



**INTERNATIONAL
OZONE
ASSOCIATION**
Europe Africa Asia Australasia Group



INTERNATIONAL CONFERENCE

27 - 29 November 2024
Porto, Portugal

Ozone and Advanced Oxidation
Science, technologies and applications for a better world

<http://www.ioa-ea3g.org/ea3g2024>

Institutional supports



PROGRAMME

BOOK OF ABSTRACTS

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WELCOME ADDRESS



The European African Asian Australasian Group of the International Ozone Association presents its EA3G2024 International Conference & Exhibition on Ozone and Advanced Oxidation – Science, Technologies and Applications for a Better World.

This event was organized to be held in Porto, Vila Nova de Gaia thanks to the collaboration with the Faculty of Engineering of the University of Porto and The University of Coimbra.

EA3G2024 continues a long series of successful conferences which were planned to provide an international forum for all concerned including fundamental, engineering and applied aspects of oxidation techniques involving ozone and advanced oxidation systems.

Population growth associated with increases in urbanization, in consumption, in industrialization, in pollution emissions already lead to shortages of water, food, raw materials and globally to excess resource use and climate change. However, climate and earth-resilient development is still possible by devoting greater efforts to certain key sectors: reduction of emissions to air, better resources management and preservation of the natural ecosystems. This involves particularly the implementation of advanced technologies.

EA3G2024 event thus aims to present an overview of the current state of knowledge and latest advances regarding the use of Ozone and Advanced Oxidation to provide solutions face to these challenges.

We would like to express our gratitude and thanks to all of you who contributed to make this event possible: University staff under the leadership of Vitor Vilar, keynote speakers, authors, exhibitors, sponsors, Association' members, chairpersons and members of the Committees.

We wish you a very enjoyable and fruitful Conference.

On behalf of the IOA-EA₃G Organising Committee,

Renate Viebahn-Hänsler
IOA-EA₃G President

THE ORGANIZER IOA-EA₃G

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 advanced oxidation.

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

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

The EA₃G group of IOA manages IOA membership and develops the Association activities in Europe, Africa, Asia and Australasia.

For any further contact

INTERNATIONAL OZONE ASSOCIATION

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www.ioa-ea3g.org





Unique Association that gathers the scientific and technical community
around fundamental, engineering and applied aspects of technologies
involving ozone and advanced oxidation systems for any purpose

You want to belong to our industry and research network and benefit entitlements of your subscription?

We strongly encourage you to start your membership and make the most of the related benefits. IOA-EA₃G has many initiatives and programs to share with you.

- Webinar series: Ozone based solutions to address current challenges / Ozone engineering – Over the year
- International Conference & Exhibition
27-29 November 2024, Porto, Portugal
Ozone & Advanced Oxidation:
Science, technologies and applications for a better world
- Book publishing
 - Ozone in Medicine - The Low-Dose Ozone Concept - Basics, Guidelines and Treatment Concepts
 - Ozone Solutions for the Removal of Microcontaminants in Wastewater
- Call for project to develop ozone and advanced oxidation solutions face to current challenges on health, environment, industry and resources.
- Technical guidelines and support in answer to global or specific needs.
- Taylor-made training course by IOA experts.



ioa-ea3g.org

Please find out how you can become more involved with IOA and its programs.

Visit ioa-ea3g.org or email ioa@esip.univ-poitiers.fr

A wide range of opportunities

Get the latest information on research topics, current issues, technologies under development, new applications and equipments in connection with ozone and related oxidants through publications and events with discounts on rates.

Meet colleagues and specialists working in your interest fields, collaborate with them to share experiences and debate positions, establish business contacts via IOA network.

Contribute to extend knowledge about ozone and related oxidants, participating at conferences, writing papers for publication.

Take part in programs for a wide admission of potentialities offered by ozone-based technologies.

 **apply online** at www.ioa-ea3g.org, page Membership, Application.

You will then receive the membership package including the Directory of Members, the IOA Technical Guidelines published by the Ozone Engineering Group, the Association newsletter Ozone News and your details for access to the peer reviewed online Journal Ozone: Science & Engineering.

Looking forward to hearing from you soon!

COMMITTEES

Scientific Committee

Prof. Michel Roustan | Emeritus Professor, INSA Toulouse, France
Dr. Sylvie Baig | Scientific Manager, Suez, France
Dr. Saad Y. Jasim | P.Eng., Editor-in-Chief Ozone News, Canada
Prof. Javier J. Navarro Laboulais | Professor, Universitat Politècnica de València, Spain
Dr. Vítor Vilar | Principal Researcher, Faculty of Engineering of the University of Porto, Portugal
Dr. Frédéric Violleau | Research Director, Ecole d'Ingénieurs de Purpan, France
Dr. Achim Ried | Distinguished Engineer Disinfection & Oxidation, Xylem Water Solutions, Germany

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Ms. Béatrice Bernard | IOA-EA₃G Secretary, Poitiers, France
Dr. Cristian Carboni | De Nora Technologies, Italy
Mr. Florencio Martin | Veolia, France
Prof. Rui Martins | Associate Professor, University of Coimbra, Portugal
Dr. Vítor Vilar | Principal Researcher, Faculty of Engineering of the University of Porto, Portugal
Dr. Renate Viebahn-Hansler | IOA-EA₃G President
Dr. Frédéric Violleau | Research Director, Ecole d'Ingénieurs de Purpan, France

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With the support of the PhD students

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SPECIAL ACKNOWLEDGEMENTS AND CONTRIBUTIONS

The success in the organization of this event results from the strong and faithful involvement of many individuals, from the support of exhibiting companies, from the generous contribution of the sponsors and from the partnership with FEUP Porto and Coimbra University.

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

Institutional supports and co-organizers



Faculty of Engineering Universidade do Porto

https://sigarra.up.pt/feup/pt/web_page.inicial



Universidade do Coimbra

<https://www.uc.pt/>

Sponsors



CMPEAE – Empresa de Águas e Energia do Município do Porto, EM

<https://aguasdoporto.pt/>



SUEZ

<https://www.suez.fr/fr-fr>



UNICAM – Sistemas Analíticos, Lda

www.thermounicam.pt



XYLEM

www.xylem.com/pt-pt

GENERAL INFORMATION

Language

The official language will be English.

Conference venue

World Of Wine (WOW)
Rua do Choupelo, 39 / 4400-088, Vila Nova de Gaia, Porto, Portugal
www.wow.pt



Registration categories

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

- IOA Member / Winter School delegate / Porto or Coimbra University - Full registration
- Non-member - Full registration
- IOA Member Student / Winter School delegate / Porto or Coimbra University - Full registration
- Non-member Student - Full registration
- One-day registration – IOA Member / Winter School delegate / Porto or Coimbra University, 27 or 28 November
- One-day registration - non-Member, 27 or 28 November
- Conference dinner
- Technical Tour

The full registration fee covers scientific sessions, electronic proceedings, abstracts book, welcome event, lunches and refreshments.

A special discount rate is available for IOA members, Winter school delegates and the delegates from Porto and Coimbra universities. Valid student ID is required for student registration.

Additional registration is required for the Conference dinner and technical tour. These options are opened to guests.

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

Liability and insurance

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

Disclaimer

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

Welcome desk

It will be opened during the conference as follows:

Wednesday, 27 Nov.	07:30 - 18:00	Thursday, 28 Nov.	08:30 - 18:00	Friday, 29 Nov.	08:30 - 12:00
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Badges

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

Coffee breaks & Lunch

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

Enjoy your stay in Porto

All in the exceptional environment of the Portugal's second-largest city, and the one that gave the country (and port wine) its name, Porto is the perfect blend of classic vibes and modern energy... Welcome to Porto!

<https://visitporto.travel/en-GB>

GENERAL PROGRAMME

The conference will include:

- > 2,5-day **scientific and technical sessions** including keynote lectures, oral presentations and poster sessions
- > Welcome addresses and conference introduction
 - o Renate Viebahn-Hänsler, IOA-EA₃G President
 - o Cristian Carboni, IOA-EA₃G President Elect
 - o Michel Roustan, IOA-EA₃G Vice-President, Chair of the Programme Committee
- > Keynote lectures
 - o The role of Digital Technology in the management of a Urban Water Cycle and Energy Utility
Ruben Fernandes, CEO, Águas e Energia do Porto (Portugal)
 - o The Road to a Net Zero Water Sector in Águas do Tejo Atlântico – Portugal
Nuno Brôco, Chairman/CEO, Águas do Tejo Atlântico (Portugal)
 - o EU Directives on Drinking Water, Reuse and Urban Wastewater Treatment: News and Challenges
Loïc Charpentier, Water Policy Manager (Belgium)
- > 2,5-day **exhibition** of ozone related products and services,
- > Half-day **technical visit** of full-scale applications,
- > **Welcome event, Conference dinner** and **Awards ceremony** for delegates and their guests.

Wednesday 27 November

7h30-9h00	Registration	
9h00-9h30	Welcome and opening session	
9h30-10h30	Keynote lectures	
10h30-11h00	Coffee break, poster exhibition	
11h00-12h30	Session 1. Gaz Liquid contactor and ancillaries	Exhibition
12h30-14h00	Lunch	
14h00-16h00	Session 2. Fundamentals	
16h00-16h30	Coffee break, poster session and exhibition	
16h30-18h30	Session 3. Advanced Oxidation Processes – Part 1	
19h00-21h00	Welcome event: Visit of the wine museum and tasting	

Thursday 28 November

8h30-10h30	Session 4. Micropollutants – Part 1	
10h30-11h00	Coffee break, poster exhibition	
11h00-12h40	Session 5. Micropollutants – Part 2	Exhibition
12h40-14h00	Lunch	
14h00-16h00	Session 6. Special applications	
16h00-16h30	Coffee break, poster session and exhibition	
16h30-18h30	Session 7. Advanced Oxidation Processes – Part 2	
20h00	Conference Dinner	

Friday 29 November

8h30-10h00	Session 8. Advanced wastewater treatment – Part 1	Exhibition
10h00-10h30	Coffee break, poster session and exhibition	
10h30-11h30	Session 9. Advanced wastewater treatment – Part 2	
11h30-12h00	Closing session and Award Ceremony	
12h00-13h30	Lunch	
13h30-18h30	Technical visits	

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

Social events

- > **Welcome event** – Wednesday 27, 19h00 - Visit of the wine museum and tasting by WOW – Offered to all delegates
- > **Conference dinner** - Thursday 28, 20h00, at WOW - Registration required

Award ceremony

To encourage young researchers, the Programme Committee will select and award a prize to the **best paper(s) presented by a Doctorate Student** during the Conference.

TECHNICAL TOURS – Friday 29 afternoon

Lever Drinking Water Treatment Plant and Serzedo WasteWater Treatment Plant



Located on the left bank of the Douro, the Lever Water Treatment Plant is the most emblematic facility of Águas do Douro e Paiva and the largest in the north of the country.

It is responsible for supplying 1.5 million inhabitants, equipped with the most advanced treatment technologies, and has an installed capacity to produce 400,000 cubic meters of water per day.

It has two sources of water in the Crestuma-Lever dam reservoir: a subaluvial one consisting of 3 catchment wells and another surface water source.

The water treatment line includes the following subsequent stages:

- > Filtration using pressurized filters to remove suspended solids
- > pH correction to optimize the two subsequent stages
- > Pre-oxidation stage with ozone
- > Powdered activated carbon dosage if necessary
- > Coagulation- flocculation to remove small suspended particles
- > Air flotation and filtration onto anthracite in a same unit
- > Final disinfection, which guarantees microbiological quality all the way to the end consumer.

