a unique machine when developing advanced control strategies to combine a cost-effective removal of nutrients (N-species) with a stable micropollutants removal and minimal bromate formation.

Session 29. Workshop / For a relevant use of ozone

29.1. For a relevant use of ozone

B. Paolini, M. Rothlin, C. Carboni, M. Roustan (Switzerland, Italy, France)

The Workshop aims to suggest an adequate process for using and implementing ozone at full scale in different sectors and application. The main Leitmotiv is to make a Reference out of this process by building a virtuous ozone cycle.

Session 30. Congress Closing and Awards Ceremony

30.1. Keynote lecture
Some highlights and challenges in ozone research from my experiences in the last 30 years

U. Von Gunten (Switzerland)

The field of oxidative water treatment and particularly ozonation has evolved significantly during the last 30 years. Initially, disinfection was the main focus, but later on, ozonation processes were applied for micropollutant abatement and this opened up new fields of research. To this end, the main initial research and application focused on the disappearance of target compounds, however, later on the formation of transformation products became more important, because they could be detected thanks to improved analytical tools.

FURTHER CONTACT

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Ozone and Advanced Oxidation

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