The sludge resulting from the process is dewatered by thickening and centrifuging. As a result of a pioneering innovation, the sludge is incorporated as a raw material for the ceramic materials industry.

As a benchmark technological facility, the Lever WTP is very popular for technical visits by universities and schools in the region.

Serzedo WasteWater Treatment Plant

The Serzedo Wastewater Treatment Plant belongs to the company Águas do Noroeste SA. It was designed to serve around 97 000 equivalent inhabitants and treat an average daily flow of 1 772 m³/d of effluent.

The treatment system carried out at this WWTP aims to ensure the final quality of the treated effluent for discharge into the River Vizela, as well as its reuse as service water.



The wastewater treatment includes the following stages:

- > Preliminary treatment, aimed at removing large and small solids through screening and sieves and removing sand, oil and grease, carried out by a desander/degreaser;
- > Neutralisation tank for any pH corrections;
- > Biological treatment carried out using an activated sludge system, which removes organic compounds and nutrients from the wastewater;
- > Tertiary treatment with the aim of removing colour from the effluent consists of two stages (line 1 and 2) of flotation/ozonation;
- > Automatic mechanical cleaning filter and a compact UV disinfection system have been installed to guarantee the right level of disinfection for reuse.

Some of the treated water is used as service water, for example for washing equipment and watering green spaces.

The tour will depart from and return to the Conference venue.

Special registration will be required. The fee will include bus transfer.

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.

EXHIBITION

ARROW LAKE | <https://arrowlake.se>

Driven by a vision to revolutionize environmental technology, **Arrow Lake** was founded in 2016 with the mission of creating the world's most advanced ozone solutions. Our goal is to reduce reliance on traditional, often harmful, methods of water and air treatment, offering a cleaner and safer alternative for both industries and communities. Based in Malmö, Sweden, Arrow Lake brings together a team of dedicated engineers, designers, and innovators who are committed to reshaping how we approach purification. Here, we design, develop, and manufacture every aspect of our technology, ensuring top-quality standards and sustainable practices. Our journey is rooted in a deep commitment to environmental stewardship, and we continue to push boundaries in ozone technology to create a more sustainable world.



BMT Messtechnik GmbH | www.bmt-berlin.de

For over 35 years, **BMT Messtechnik GmbH** has specialised in the photometric measurement of ozone in air, oxygen, and water. As a technology leader in ozone measurement, we are dedicated to delivering measuring devices that boast the highest levels of accuracy, durability, and longevity on the market. We provide a comprehensive range of devices to address every conceivable issue.

Additionally, BMT offers compact and advanced air-cooled ozone generators suitable for ozone experiments and small-scale ozone systems. Our ozone instruments are globally utilised in various applications, including semiconductor, pharmaceutical, ballast water treatment, medical, and chemical industries.

For ozone treatment of water and wastewater, BMT provides complete solutions that cover all aspects of ozone measurement within a plant.



Fraunhofer Portugal AWAM | <https://www.awam.fraunhofer.pt/>

Fraunhofer Portugal AWAM pursues applied research with a clear customer focus to provide technical solutions and suitable business models for closing regional water, energy, and resource loops. The research centre focuses its activities on the topics of water treatment, water monitoring and reuse, renewable fuels production, carbon capture and utilization, and added-value compound recovery, working with companies and other partners interested in outsourcing/co-developing their applied research projects in the following Business Areas: Water, Energy and Resource Valorisation.



VentilAQUA | www.ventilaqua.com

VentilAQUA is a key global player in advanced wastewater treatment and reuse technologies, aiming to save water and protect the environment. The company provides customized solutions for industrial treatment plants, allowing clients to recycle and reuse water while ensuring environmental responsibility and regulatory compliance. With a strong commitment to innovation, VentilAQUA invests continuously in Research and Development, applying advanced technologies like electrocoagulation and oxidation techniques. Each system is tailored to meet the specific needs of clients, focusing on sustainability and efficient water use to minimize environmental impact. Operating across the 5 continents with more than 100 regional distributors, VentilAQUA supports a global mission of water conservation and environmental protection, reducing chemicals, energy consumption, waste generation and CO2 emissions.



Veolia Water Technologies & Solutions | watertechnologies.com

With operations in 130 countries and over 10,000 employees worldwide, **Veolia Water Technologies & Solutions** solves the toughest water, wastewater and process challenges around the globe.

Leveraging a comprehensive set of chemical, equipment and digital enabled services and products, the company helps customers optimize water resources and overcome process challenges. Veolia Water Technologies & Solutions serves customers across all industries, including food and beverage, metals and mining, power, pharmaceutical, oil and gas, chemicals, petrochemicals, pulp and paper, and utilities.

Learn more at watertechnologies.com and connect with us on [LinkedIn](#).



XYLEM | www.xylem.com/pt-pt

Xylem is a leading global water technology company, dedicated to providing innovative technological solutions to meet water-related challenges. Our work is vital: we transport water to where it is needed, treat it to ensure its purity and monitor its quality. We focus on the world's most critical water problems, promoting sustainability and efficiency in water management.

We offer a comprehensive portfolio of products and solutions, including pumps, water treatment and monitoring systems, as well as control and management technologies. Our leading brands include Flygt, Lowara, Xylem Vue Powered by GoiAgua, WTW, Godwin, Wedeco, Pure Technologies, Sanitaire, among others, each specialising in different areas of the water cycle.



SCIENTIFIC AND TECHNICAL PROGRAMME

The Scientific Programme includes:

More than 60 presentations

- > Keynote lectures,
- > Long oral presentations,
- > Short oral presentation for poster introduction and Poster exhibition,

Wednesday 27th November

9h00-9h30	Welcome and opening session , R. Viehban, C. Carboni (IOA-EA ₃ G President & President Elect)
9h30	Keynote lectures The role of Digital Technology in the management of a Urban Water Cycle and Energy Utility <u>Ruben Fernandes</u> , CEO, Águas e Energia do Porto (Portugal) The Road to a Net Zero Water Sector in Águas do Tejo Atlântico - Portugal <u>Nuno Brôco</u> , Chairman/CEO, Águas do Tejo Atlântico (Portugal) EU Directives on Drinking Water, Reuse and Urban Wastewater Treatment: News and Challenges <u>Loïc Charpentier</u> , Water Policy Manager (Belgium)
10h30-11h00	Coffee break, poster exhibition
11h00-12h30	Session 1. Gaz Liquid contactor and ancillaries Chair: Em. Pr. Michel Roustan
11h00	1.01. Overview of Gas-Liquid contactor for ozone application <u>M. Roustan</u> (France)
11h10	1.02. Assessment of Topological Characteristics of a Novel Micro/Meso-Structured Static Mixer on the Gas-Liquid Mass Transfer Performance <u>P.H. Marrocos</u> , I.S. Fernandes, M.M. Pituco, J.C.B. Lopes, M.M. Dias, R.J. Santos, V.J.P. Vilar (Portugal)
11h30	1.03. Sidestream Ozone Injection System Based on a Novel Micro/Meso-Structured Static Mixer for Pre-Oxidation of Drinking Water <u>M.M. Pituco</u> , P.H. Marrocos, F.C. Moreira, V.J.P. Vilar (Portugal)
11h50	1.04. CFD-based Assessment of the Interfacial Area Generation Mechanisms of Gas-Liquid Flows in a Novel Micro/Meso-Structured Static Mixer <u>P.H. Marrocos</u> , I.S. Fernandes, M.M. Pituco, J.C.B. Lopes, M.M. Dias, R.J. Santos, V.J.P. Vilar (Portugal)
12h05-12h30	Poster short oral presentation and exhibition 1.05. Multi-membrane module for gas-liquid contact: proposal of a scale-up methodology for ozone side-stream injection systems <u>V.J.P. Vilar</u> , M.P. Caixeta, P.H. Marrocos, R.J. Santos (Portugal) 1.06. Design of an ozone sidestream injection scheme: assessment of the influence of nozzle length on mixing efficiency <u>L.J.R. Cullen</u> , P.H. Marrocos, R.J. Santos, V.J.P. Vilar (Portugal) 1.07. Design optimisation of a flow distribution device incorporated in a sidestream injection system for ozone water treatment <u>L.J. Cullen</u> , P.H. Marrocos, R.J. Santos, V.J.P. Vilar (Portugal) 1.08. Sustainability Assessment of Sidestream Ozone Injection Systems for Water Treatment: Venturi Injector vs Static Mixer C. Velhas, T. Mata, P. Marrocos, S. Almeida, S. Costa, <u>V. Vilar</u> , A. Martins (Portugal) 1.09. A review of O₂/O₃ gas separation technologies <u>I. Rodrigues</u> , V. Vilar, A. Ferreira (Portugal) 1.10. PDMS membrane for O₂/O₃ gas separation using a spiral wound module <u>I. Rodrigues</u> , V. Vilar, A. Ferreira (Portugal)
12h30-14h00	Lunch

Exhibition

14h00-16h00	Session 2. Fundamentals Chair: Prof. Javier J. Navarro Laboulais	Exhibition
14h00	2.01. Design of Electrochemical Ozone Production Zero-Gap Cells Based on Optimising sp² Carbon Content in Boron Doped Diamond Electrodes <u>J.J. Tully</u> , I.M. Terrero Rodriguez, M. Kaewsen, G.F. Wood, D. Houghton, Y. Han, T.P. Mollart, J.V. Macpherson (UK)	
14h20	2.02. Ozonated Water Preparation in Dental Offices: Estimation of Ozone Gas Solubility Ratio – Optimum Configurations and Practical Guidelines <u>F. Sabbah</u> , W. Domb (Lebanon, Spain, USA)	
14h40	2.03. pH effect on the water color and turbidity during the ozonation of diclofenac <u>N. Villota</u> , E.V. Tosi-Zarate, U. Duoandicochea, J.M. Lomas (Spain)	Exhibition
15h00	2.04. Insights into the role of β-MnO₂ and oxalic acid complex expediting ozonation: Structural properties and mechanism <u>J. Liu</u> , Y. Xiangjuan, C. Sans (Spain, China)	
15h20	2.05. Standardisation of Gaseous Ozone testing to improve understanding of disinfectant efficacy; Recommendations of methods and conditions for comparative studies <u>Z. Hamid</u> (UK)	
15h40-16h00	Poster short oral presentation and exhibition	
	2.06. Determination of inhibiting, promoting and initiating factors of ozone decomposition in a surface water <u>F.J. Beltrán</u> , F.J. Rivas, M.A. Jiménez-López (Spain)	
	2.07. Metrodinazole ozonation modelling in surface water M.A. Jiménez-López, F.J. Beltrán, <u>F.J. Rivas</u> (Spain)	
	2.08. Kinetic characterization of Acetaminophen, Diclofenac and Sulfomethoxazole ozonation by in-situ UV absorption spectroscopy. M.A. Prada-Vásquez, R.A. Torres-Palma, J. Da Silva, A. Chica, <u>J. Navarro-Laboulais</u> (Colombia, Spain)	
	2.09. Using of new innovative ozone therapies in patients with malignancies <u>S.N. Navruzov</u> , B.S. Navruzov, A.M. Khakimov, D.A. Aliyeva (Uzbekistan)	
	2.10. Ozone therapy for miscarriage <u>S. Navruzov</u> , A. Shodiev, R. Navruzova, Sh. Navruzova (Uzbekistan)	
16h00-16h30	Coffee break, poster session and exhibition	
16h30-18h30	Session 3. Advanced Oxidation Processes Chair: Dr. Sylvie Baig	
16h30	3.01. Ozone and advanced oxidation processes – Key features <u>S. Baig</u> (France)	
16h50	3.02. Innovative Advanced Catalytic Integrated System for Organic and Inorganic Pollutants Abatement <u>A.S.G.G. Santos</u> , A.R.L. Ribeiro, J. Restivo, C.A. Orge, M.F.R. Pereira, O.S.G.P. Soares (Portugal)	
17h10	3.03. Optimization of reaction conditions for catalytic oxalic acid ozonation using 3D-printed carbon materials <u>J.R.M. Barbosa</u> , J. Restivo, C.A. Orge, A.F.P. Ferreira, M.F.R. Pereira, A.M. Ribeiro, O.S.G.P. Soares (Portugal)	
17h30	3.04. Photolytic ozonation as promising alternative AOP using UV-LEDs P. Sperle, B. Broelhorst, J. Mielcke, <u>A. Ried</u> (Germany)	
17h50	3.05. Application of supported WO₃ and MoxOy nanostructures in catalytic and photocatalytic ozonation for the water microcontaminants removal J. Lincho, P. Mazierski, A. Zaleska-Medynska, R. C. Martins, <u>J. Gomes</u> (Portugal, Poland)	
18h10	3.06. Phosphorus Modified Mg Ferrite Composites for Photocatalytic Ozonation of Lomefloxacin H. Jarusheh, F. Banat, M. Abu Haija, <u>G. Palmisano</u> (United Arab Emirates)	
19h00-21h00	Visit of the wine museum and tasting	

Thursday 28th November

8h30-10h30	Session 4. Micropollutants Chair: Dr. Achim Ried	
8h30	4.01. 15 years of ozonation for micropollutants removal in Europe – A review A. Wieland, <u>U. Hübner</u> , H. Stapel, A. Ried (Germany)	Exhibition
8h50	4.02. Combination of ozonation with GAC, AIX and biochar post-treatment for removal of pharmaceuticals and transformation products from municipal WWTP effluent <u>M. Fakioglu</u> , O. Golovko, C. Baresel, L. Ahrens, I. Ozturk (Turkey, Sweden)	
9h10	4.03. Ozone Injection System Based on a Novel Micro/Meso-Structured Static Mixer for the Removal of Contaminants of Emerging Concern from Secondary Effluent of Urban WWTP <u>M.M. Pituco</u> , P.H. Marrocos, R. Montes, R. Rodil, J.B. Quintana, F.C. Moreira, V.J.P. Vilar (Portugal, Spain)	
9h30	4.04. Ozone-based treatment of nanofiltration retentate from municipal secondary effluent applying a stainless-steel membrane contactor M. Lima, C. Santos, M.P. Castro, R. Montes, J.B. Quintana, R. Rodil, <u>A. Gomes</u> , M. Rodrigo, M. Dezotti, V. Vilar (Brazil, Portugal, Spain)	
9h50	4.05. PFOA and PFOS removal in drinking water through GAC adsorption, ozonation and carbocatalytic ozonation <u>J. Cotolí-Sancho</u> , F. Bernat-Quesada, Y. Picó-García, M. Añó-Soto (Spain)	
10h10-10h30	Poster short oral presentation and exhibition	
	4.06. Fluorine organic compounds removal by catalytic ozonation and hydrogenation processes <u>C.A. Orge</u> , C. Lopes, M.F.R. Pereira, O.S.G.P. Soares (Portugal)	Exhibition
	4.07. Antibiotics removal from aquaculture effluents by ozonation: chemical and toxicity descriptors <u>A.M. Gorito</u> , P. Rodrigues, L. Guimarães, C.M.R. Almeida, M.F.R. Pereira, A.R.L. Ribeiro, A.M.T. Silva (Portugal)	
	4.08. CO₂-Activated Grape Seed Biocarbon: A Promising Adsorbent for Removal of Antibiotics from Water Bodies <u>N. Miquel</u> , S. Moles, P. Barlés, R. Mosteo, M.P. Ormad (Spain)	
	4.09. Removal of antibiotic from model wastewater and sewage sludge to increase biogas production potential <u>A. Žgajnar Gotvajn</u> , J. Derco, M. Cehovin (Slovenia, Slovak Republic)	
10h30-11h00	Coffee break, poster exhibition	
11h00-12h40	Session 5. Micropollutants Chair: Dr. Saad Y. Jasim	
11h00	5.01. Elimination of pharmaceutical compounds by catalytic ozonation using commercial Y-zeolites in real municipal wastewater treatment plants effluents M.A. Prada-Vásquez, C. Simarro-Gimeno, S.A. Cardona-Gallo, E. Pitarch, F. Hernández, R.A. Torres-Palma, A. Chica, <u>J. Navarro-Laboulais</u> (Colombia, Spain)	Exhibition
11h20	5.02. Online monitoring of Contaminants of Emerging Concern (CEC) during Advanced Oxidation Processes (AOPs) by using a fluorescence sensor <u>P. Roccaro</u> , L. Marino, E. Gagliano, D. Santoro (Italy, Canada)	
11h40	5.03. Advancements in Combatting Antibiotic-Resistant Bacteria in Hospital Wastewater using electro-ozonizers <u>S.E. Correia</u> , V. Pertegal, E. Lacasa, P. Cañizares, M.A. Rodrigo, C. Sáez (Spain)	
12h00	5.04. Remediation of Contaminated Soils by Electrochemically Generated Gaseous Ozone <u>G. Bou-Habib</u> , A. Moratalla, E. Lacasa, M.A. Rodrigo, C. Sáez (Spain)	
12h20	5.05. Advanced full-scale Ozone Applications for Micropollutant Abatement in Municipal Wastewater T. van den Eijnde, <u>T. Spit</u> , E. Broeders (The Netherlands)	
12h40-14h00	Lunch	
14h00-16h00	Session 6. Special applications Chair: Mr. Florencio Martin	
14h00	6.01. Demonstrating efficacy of ozone disinfection <u>B. Meyrick</u> (United Kingdom)	Exhibition
14h20	6.02. WhanHua – Combination of ozone and biofiltration for the removal of hard COD <u>L. De Franceschi</u> , J. Yang, Y. Chen, A. Murillo, C. Bopp, L. Dinkloh (Switzerland, China, Germany)	
14h40	6.03. Comparison of ozonation combined with UV/H₂O₂ processes for textile wastewater treatment and reuse <u>A. Ouissa</u> , C.A. Orge, O.S.G.P. Soares, A. Cunha, M. Catarino, F. Sampaio, A.L. Gonçalves, M.F.R. Pereira (Portugal)	

15h00-16h00	Poster short oral presentation and exhibition	<p>6.04. Electrocoagulation based processes for the landfill leachate treatment J. Duarte, R.C. Martins, Paulo R.F. Rocha, D. Correia, <u>E. Domingues</u> (Portugal)</p> <p>6.05. Optimizing Full-Scale Leachate Treatment Towards Safe Environmental Discharge S.G.S. Santos, D.F.S. Morais, A.I.R. Costa, R.J.E. Martins, R.A.R. Boaventura, V.J.P. Vilar, <u>T.F.C.V. Silva</u> (Portugal)</p> <p>6.06. Evaluation of ozonation performance in removing phenolic compounds to enhance anaerobic digestion of olive mill wastewater T. Vaz, S. Domingues, M.J. Quina, <u>R.C. Martins</u>, J. Gomes (Portugal)</p> <p>6.07. Innovative Waste Activated Sludge Pre-treatment Using a Raceway Pond Reactor: Integration of Low-Temperature and Solar Radiation J.P. Monteiro, <u>C. Cruzeiro</u>, M. Salomé Duarte, M. Alcina Pereira, V.J.P. Vilar (Portugal)</p> <p>6.08. Advanced pre-treatment for enhanced anaerobic digestion of waste activated sludge: low thermal combined with solar radiation J.P. Monteiro, <u>C. Cruzeiro</u>, M. Salomé Duarte, M. Alcina Pereira, V.J.P. Vilar (Portugal)</p> <p>6.09. Valorization of lignin from the black liquor of pulp processing using electrochemical technologies D.F.S. Morais, L.M.G. Sena, J.M. Ribeiro, T.S. Lopes, P. Dias, A. Mendes, C.A.E. Costa, A.E. Rodrigues, R.A.R. Boaventura, C.J. Tavares, V.J.P. Vilar, <u>F.C. Moreira</u> (Portugal)</p> <p>6.10. Recent advancements in the production of ozone by water electrolysis <u>A.R. De Olivera</u>, F.C. Moreira, M.A. Rodrigo, V.J.P. Vilar (Portugal, Spain)</p> <p>6.11. In-situ electrochemical regeneration of antibiotic-loaded clay in a continuous reactor <u>R. Antonelli</u>, A.R.S. Gois, M.R. Massignan, G.R.P. Malpass, A.C.S.C. Teixeira (Brazil, Portugal)</p> <p>6.12. Gaseous Ozone used for the Reduction of Listeria monocytogenes: Efficacy for Surface and Aerosol Disinfection <u>J. Macleod</u>, J. Blaxland (UK)</p>
16h00-16h30	Coffee break, poster session and exhibition	
16h30-18h30	Session 7. Advanced Oxidation Processes Chair: Dr. Vítor Vilar	
16h30	7.01. Evaluation of different synthesis routes to obtain magnetic TiO₂ and Carbon Quantum Dots composites for antibiotics' photocatalysis <u>V. Silva</u> , G. Pereira, N.J.O. Silva, M. Otero, V. Calisto, D.L.D. Lima (Portugal, Spain)	
16h50	7.02. Reduction of bromate formation during wastewater ozonation <u>K.F. Guerrero-Granados</u> , D. Schomers, J. Mante, M. Kolkmann, A. Boegers, S. Panglisch, J. Tuerk (Germany)	
17h10	7.03. Use of O₃, O₃/UV & O₃/H₂O₂ in the treatment of water containing antibiotics <u>H. Zúñiga-Benítez</u> , S. Trujillo-Alzate, M. Araque-González, G. A. Peñuela (Colombia)	
17h30	7.04. The photocatalytic decolorization of arylazo pyridone dyes <u>M. Stojković</u> , A. Mašulović, V. Dokić, V. Pavićević, J. Ladarević, D. Mijin (Serbia)	
17h50-18h30	Poster short oral presentation and exhibition	
	7.05. Insights into the valorization of sewage sludge for enhanced water treatment J. Nieto-Sandoval, R. Cavalcante, Z. Sun, <u>J. Liu</u> , P. Llopart, B. Bayarri, C. Sans (Spain, Brazil)	
	7.06. Degradation and mineralization of lamotrigine in solution alone and in drug mixtures by catalytic ozonation <u>D. Montenegro</u> , C.A.L. Graça, F. Machuca, O.S.G.P. Soares (Colombia, Portugal)	
	7.07. Assessment of heterogeneous photocatalysis as disinfection step for reuse water: control of bacteria and protozoa N. Larumbe, M.C. Hidalgo, N. Miguel, R. Torres-Palma, <u>R. Mosteo</u> (Spain, Colombia)	
	7.08. Toxicity Assessment of Nanosized Photocatalysts A.V. Scalco, E.B. Figueiredo, P.G.M. Couto, C. Kreutz, <u>A.M.C Ferrari</u> , M.L. Gimenes, N.R.C. Fernandes (Brazil)	
	7.09. Development of eco-friendly catalytic membranes for ozone-driven water treatment <u>C.A.L. Graça</u> , D.P. Ferreira, A.M. T. Silva, O.S.G.P. Soares (Portugal)	
	7.10. Graphitic Carbon Nitride Doping and Chemical Modification for PPCPs Mixture Degradation in Photocatalytic Ozonation <u>E. Fernandes</u> , P. Mazierski, A. Zaleska-Medynska, R.C. Martins, J. Gomes (Portugal, Poland)	
	7.11. Multi-Barrier Approach for the Treatment of Secondary Urban Wastewater Targeting CECs Removal and Disinfection: Integration of Membrane Nanofiltration with UV-C/Persulfate Oxidation <u>C.S. Santos</u> , S. Ribeirinho, R. Montes, R. Rodil, J.B. Quintana, O. Pastor, A.I. Gomes, V.J.P. Vilar (Portugal, Spain)	
	7.12. Valorization of CO₂ into Methane via Solar Photo-Thermocatalytic Hydrogenation over Plasmonic Metal-Semiconductor Nanocomposites R.D.G. Matias, R.P. Rocha, O.S.G.P. Soares, R.A.R. Boaventura, A.F.P. Ferreira, V.J.P. Vilar, <u>T.F.C.V. Silva</u> (Portugal)	
20h00	Conference Dinner	

Friday 29th November

8h30-10h00	Session 8. Advanced wastewater treatment Chair: Pr. Frédéric Violleau	Exhibition
8h30	8.01. Applications of Ozone and Advanced Oxidation in Indirect and Direct Potable Reuse Treatment <u>A. Ried</u> (Germany)	
8h50	8.02. Ozone in Operation – Long-term Benefits of Combining Ozone and Activated Carbon for Micropollutant removal <u>A. Murillo</u> , C. Bopp, L. Dinkloh, L. De Franceschi (Switzerland, Germany)	
9h10	8.03. Enhancing Ceramic Microfiltration Flux and Water Quality through Ozonation in Surface Water Treatment and WWTP Effluent Reuse <u>M. Spruijt</u> , J. Zheng, H. Shorney-Darby (The Netherlands)	
9h30	8.04. Integration of membrane bioreactor with ozonation for the quaternary treatment of urban wastewaters <u>C.S. Santos</u> , K. Rodrigues, P. H. Marrocos, A. Narcizo, R. Montes, R. Rodil, J. B. Quintana, A. I. Gomes, V.J.P. Vilar (Portugal, Spain)	
9h50-10h00	Poster short oral presentation and exhibition	
	8.05. Ozone advanced treatment for pathogen elimination and disinfection by-product management in potable water reuse <u>L.R. De C. Costa</u> , L. Li, K.R. Pagilla, L.A. Féris (Brazil, USA) 8.06. Assessment of TiO₂ ceramic membranes performance for winery wastewater treatment <u>V. Mendes</u> , F. Pereira, B. Esteves, C.V. Miguel (Portugal) 8.07. The operating temperature influence on the structure of the bacterial community and the abundance of antibiotic resistance genes in secondary treated wastewater <u>S. Ribeirinho-Soares</u> , V. Braga, S. Cabral, V.J.P. Vilar, C.M. Manaia, O.C. Nunes (Portugal)	
10h00-10h30	Coffee break, poster session and exhibition	
10h30-11h30	Session 9. Advanced wastewater treatment Chair: Pr. Rui Martins	
10h30	9.01. Production of reclaimed water for reuse: a case study at Gaia Litoral WWTP <u>J. Vilaça</u> , L. C. Lopes, I. Baptista, R. Jorge, L. Marinheiro, S. Löblich (Portugal)	
10h50	9.02. Innovative control strategies for advanced water treatment by ozonation <u>A. Ried</u> , U. Hübner, A. Wieland (Germany)	
11h10	9.03. Ozone in Operation – Insights from 10 years of micropollutant treatment at ARA Neugut <u>C. Bopp</u> , N. Hubaux, A. Murillo, L. Dinkloh, L. De Franceschi (Switzerland, Germany)	
11h30-12h00	Closing session and Award Ceremony	
12h00-13h30	Lunch	
13h30-18h30	Technical visit	

KEYNOTE SPEAKERS



Ruben Fernandes is the CEO of the municipal company Águas e Energia do Porto EM.

He is also an Invited Professor at the School of Economics and Management of the University of Porto.

Previously he was the Coordinator of the Regional Dynamics Monitoring Unit at CCDR-N (Norte Regional Coordination and Development Commission) – a regional body of the Portuguese Government tasked with implementing regional policies in the Northern Region of Portugal.

He got his master's degree in Economics and his doctorate degree in Civil Engineering, both at the University of Porto.



Nuno Brôco has 25 years of experience in private and public company management and is currently the Chairman and CEO of Águas do Tejo Atlântico, the AdP group largest company on wastewater management.

He's also board member of Water Europe. Previously he was Chairman and CEO of AdP VALOR, the AdP Group company responsible to foster innovation, digital transition and circular economy.

During 11 years he has been Head of the Engineering Department of Águas de Portugal Group and also responsible for the Corporate Innovation in AdP Group.

Starts his career with SUEZ Group, as specialist in water and wastewater treatment processes, then as Head of the Degrémont Portugal Production Department and finally as Degrémont Iberia Country Manager for Portugal.



Loïc Charpentier is the manager of the advocacy program of Water Europe, the European association of the innovative water sector.

He also contributes to the communication of EU research & innovation projects on behalf of Water Europe to the European institutions and manages the MEP Water Group's secretariat.

He is also involved in different European research clusters and the chairman of the Policy working group of the ZeroPollution4Water cluster.

He is a member of the Brussels Sustainability Club.

With a background in law and a master in European studies, Loïc worked previously at the European Association of Research and Technology organisations as policy assistant.

In 2017, he received the College of Europe – Arenberg European Prize for its master thesis, a comparative study of the European integration and the creation of the federal states of Indonesia.

ABSTRACTS OF PRESENTATIONS

Keynote lectures

<p>The role of Digital Technology in the management of a Urban Water Cycle and Energy Utility Ruben Fernandes, CEO, Águas e Energia do Porto (Portugal)</p> <p>In the last few years, Porto's Water and Energy management Utility embarked on a strategic digital transformation journey, analyzing processes and engaging employees to foster innovation. Embracing technologies like digital twins, IoT, big data, or automation, the Utility optimized its operations, ensuring efficiency, sustainability, and security. A robust data management integration or digital developments oriented towards customer needs, facilitated effective information, enhancing service delivery and environmental stewardship. Employees, customers and new technologies fueled innovation, while a resilient organizational culture encouraged continuous learning and Utilities adaptation.</p>
<p>The Road to a Net Zero Water Sector in Águas do Tejo Atlântico - Portugal Nuno Brôco, Chairman/CEO, Águas do Tejo Atlântico (Portugal)</p> <p>Águas do Tejo Atlântico ambition is to be energy neutral by 2030 and the Portuguese Wastewater utility with the lowest carbon footprint. In line with European and national policies, Águas do Tejo Atlântico is implementing a strategic plan that aims to reduce energy consumption and strongly increase its own production of 100% renewable energy, allowing it to achieve energy neutrality by 2030. Promoting a culture of energy management in the company and integrating the 23 facilities that represent 80% of the company's consumption into the Energy Management System are two main goals that we have set to achieve in 2024/25.</p>
<p>EU Directives on Drinking Water, Reuse and Urban Wastewater Treatment: News and Challenges Loïc Charpentier, Water Policy Manager (Belgium)</p>

Session 1. Gaz Liquid contactor and ancillaries

<p>1.01. Overview of Gas-Liquid contactor for ozone application M. Roustan (France) This presentation will consist in a brief overview of the panel of ozone contactors.</p>
<p>1.02. Assessment of Topological Characteristics of a Novel Micro/Meso-Structured Static Mixer on the Gas-Liquid Mass Transfer Performance P.H. Marrocos, I.S. Fernandes, M.M. Pituco, J.C.B. Lopes, M.M. Dias, R.J. Santos, V.J.P. Vilar (Portugal) This study analyses the effect of a geometrical property, the channel length, of the micro/meso-structured static mixer NETmix on the gas-liquid mass transfer performance. Three NETmix plates were constructed with different dimensions to assess experimentally the volumetric mass transfer coefficients at different operating conditions. Coupling the experimental data with bidimensional computational fluid dynamics simulations enabled a separate evaluation of the mass transfer coefficient. It was found that a reduction in the channel length from 4 mm to 2 mm increased the mass transfer coefficient (kL) by 10%, whereas a reduction from 4 mm to 1 mm achieved a larger increase in kL by 27%.</p>
<p>1.03. Sidestream Ozone Injection System Based on a Novel Micro/Meso-Structured Static Mixer for Pre-Oxidation of Drinking Water M.M. Pituco, P.H. Marrocos, F.C. Moreira, V.J.P. Vilar (Portugal) A sidestream ozone (O₃) injection system based on a novel design of a pressurized micro/meso-structured NETmix static mixer has been developed for the pre-oxidation of freshwater for human consumption. The NETmix has an exclusive geometry that promotes a high intensity of O₃ gas-water mass transfer, thus it is intrinsically advantageous for sidestream injection systems. A pilot-scale prototype was installed at Lever Water Treatment Plant (located in the north of Portugal), enabling the direct comparison with a full-scale sidestream system using a Venturi injector. Water disinfection was assessed as a function of NETmix operating pressure, applied O₃ dose and hydraulic residence time on the contact tank. Additionally, the effect of the ozonation system on the downstream coagulation/flotation step was also evaluated. The use of the NETmix injector allowed a reduction in the O₃ dosage and contact time requirements to achieve satisfactory water disinfection/oxidation and provide favourable conditions to maximize the efficiency of the coagulation/flotation step.</p>
<p>1.04. CFD-based Assessment of the Interfacial Area Generation Mechanisms of Gas-Liquid Flows in a Novel Micro/Meso-Structured Static Mixer P.H. Marrocos, I.S. Fernandes, M.M. Pituco, J.C.B. Lopes, M.M. Dias, R.J. Santos, V.J.P. Vilar (Portugal) A description of the interfacial area generation phenomenon associated with a gas-liquid flow in the micro/meso-structured static mixer NETmix is developed in this work. Based on bidimensional computational fluid dynamics simulations as well as an algorithmic image processing methodology, three different geometrical representations of the NETmix were evaluated to construct a mathematical model able to successfully predict interfacial area values related to the two-phase flow at dissimilar operating conditions. It was analysed the effect of channel length and conditions of liquid and gas phase Reynolds numbers, resulting in a model with a maximum deviation of 11%.</p>

1.05. Multi-membrane module for gas-liquid contact: proposal of a scale-up methodology for ozone side-stream injection systems

V.J.P. Vilar, M.P. Caixeta, P.H. Marrocos, R.J. Santos (Portugal)

Ozone is a highly reactive oxidizing agent, which makes it effective at destroying a wide range of pathogens and harmful contaminants. Among several methods to inject ozone into the water, membranes have been proven to be a viable alternative to promote gas-liquid contact since they can produce small bubbles with a homogeneous distribution, resulting in better use of the bubbles' interfacial area, improving the mass transfer process compared to other conventional gas-liquid contactors. At the lab scale, membrane reactors/contactors have already proved to be an interesting approach for ozonation processes. However, an industrial module has yet to be studied. This work proposes a methodology to scale up a membrane module, proposing an industrial concept design of a multi-membrane module. It uses a novel hybrid CFD-analytical model developed in previous works to simulate and predict the bubble dispersion and compute the ozone mass transfer coefficient, interfacial area, and gas holdup of the multi-membrane module.

1.06. Design of an ozone sidestream injection scheme: assessment of the influence of nozzle length on mixing efficiency

L.J.R. Cullen, P.H. Marrocos, R.J. Santos, V.J.P. Vilar (Portugal)

This work studied the influence of nozzle length on the mixing efficiency of a sidestream nozzle injection system conceived to mix an ozone-enriched sidestream with the main water flow. Computational Fluid Dynamics (CFD) tools were used to simulate tracer experiments in a two-dimensional model of the main tube featuring built-in lateral nozzles. Mixing performance was assessed by analysing intensity of segregation and mixing length. Effective mixing occurred for all nozzle lengths tested, as nearly homogeneous tracer concentrations were achieved in each case. However, increasing nozzle length enhanced mass transfer between water and tracer. Finally, mixing is promoted by the interaction of the jets issuing from the lateral nozzles with the main flow, leading to vortex shedding downstream of the nozzles.

1.07. Design optimisation of a flow distribution device incorporated in a sidestream injection system for ozone water treatment

L.J. Cullen, P.H. Marrocos, R.J. Santos, V.J.P. Vilar (Portugal)

The main goal of this work was the optimisation of the geometry of a flow distribution device incorporated in a sidestream injection system for ozone water treatment. The ozone-enriched liquid sidestream is mixed with the main water flow using two mixing nozzles. The branch length and curvature of the elbows of the distributor were optimised using Computational Fluid Dynamics (CFD) tools, targeting a minimum total pressure drop and a uniform flow distribution. The optimised configuration of the flow distributor resulted in a total pressure drop of 213 Pa.

1.08. Sustainability Assessment of Sidestream Ozone Injection Systems for Water Treatment: Venturi Injector vs Static Mixer

C. Velhas, T. Mata, P. Marrocos, S. Almeida, S. Costa, V. Vilar, A. Martins (Portugal)

Sustainability in the treatment of water for human consumption has become a central concern in recent decades. The aim is to minimise its environmental impact through technologies that reduce energy consumption and limit the use of chemical products. This study aims to evaluate and compare the sustainability of two ozonation systems, where the main difference is the type of gas/liquid injector - Venturi (System A) vs NETmix (System B). System A is being used at full-scale at Lever Water Treatment Plant (WTP), while System B is still in the pilot phase. The sustainability evaluation was carried out through a Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). The LCA study showed that the items in System A with the greatest environmental impact are energy and net O₂, while the LCC study showed that CAPEX costs are much lower than OPEX costs. A comparison between the systems shows that System B is more sustainable from a social point of view, as it obtained a Global Social Index (GSI) of 97% than System A (71%).

1.09. A review of O₂/O₃ gas separation technologies

I. Rodrigues, V. Vilar, A. Ferreira (Portugal)

Ozone (O₃), a triatomic oxygen molecule, is an oxidant commonly used in water and wastewater treatment. However, ozone generation is an intense energy consumption process since the weight percentage of ozone that can be generated from an oxygen-rich feed stream is very low (6-15 wt. %), limiting its use. One strategy to overcome this problem is through the separation of oxygen from ozone, producing an O₃-enriched gas stream, and reusing the oxygen as a gas supply to the ozone generator. This work aims to undergo a literature review on O₂/O₃ gas separation considering adsorption, cryogenic liquefaction, and membrane separation technologies. This review work concludes that extensive research is still needed in this field, as only nine studies have explored the use of membrane and adsorption technologies. Particularly, pressure swing adsorption systems using zeolites and ozone-resistant polymeric (PTFE, PVDF, PDMS) and inorganic membranes have been the focus for O₂/O₃ gas separation.

1.10. PDMS membrane for O₂/O₃ gas separation using a spiral wound module

I. Rodrigues, V. Vilar, A. Ferreira (Portugal)

Ozone (O₃) is a powerful oxidizing agent widely used for disinfection and oxidation of water and wastewater. However, ozone generation is an intense energy consumption process since the weight percentage of ozone that can be generated from an oxygen-rich feed stream is very low (6-15 wt. %), limiting its use. To address this issue, ozone-selective membranes can be used to separate O₂ from O₃, enabling the recovery and recycle of the O₂ back to the ozone generator. A PDMS membrane with an effective area of 0.14 m² was employed in a spiral wound module to study O₂/O₃ separation. The best result was obtained for nitrogen (used as a carrier gas) flow rate of 0.265 SLPM, with an O₂ and O₃ permeance of 9.05×10⁻⁸ mol·m⁻²·s⁻¹·Pa⁻¹ and 3.45×10⁻⁸ mol·m⁻²·s⁻¹·Pa⁻¹, respectively, and a real O₂/O₃ selectivity of 1.43, achieving the desired separation. The stability test and SEM analysis showed that the PDMS membrane in its actual configuration might not be stable for O₂/O₃ separation.

Session 2. Fundamentals

2.01. Design of Electrochemical Ozone Production Zero-Gap Cells Based on Optimising sp²Carbon Content in Boron Doped Diamond Electrodes

J.J. Tully, I.M. Terrero Rodriguez, M. Kaewsen, G.F. Wood, D. Houghton, Y. Han, T.P. Mollart, J.V. Macpherson (UK)

We present our work in elucidating the role of deliberately incorporated sp² carbon on the efficiency and productivity of an electrochemical ozone generator using Boron Doped Diamond (BDD) as electrodes. In particular we use freestanding, commercially available BDD and control the amount of surface incorporated sp² carbon by laser micromachining holes into the electrodes, before integrating these electrodes into a custom designed zero-gap cell and testing their ozone generation performance. This approach allowed us to vary the amount of sp² carbon on the electrode surface between 5 and 80% of the total area, which is significantly more than is possible by tuning BDD growth conditions. This allowed us to determine that sp² proportions > 60% are required to enhance ozone production in these cells. Notably the laser formed sp² carbon material is found to be extremely stable, with minimal degradation in performance after 20 hrs of continuous ozone generation.

2.02. Ozonated Water Preparation in Dental Offices: Estimation of Ozone Gas Solubility Ratio –Optimum Configurations and Practical Guidelines

F. Sabbah, W. Domb (Lebanon, Spain, USA)

Ozone use in dentistry is growing and is attracting more attention, especially in the present COVID-19 pandemic. Ozonated water volumes used in dental offices exceed by far those used in other healthcare-related settings. In addition, different water sources or chemistry are routinely used to prepare ozonated water i.e. distilled / bi-distilled, reverse osmosis, saline, and city water. In practice, dentists wish to prepare enough volume to meet the dental office ozonated water consumption and to reach the desired concentration in the least amount of ozonation time.

2.03. pH effect on the water color and turbidity during the ozonation of diclofenac

N. Villota, E.V. Tosi-Zarate, U. Duoandicochea, J.M. Lomas (Spain)

During the ozonation of aqueous samples of diclofenac, the formation of an intense yellow color in the water occurs. To study this phenomenon in this work, DCF solutions of 50.0 mg/L have been ozonated by varying the initial pH of the water between 2.0 and 13.0, in order to examine its effect on the main indicator parameters of water quality. The ozonation treatment leads to degradation of DCF in 30 min using molar ratios of 2 mol DCF: 1 mol O₃. The water pH evolves during ozonation towards a pK_a DCF=4.15. The formation of yellow color happens during the first 30 min of reaction, until reaching a maximum value and then fading. The height of color intensity is generated at [pH]₀=12.8. The formation of turbidity arise ozonizing at [pH]₀<4.0, when DCF is no longer soluble in water. Maximum turbidity (75 NTU) is produced at [pH]₀=3.0. The mass transfer k_{La}=0.0013 (1/min) is upmost operating at [pH]₀=8.0, when the DCF is mineralized to nitrate.

2.04. Insights into the role of β-MnO₂ and oxalic acid complex expediting ozonation: Structural properties and mechanism

J. Liu, Y. Xiangjuan, C. Sans (Spain, China)

In this study, a β-MnO₂-oxalic acid (β-MnO₂-OA) complex was constructed and used in catalytic ozonation process (HCO) for pCBA degradation (β-MnO₂/OA/O₃). The addition of OA enhanced not only k value of β-MnO₂/OA/O₃ process by 4 times that of ozonation alone, but also had advantageous effects on co-degradation of contaminant and OA. Systematic characterization techniques (XPS, H₂-TPR, TEM and Py-IR.) confirmed the enhanced electron transfer ability and redox property of β-MnO₂-OA complex. More oxygen vacancies and reactive oxygen species (ROS) were generated through facilitating oxygen species migration. Besides, sodium pyrophosphate tests demonstrated that Mn³⁺ was mainly responsible for the formation of β-MnO₂-OA complex. Finally, a feasible mechanism involving solid-liquid interface reaction was elaborated, which presented a potential strategy improving catalytic ozonation performance.

2.05. Standardisation of Gaseous Ozone testing to improve understanding of disinfectant efficacy; Recommendations of methods and conditions for comparative studies

Z. Hamid (UK)

Following the UK's transition from the EU, the introduction of new or novel biocidal products must comply with the Biocidal Products Regulation (BPR). The unique characteristics of ozone, including its generation, intrinsic properties and safety considerations do not fully conform to the preferred methodologies for testing surface biocidal efficacy such as BS EN 17272:2020. Whilst certain aspects of these methodologies are appropriate, there is a need to tailor testing standards.

2.06. Determination of inhibiting, promoting and initiating factors of ozone decomposition in a surface water

F.J. Beltrán, F.J. Rivas, M.A. Jiménez-López (Spain)

A study of ozone decomposition kinetics in a surface water with the objective of determining its inhibiting, promoting and initiating factors that influence the process rate has been carried out. The study will allow the rate of ozone decomposition in a surface water, affected by the presence of inhibitors, promoters and initiators of ozone decomposition, be included in kinetic models of ozone advanced oxidation processes.

2.07. Metronidazole ozonation modelling in surface water

M.A. Jiménez-López, F.J. Beltrán, F.J. Rivas (Spain)

Modelling of metronidazole (MTZ) ozonation in surface water, both in the presence and absence of hydrogen peroxide, has been performed by solving a system of differential equations derived from a semicontinuous process conducted in a perfectly mixed bubble contactor. The impact of naturally occurring substances in surface water has been accounted for by incorporating two factors that influence the reactivity of ozone and hydroxyl radicals. Simulated outcomes consistently match the profiles of MTZ removal and the accumulation of dissolved ozone in the liquid bulk, irrespective of the presence or absence of hydrogen peroxide.

2.08. Kinetic characterization of Acetaminophen, Diclofenac and Sulfomethoxazole ozonation by in-situ UV absorption spectroscopy

M.A. Prada-Vásquez, R.A. Torres-Palma, J. Da Silva, A. Chica, J. Navarro-Laboulais (Colombia, Spain)

The kinetic rate constants of the pharmaceutical compounds Acetaminophen (ACE), Sulfomethoxazole (SMX) and Diclofenac (DCF) were determined in a bubble column reactor measuring the UV-Vis absorption spectra in the reaction course. The proximity of extinction coefficients for all the substances makes difficult the signal deconvolution. A generalized gas-liquid mass transfer model for an open-gas closed-liquid bubble column reactor has been considered for the determination of rate constants. The model can be easily extended to more complex kinetics.

2.09. Using of new innovative ozone therapies in patients with malignancies

S.N. Navruzov, B.S. Navruzov, A.M. Khakimov, D.A. Aliyeva (Uzbekistan)

Malignant neoplasms are a rather common type of pathology around the world. In this regard, the problems of their treatment and the use of various innovative methods are important. One of the main standards for the treatment of this pathology is combined / complex methods, which, along with the therapeutic effect, have some side effects, manifested in the form of immunosuppression and suppression of hematopoietic processes. This report describes the use of ozone therapy in combination with chemotherapy in the integrated treatment of patients with rectal cancer. Ozonation contributed to the absence of local radiation reactions, toxic manifestations and hemodynamic disorders, which persisted throughout the course of treatment, from the blood side - an increase in the number of lymphocytes, normalization of ESR and hemoglobin levels.

2.10. Ozone therapy for miscarriage

S. Navruzov, A. Shodiev, R. Navruzova, Sh. Navruzova (Uzbekistan)

About 13 million premature babies are born annually in the world, accounting for 60-70% of early neonatal mortality and 65-75% of infant mortality. Premature newborns account for 40-80% of perinatal mortality. All this strongly indicates the need to find new approaches to solving the problem. Nowadays, there are more and more publications about ozone therapy. The study of its effect on the body has shown its antimicrobial effect, the ability to improve blood circulation in tissues, and stabilize the state of cell membranes. Ozone has also found wide application in surgery and other branches of medicine, but so far there have been only isolated reports of its use for the treatment of obstetric pathology.

Session 3. Advanced Oxidation Processes

3.01. Ozone and advanced oxidation processes – Key features

S. Baig (France)

Advanced Oxidation Processes (AOPs) are characterized by common principle and goal of creating an extremely powerful oxidant, mainly the hydroxyl radical in order to obtain high removal efficiencies for pollutants resistant to conventional oxidation. Although known for more than thirty years for some of them that combines ozone, UV radiation and hydrogen peroxide, they are currently receiving renewed interest for enhanced removal of micropollutants. The full panel of technologies also now include electro-oxidation, sonolysis, plasma, electron beam etc., at various development stages. The extent of the application field and complexity of the oxidation processes involve a large knowledge and require a real implementation of a process engineering approach to make them the most efficient and therefore technically and economically viable. Special emphasis is made on the suitable approach for their next application at full scale by considering the related key parameters.

3.02. Innovative Advanced Catalytic Integrated System for Organic and Inorganic Pollutants Abatement

A.S.G.G. Santos, A.R.L. Ribeiro, J. Restivo, C.A. Orge, M.F.R. Pereira, O.S.G.P. Soares (Portugal)

A newly developed technology was tested to perform the simultaneous degradation of organic and inorganic species present in water. The continuous catalytic system, consisting of the integration of catalytic ozonation and catalytic reduction processes, was applied to perform the degradation of brominated organic pollutants with the subsequent conversion of the formed BrO_3^- ion into Br^- . The integrated treatment system was successfully applied, allowing the reduction of BrO_3^- concentration in water to values below the imposed advised legal limit under the application of optimized reaction conditions.

3.03. Optimization of reaction conditions for catalytic oxalic acid ozonation using 3D-printed carbon materials

J.R.M. Barbosa, J. Restivo, C.A. Orge, A.F.P. Ferreira, M.F.R. Pereira, A.M. Ribeiro, O.S.G.P. Soares (Portugal)

New approaches to enable the introduction of carbon powder catalysts used in advanced water treatment processes have been recently developed. Additive manufacturing, also known as 3D-printing, is a pathway to develop macrostructures catalysts from previous powder formats. Carbon materials show promising results as catalysts for organic pollutants degradation by, ozonation. The present study evaluated the application of developed 3D printed carbon-based catalysts (3DPCs) in ozonation reactions for oxalic acid (OxAc) degradation. However, since these catalysts did not show mechanical stability at previous reaction conditions used for powder catalysts, optimization and new set-ups were developed that permitted the observation of the catalytic capacity of 3DPCs. A stirrer with a basket case was successfully implemented and different mixing velocities (rpm) were studied to achieve the optimum operating conditions.

3.04. Photolytic ozonation as promising alternative AOP using UV-LEDs

P. Sperle, B. Broelhorst, J. Mielcke, A. Ried (Germany)

Within this study the H_2O_2 -UV advanced oxidation process (AOP) is compared to photolytic ozonation (O_3 -UV) concerning trace organic chemicals (TOrcs) removal efficiency when using UV-LEDs. Whereas H_2O_2 -UV has a higher quantum yield for radical formation, a higher molar absorption coefficient is of importance for the O_3 -UV combination. In pilot-scale experiments using an artificial water matrix, the removal of para-chlorobenzoic acid (p-CBA) was studied using an UV-LED reactor. When irradiating with the identical number of UV-LEDs the O_3 -UV AOP showed a three times higher removal efficiency. This is linked to the higher molar absorption coefficient of O_3 . Overall, O_3 -UV seems to be a promising alternative to H_2O_2 -UV when using UV-LEDs. The study is part of the Life EU project PRISTINE (LIFE21-ENV-ES-PRISTINE-101074430).

3.05. Application of supported WO_3 and MoxOy nanostructures in catalytic and photocatalytic ozonation for the water microcontaminants removal

J. Lincho, P. Mazierski, A. Zaleska-Medynska, R. C. Martins, J. Gomes (Portugal, Poland)

The presence of contaminants of emerging concern (as pharmaceuticals and personal care products) in different water resources worldwide is an imminent danger for the ecosystems and human health. Several compounds are released to nature due to their inefficient elimination in the conventional wastewater treatment plants. Ozonation is an advanced oxidation process capable of efficiently remove several organic contaminants from water. The use of catalytic and photocatalytic ozonation can improve the ozone efficiency and decrease the amount of ozone required for the elimination of pollutants. Therefore, in this study, it is evaluated the efficiency of WO_3 and MoxOy nanostructures in catalytic and photocatalytic ozonation for the removal of a mixture of three parabens. The use of catalysts decreased the necessary ozone doses probably due to a higher generation of hydroxyl radicals, with the results suggesting ozone decomposition at the catalytic surface.

3.06. Phosphorus Modified Mg Ferrite Composites for Photocatalytic Ozonation of Lomefloxacin

H. Jarusheh, F. Banat, M. Abu Haija, G. Palmisano (United Arab Emirates)

Phosphorus-modified Mg ferrite ($\text{P-MgFe}_2\text{O}_4$) nanoparticles were prepared by a simple sol-gel auto-combustion process and used for the photocatalytic ozonation of lomefloxacin (LOM). The HPLC study demonstrated that the degradation of LOM was reduced by 99.98% after 90 minutes in the photocatalytic ozonation system. The decay rate of lomefloxacin was observed to conform to a pseudo-first-order reaction. The sample $\text{P}_{0.035}\text{Cu}_{0.965}\text{Fe}_2\text{O}_4$ exhibited the greatest photocatalytic degradation and the largest specific surface area. The results obtained from the EPR examination showed that the produced ferrites had superoxide and hydroxyl radicals' generation. The results of this study show that adding phosphorus modification to the magnesium ferrite photocatalyst increased the specific surface area and photocatalytic activity. In addition, the inclusion of phosphorus helped to facilitate the effective separation of electron-hole pairs by efficiently capturing electrons in the conduction band, hence increasing the efficiency of degradation.

Session 4. Micropollutants

4.01. 15 years of ozonation for micropollutants removal in Europe – A review

A. Wieland, U. Hübner, H. Stapel, A. Ried (Germany)

Ozonation is a well-established process for the elimination of chemicals of emerging concern at municipal wastewater treatment plants. Since the first installations in Bad Sassendorf/Germany in 2009 and at WWTP Neugut/Switzerland in 2014, more projects were realized in different sizes and configuration in Europe. This paper will give an overview about the technical and regulatory changes during the last 15 years of operation of ozonation systems, discuss lessons learned from pilot- and full-scale operation, and outline expected future trends and required developments.

4.02. Combination of ozonation with GAC, AIX and biochar post-treatment for removal of pharmaceuticals and transformation products from municipal WWTP effluent

M. Fakioglu, O. Golovko, C. Baresel, L. Ahrens, I. Ozturk (Turkey, Sweden)

Research attention towards the elimination of the pharmaceuticals from the wastewater has been increased in recent years. This study aims to examine the removal efficiency for 24 selected pharmaceuticals and the fate of their 7 main metabolites including several oxidation transformation products by various technique combinations (O_3 -GAC, O_3 -Biochar and O_3 -AIX) applied on the effluent from a full-scale WWTP. The average removal of pharmaceuticals ranged between 8.8-97% with an O_3 dose of 0.28 g O_3 /g DOC. Overall, the investigated metabolites of pharmaceuticals exhibited lower removal efficiency with O_3 compared to the parent compounds. GAC was the best performing sorbent among all materials, where even after two weeks of continuous operation, nearly all compounds were removed below LOQ. Although biochar 1 (30-89%) showed better performance than biochar 2 (9-82%), both sorption materials showed reduced sorption capacity over the time period of two weeks for most of the target compounds. On the other hand, AIX had lower removal rates (2-55%). GAC was the most successful combination with O_3 for the removal of pharmaceuticals (>99%) and oxidation transformation products (>60%).

4.03. Ozone Injection System Based on a Novel Micro/Meso-Structured Static Mixer for the Removal of Contaminants of Emerging Concern from Secondary Effluent of Urban WWTP

M.M. Pituco, P.H. Marrocos, R. Montes, R. Rodil, J.B. Quintana, F.C. Moreira, V.J.P. Vilar (Portugal, Spain)

An innovative high-intensity mixer based on the NETmix technology was applied as an ozone (O_3) gas injection system to promote the removal of contaminants of emerging concern (CECs) present in secondary-treated urban wastewater (UWW). The NETmix is a micro/meso-structured static mixer consisting of a network of unit cells comprising mixing cylindrical chambers interconnected by prismatic channels. Its exclusive geometry generates successive contacting and splitting of flows, boosting mass transfer rates and rapidly developing an O_3 -enriched liquid stream. Different CECs groups (e.g., pharmaceuticals, pesticides, food additives and industrial chemicals) were detected in the UWW matrix. Ozonation process was carried out in continuous mode with a system residence time of 55 s and the effect of specific O_3 dose was investigated. Removals $\geq 80\%$ were attained for 22 out of 25 target CECs applying an O_3 dose of 0.6 g O_3

g_{DOC}⁻¹.

4.04. Ozone-based treatment of nanofiltration retentate from municipal secondary effluent applying a stainless-steel membrane contactor

M. Lima, C. Santos, M.P. Castro, R. Montes, J.B. Quintana, R. Rodil, A. Gomes, M. Rodrigo, M. Dezotti, V. Vilar (Brazil, Portugal, Spain)

This research explores the effectiveness of ozone (O_3) alone and combined with hydrogen peroxide (O_3/H_2O_2) and peroxydisulfate (O_3/PDS), using a stainless-steel membrane contactor to treat nanofiltration retentate (NF_R) from municipal secondary effluent. Treatment performance was assessed considering 13 contaminants of emerging concern (CEC) quantified in the NF_R matrix. For O_3 -only tests, increasing the O_3 dose improved performance, though O_3 transfer efficiency decreased when the highest O_3 dose was applied. The O_3/H_2O_2 process effectively removed CECs, utilizing O_3 more efficiently (less O_3 off-gas and dissolved O_3) than observed for O_3 -only. No performance improvements were verified for O_3/PDS tests compared to O_3 -only. The flame-retardant melamine was the only CEC resistant to oxidation under all tested conditions.

4.05. PFOA and PFOS removal in drinking water through GAC adsorption, ozonation and carbocatalytic ozonation

J. Cotelí-Sancho, F. Bernat-Quesada, Y. Picó-García, M. Añó-Soto (Spain)

Per- and polyfluoroalkyl substances (PFAS), particularly perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), are persistent contaminants in potable water that pose significant health risks. This study evaluates the effectiveness of granular activated carbon (GAC) adsorption, ozonation, and an innovative ozonation-carbocatalysis hybrid technique, where carbon acts as an ozone catalyst, for the removal of these pollutants. By comparing these methods, we aim to determine the most efficient and sustainable approach for PFOA and PFOS elimination, contributing to improved water treatment practices and public health protection.

4.06. Fluorine organic compounds removal by catalytic ozonation and hydrogenation processes

C.A. Orge, C. Lopes, M.F.R. Pereira, O.S.G.P. Soares (Portugal)

Halogenated compounds have been detected in various water environments, including surface water and groundwater, ranging from ng/L to $\mu\text{g/L}$ levels. Harmful effects on humans require the development of efficient treatments for their complete degradation. Advanced oxidation processes (AOPs), such as catalytic ozonation (CatOZO), and catalytic hydrodehalogenation (CatHDDH), are promising technologies to remove this kind of pollutants. In this study, the degradation of perfluoroheptanoic acid (PFHpA) was evaluated by CatOZO and CatHDDH in the presence of different catalysts. Activated carbon-based materials presented interesting results in both processes and a prepared metal-organic framework, ZIF-67, also achieved a fast pollutant decay when combined with H_2 .

4.07. Antibiotics removal from aquaculture effluents by ozonation: chemical and toxicity descriptors

A.M. Gorito, P. Rodrigues, L. Guimarães, C.M.R. Almeida, M.F.R. Pereira, A.R.L. Ribeiro, A.M.T. Silva (Portugal)

Antibiotics (ABs) are commonly used in aquaculture to prevent fish diseases, but many end up released in effluents, posing risks to environment and human health. Ozonation has been applied to improve water quality in aquaculture; however, information on AB's removal is scarce. This study explored ozone (O_3) to remove five fishery ABs (florfenicol (FF), oxytetracycline (OTC), sulfadimethoxine (SDM), sulfamethoxazole (SMX), and trimethoprim (TMP)) from aquaculture effluents, evaluating their potential toxicity on zebra-fish (*Danio rerio*). Both batch and continuous O_3 experiments were conducted to assess AB's degradation kinetics, the role of hydroxyl radicals (HO^\bullet) and the water matrix in their degradation, and respective AB's removal mimicking real scenarios. The results were promising, showing excellent removals for most ABs (> 96%), except for FF (68%), which was mainly removed by HO^\bullet and was highly influenced by the water matrix. The treated effluents were not toxic to zebrafish embryos. Full-scale studies are now needed before application in aquaculture farms.

4.08. CO₂-Activated Grape Seed Biocarbon: A Promising Adsorbent for Removal of Antibiotics from Water Bodies

N. Miguel, S. Moles, P. Barlés, R. Mosteo, M.P. Ormad (Spain)

This research work highlights the growing concern over emerging contaminants in water bodies, such as antibiotics and caffeine, and points out the limitations of conventional treatment methods. It underscores the potential of CO₂-activated grape seed biocarbon as a promising adsorbent for removing these contaminants, demonstrating efficacy comparable to of commercial activated carbon in adsorbing common antibiotics. This approach also offers additional benefits by potentially mitigating greenhouse gas emissions.

4.09. Removal of antibiotic from model wastewater and sewage sludge to increase biogas production potential

A. Žgajnar Gotvajn, J. Derco, M. Cehovin (Slovenia, Slovak Republic)

Contamination of the environment by antibiotics has potentially adverse consequence raising severe concerns. Pharmaceuticals were detected and identified in surface, ground, and drinking waters as well as in soils world-wide. Wastewater treatment plant (WWTP) effluents are recognized as the main source of pharmaceuticals because a global increase in the use of pharmaceuticals is driven by development, population aging and efforts to improve health and fitness of population. The use of pharmaceuticals in animal and meet production, aquaculture, disposal of expired medicines, and hospital activities can cause severe environmental pollution, detected mainly lately when enabled by sophisticated analytical techniques. As a result, bacterial resistancy to antibiotics due to adaptation and adjustment to the presence of antibiotics can occur. Therefore, such a pollutant needs to be removed before disposal of wastewater into the environment.

The aim of the study was the assessment of inhibition of Amoxicillin (AMX) in different concentrations to biogas production of amoxicillin-contaminated waste sludge and to evaluate ozonation as a promising method for removal of AMX from wastewater prior to biological treatment and its possible adsorption onto the biological sludge. AMX with molecular formula $C_{16}H_{19}N_3O_5S$, quite good solubility in water ($3430 \text{ mg}\cdot\text{L}^{-1}$ at 25°C) is one of the most successful semi-synthetic Penicillin-based antibiotic which is used for different applications.

Session 5. Micropollutants

5.01. Elimination of pharmaceutical compounds by catalytic ozonation using commercial Y-zeolites in real municipal wastewater treatment plants effluents

M.A. Prada-Vásquez, C. Simarro-Gimeno, S.A. Cardona-Gallo, E. Pitarch, F. Hernández, R.A. Torres-Palma, A. Chica, J. Navarro-Laboulais (Colombia, Spain)

Twenty-five pharmaceutical compounds (PhCs) detected in effluents from two municipal wastewater treatment plants both located in the Mediterranean coast of Spain have been removed using Faujasite-type Y-zeolite in a catalytic-ozonation process. Direct ozonation and zeolite adsorption experiments prove the synergic effect of Y-zeolite on ozonation. Two zeolites with different Si:Al ratio, 12 and 60, have been used in this study. The results showed that the simultaneous use of ozone and NaY zeolites significantly improved the micropollutants degradation rate, able to degrade 95% of the total mixture of PhCs within the early 9 min using the zeolite NaY-12 (24.4 mg O₃ L⁻¹ consumed), while 12 min of reaction with the zeolite NaY-60 (31 mg O₃ L⁻¹ consumed). Results showed that the Brønsted acid sites seemed to play an important role in the effectiveness of the treatment with ozone.

5.02. Online monitoring of Contaminants of Emerging Concern (CEC) during Advanced Oxidation Processes (AOPs) by using a fluorescence sensor

P. Roccaro, L. Marino, E. Gagliano, D. Santoro (Italy, Canada)

In this study, a microbial/tryptophan-like fluorescence sensor was employed to investigate the possibility of real-time monitoring of CEC at naturally occurring concentrations during UV and ozone-based AOPs at pilot scale. The investigated AOPs include O₃, O₃/H₂O₂ and UV/H₂O₂, with a flowrates ranged from 0.3 to 6 m³/h. The fluorescence sensor was installed downstream of the system, being able to detect the fluorescence of both AOP influent and treated water, respectively before and after the dosing of reagents. The online sensor showed excellent sensitivity to detect in real-time the fast degradation of microbial/tryptophan fluorescence caused by the release of •OH during the AOPs. The removal of CEC was correlated with real-time fluorescence removal obtained with the online sensor. In general, high correlations were found between real-time fluorescence and CEC removals, developing linear models for UV/H₂O₂ process, linear and non-linear models for O₃-based AOPs. Online fluorescence is an excellent tool to monitor CEC in different water matrices.

5.03. Advancements in Combatting Antibiotic-Resistant Bacteria in Hospital Wastewater using electro-ozonizers

S.E. Correia, V. Pertegal, E. Lacasa, P. Cañizares, M.A. Rodrigo, C. Sáez (Spain)

In this research, the electrochemical generation of an ozone gas stream is evaluated using two Polymer Electrolyte Membrane (PEM) type-cell to mitigate the spread of antibiotic resistance in hospital wastewater. Firstly, the influence of the current density in the ozone gas concentrations. Gas phase ozone concentrations from 0.02 to 5.74 mg L⁻¹ are generated. In addition, the inactivation of *Klebsiella pneumoniae* (*K. pneumoniae*) by the ozone gas stream is evaluated. The results indicate that full disinfection is achieved for ozone concentrations above 0.5 mg L⁻¹ for contact times of 180 min. Furthermore, the removal of four Antibiotic Resistance Genes (ARGs) was investigated. Log removal values of 2.89, 3.04, 3.17, and 5.43 were obtained for bla_{KPC}, bla_{SHV}, bla_{TEM} and, aac(6')-Ib, respectively. According to the results, the proposed technology is capable of mitigating the spread of antibiotic resistance in both hospital wastewater.

5.04. Remediation of Contaminated Soils by Electrochemically Generated Gaseous Ozone

G. Bou-Habib, A. Moratalla, E. Lacasa, M.A. Rodrigo, C. Sáez (Spain)

In this work, the removal of pesticides in contaminated soils was evaluated by gaseous ozone electrochemically generated in an electro-ozonizer (Proton Exchange Membrane (PEM) cell). Firstly, the influence of the current density on the generation of ozone gas in the electrochemical step was studied. The results indicated that ozone gas with rates ranging from 0.031-0.231 mg O₃ min⁻¹ can be produced by applying current densities of 42-125 mA cm⁻². Finally, the effectiveness of electrogenerated gaseous ozone for the remediation of soils polluted with trichlorobenzene (TCB) and hexachlorocyclohexane (HCH) was evaluated. The study showed that it is possible to remove target compounds from soils by applying ozone gas. However, the degradation rate depends on the ozone dose rate, the height of the soil column and the type of pesticide. The results indicate that the use of ozone gas produced by electro-ozonizers could be a viable alternative method for the remediation of pesticide contaminated soils.

5.05. Advanced full-scale Ozone Applications for Micropollutant Abatement in Municipal Wastewater

T. van den Eijnde, T. Spit, E. Broeders (The Netherlands)

The collaborative efforts between Witteveen+Bos and Nijhuis Saur Industries (CLC Water) have led to the successful design and commissioning of multiple full-scale ozone installations for micropollutant abatement of municipal wastewater in The Netherlands. Through these projects, we have gained a wealth of knowledge related to the design and operation of ozone injection systems, optimization of ozone dosage to achieve target treatment efficiencies, and effective strategies for minimizing bromate formation. Furthermore, we have gained knowledge in applying ozone in a broader configuration, e.g. in combination with activated carbon treatment systems. Resulting in a comprehensive post-treatment solution for a wider range of pollutants in wastewater treatment effluent.

Session 6. Special applications

6.01. Demonstrating efficacy of ozone disinfection

B. Meyrick (United Kingdom)

This work presents findings from a UK-based collaborative initiative between Cardiff Metropolitan University and Ozone Industries Ltd., aimed at evaluating the effectiveness of ozone disinfection technology in mitigating bioaerosols and biofilms. With evolving EU regulations on chemical biocides, there's a pressing need to demonstrate efficacious data for ozone-based technology. This study is focused within the Welsh food sector, where microbial contaminants pose significant risks to product quality and consumer health.

6.02. WhanHua – Combination of ozone and biofiltration for the removal of hard COD

L. De Franceschi, J. Yang, Y. Chen, A. Murillo, C. Bopp, L. Dinkloh (Switzerland, China, Germany)

In Yantai, a coastal city in the northeast of China, more than 100 effluents from Wanhua Chemical Industrial Park are collected and treated by Reverse Osmosis (RO) so that the permeate from RO can be recycled for industrial use. In 2020, Ozonia was involved in the project to study and furnish a treatment line to remove COD, TOC, and TN from the RO concentrate. The present paper demonstrates how ozone and collaborative technologies, bio-based, spelled the end of discharging the RO concentrate directly into the sea without any additional treatment. Besides, a REX (Return on Experience) study has been conducted, where design parameters in terms of effluent conditions and treatment performances are compared with the actual parameters after three years of continuous operation. Both positive and negative lessons are learned and presented in the paper to improve the process in the future. Here, the benefits of continuous improvement come into their own in the context of the Return of Experience. The reality of operations is confronted with the expectations of design.

6.03. Comparison of ozonation combined with UV/H₂O₂ processes for textile wastewatertreatment and reuse

A. Ouissal, C.A. Orge, O.S.G.P. Soares, A. Cunha, M. Catarino, F. Sampaio, A.L. Gonçalves, M.F.R.Pereira (Portugal)

The use of ozone technologies to treat pollutants in water has been the focus of attention in the literature during the last few years. Examples of their application as eco-effective alternatives have been presented for several types of contaminants in water. In the last decades, H₂O₂ has been widely used as an oxidant to remove recalcitrant pollutants from different industrial wastewaters. The combination of O₃/H₂O₂ or O₃/UV systems provides better removal of organic contaminants because they accelerate the decomposition of ozone to form hydroxyl radicals. The primary objective of this work is to identify the most efficient and cost-effective treatment suitable for industrial applications, specifically within the textile industry, where reducing the environmental impact of dyeing processes is crucial. Results indicate that the 25 O₃ treatment (25 g/m³ in the inical concentration of ozone) achieves the highest performance when applied as a tertiary process to an activated sludge industrial effluent, demonstrating significant color and TOC reduction improvements. This method outperforms others due to its superior balance of high efficiency and lower operational costs. Consequently, the 25 O₃ treatment is recommended for industrial application, particularly in the textile sector, to enhance wastewater treatment processes and support the environmental sustainability of this industrial sector. According to the experiments for reutilization of this effluent in textile dyeing processes, it was demonstrated that the effluent treated in these conditions (in concentrations up to 75%) can be reused in these processes, enabling similar colors as those obtained when using tap water in the process.

6.04. Electrocoagulation based processes for the landfill leachate treatment

J. Duarte, R.C. Martins, Paulo R.F. Rocha, D. Correia, E. Domingues (Portugal)

Landfill leachate is a growing concern since it can contaminate water resources and soils due to its complex composition (metals and biorefractory organic contaminants). Since conventional processes are inefficient in totally treating landfill leachate, electrocoagulation, electro-Fenton, and electro-persulfate emerge as possible solutions. For the electrocoagulation optimized conditions (raw leachate pH, 0.5 A, inter-electrode distance of 1 cm, iron electrodes with a surface area of 15 cm²), the removal rates for Zn, Fe, Cu, TOC, and color were 90.4, 85.7, 97.9, 33.5, and 58.2%, respectively. Electro-Fenton process at pH 3, a current of 0.5 A and 20 mM of H₂O₂, resulted in removal rates of 50.8% for Zn, 98.7% for Fe, 66.5% for Cu, 10.9% for COD, and 91.2% for color. The electro-persulfate process with a persulfate load of 1.2 g/L and at 0.5A achieved the removal rates for Zn, Fe, Cu, COD, and color of 94.2, 22.4, 44.3, 26.9%, and 38.1%, respectively.

6.05. Optimizing Full-Scale Leachate Treatment Towards Safe Environmental Discharge

S.G.S. Santos, D.F.S. Morais, A.I.R. Costa, R.J.E. Martins, R.A.R. Boaventura, V.J.P. Vilar, T.F.C.V. Silva (Portugal)

This work aimed to improve the overall efficiency of a full-scale leachate treatment plant (LTP), comprising biological oxidation (BO) followed by dissolved air flotation (DAF), to comply with requirements for discharge into municipal sewers as regards total nitrogen (TN < 0.3 g/L), chemical oxygen demand (COD < 1 g O₂/L) and color (eye-transparent at a 1:20 dilution). To achieve these goals: (i) an external carbon source was added to the BO unit to promote denitrification; and (ii) the coagulant dose was increased, and the flocculant was replaced in the DAF unit. In addition, to meet the stricter COD requirement for final discharge into water bodies (COD < 0.15 g O₂/L), ozonation trials (1.4–16.5 mg O₃/min; 0-180 min) complemented by BO (through Zhan-Wellens test) at the lab-scale were also conducted with coagulated leachate (from the DAF unit). For an O₃ dosage of 0.76 kg O₃/m³, the ozonation process enhanced leachate's biodegradability by up to 47%, enabling the BO to reach a COD value compliant with discharge regulations for water bodies.

6.06. Evaluation of ozonation performance in removing phenolic compounds to enhance anaerobic digestion of olive mill wastewater

T. Vaz, S. Domingues, M.J. Quina, R.C. Martins, J. Gomes (Portugal)

The increasing consumption of water, the contamination of water courses by the anthropogenic activities and climate change have sparked the search for viable technologies that can provide water of quality from contaminated sources. The olive oil industry is a large water consumer and produces enormous amounts of wastewater, the olive mill wastewater (OMW). These wastewaters are characterized by high levels of phenolic compounds which, due to their toxicity, can inhibit the biological treatment of OMW. In times of great pressure on water resources and energy demand, the goal of this work is to evaluate the ozonation process as a pre-treatment of OMW before anaerobic digestion (AD) as a way to break the aromatic bonds of phenolic compounds and thus maximize the production of biogas by AD.

6.07. Innovative Waste Activated Sludge Pre-treatment Using a Raceway Pond Reactor: Integration of Low-Temperature and Solar Radiation

J.P. Monteiro, C. Cruzeiro, M. Salomé Duarte, M. Alcina Pereira, V.J.P. Vilar (Portugal)

A novel approach for the pre-treatment of waste activated sludge (WAS) before anaerobic digestion (AD) was implemented combining thermal and solar radiation using a raceway pond reactor (RPR). WAS pre-treatment was applied for five hours at 50, 60, and 70°C with a solar UV output of 0.84 W. Overall, the solubility of organic materials increased with higher temperatures and longer reaction durations. The use of solar radiation significantly contributed to the disintegration of WAS. This transformative process results in a shift from tightly bound to loosely bound and soluble extracellular polymeric substances (EPS) fractions, consequently leading to an improvement in methane production. The increased availability of biodegradable organic matter is key to the enhanced efficiency of AD.

6.08. Advanced pre-treatment for enhanced anaerobic digestion of waste activated sludge: low thermal combined with solar radiation

J.P. Monteiro, C. Cruzeiro, M. Salomé Duarte, M. Alcina Pereira, V.J.P. Vilar (Portugal)

Anaerobic digestion (AD) is crucial for sewage sludge stabilization and biogas production. However, waste activated sludge (WAS) biodegradability may be constrained by a slow hydrolysis rate. Therefore, the present study aims to analyze the utilization of low-temperature conditions (set to 50, 60 and 70 °C) combined with solar radiation to overcome the rate-limiting hydrolysis phase. The temperature increase improved WAS solubilization (between 6 to 17%) and the highest methane yield of 207 ± 12 L CH₄ kg⁻¹ VS was achieved at 70 °C with radiation, resulting in 75% higher production compared to the control. Overall, the results indicate that incorporating radiation into the low-temperature pre-treatment enhances the solubilization rate of waste activated sludge (WAS), achieving a 4% increase compared to pre-treatment without radiation. Additionally, this method boosts methane production, yielding approximately 16% more methane than the non-radiation pre-treatment.

6.09. Valorization of lignin from the black liquor of pulp processing using electrochemical technologies

D.F.S. Morais, L.M.G. Sena, J.M. Ribeiro, T.S. Lopes, P. Dias, A. Mendes, C.A.E. Costa, A.E. Rodrigues, R.A.R. Boaventura, C.J. Tavares, V.J.P. Vilar, F.C. Moreira (Portugal)

This study aligns with the circular economy concept by focusing on unlocking lignin from black liquor, a waste stream from pulp processing, to produce value-added chemicals. The pulp industry is one of the largest global producers of lignin, but nearly all the lignin is being burned as low-value fuel. Here, initial steps were taken towards the development of a cutting-edge technology for lignin valorization based on the photoelectrocatalysis (PEC) process. The oxidation of Kraft lignin was conducted in a filter-press electrochemical cell under ambient pressure and room temperature, employing a photoanode composed of a niobium doped titanium dioxide (TiO₂:Nb) photocatalyst. The obtained results indicate that the produced photoanode is capable of oxidizing lignin. The PEC process at a cell potential of 0.8 V provided the best results, yielding 26 ± 1 mg kg⁻¹ of low-molecular-weight phenolic products (LMPPs) after 7 h of reaction and a consumed charge of 5 C g_{Lignin}⁻¹. Most of the generated organics consisted of syringyl-type units.

6.10. Recent advancements in the production of ozone by water electrolysis

A.R. De Olivera, F.C. Moreira, M.A. Rodrigo, V.J.P. Vilar (Portugal, Spain)

Ozone (O₃) is a popular and eco-friendly oxidant that can be produced electrochemically via water electrolysis, either in gas phase or dissolved in solution. The current study reviews the latest developments in the production of O₃ via water electrolysis, focusing on electrode materials and electrochemical flow reactors employed to improve process efficiency. Water electrolysis is a green and economic alternative technology compared to conventional technologies, such as the corona electrical discharge. This process is more effective at low temperatures ($T < 20$ °C), low cell voltages, and acidic pH medium (pH < 6). Recent advancements have shown that diamond-coating electrodes are the most efficient anode materials developed to date. However, these materials are costly. The electro-ozonizers based on the membrane electrode assembly (MEA) configuration have shown increased effectiveness in producing O₃, but at high energetic expenses. Further optimization of both electrode materials and electrochemical devices is required.

6.11. In-situ electrochemical regeneration of antibiotic-loaded clay in a continuous reactor

R. Antonelli, A.R.S. Gois, M.R. Massignan, G.R.P. Malpass, A.C.S.C. Teixeira (Brazil, Portugal)

This study aimed to investigate the in-situ electrochemical regeneration of a clay-packed reactor in the removal/degradation of the antibiotic sulfamethoxazole (SMX) using two systems (NaCl/DSA and Na₂SO₄/BDD). The focus of this study was to understand the regeneration process and investigate the quality of the electrochemical solution generated. According to the results, clay regeneration was more efficient with the NaCl/DSA system, indicating that the contribution of active chlorine species plays an important role in SMX degradation. Furthermore, NaCl favoured greater desorption of the antibiotic from clay than Na₂SO₄. However, the electrochemical solution generated revealed high toxicity to *L. sativa* when NaCl was used in contrast to Na₂SO₄. On the other hand, the use of photolysis significantly reduced the toxicity of the electrochemical solution, promoting high regeneration efficiency.

6.12. Gaseous Ozone used for the Reduction of *Listeria monocytogenes*: Efficacy for Surface and Aerosol Disinfection

J. Macleod, J. Blaxland (UK)

Listeria monocytogenes is a foodborne pathogen associated with listeriosis, a disease principally affecting younger, older, immunocompromised and pregnant individuals. In 2022, England and Wales reported 167 cases with a case fatality rate of 23.1% in non-pregnancy related cases. *L. monocytogenes* is found ubiquitously in the environment and, as a result, harbours stress tolerances to stressors such as low and high temperatures, osmotic stress, oxidative stress and antimicrobials. These stress adaptations enable *L. monocytogenes* to infiltrate and persist in the food manufacturing environment (FME). Presently, chemical biocides are the principal disinfection method used alongside processing to remove spoilage organisms and pathogens from food contact surfaces and product. Resistance to these biocides has been observed, therefore non-chemical disinfection methods have been the continued target of research.

Session 7. Advanced Oxidation Processes

7.01. Evaluation of different synthesis routes to obtain magnetic TiO₂ and Carbon Quantum Dots composites for antibiotics' photocatalysis

V. Silva, G. Pereira, N.J.O. Silva, M. Otero, V. Calisto, D.L.D. Lima (Portugal, Spain)

The presence of antibiotics in the aquatic environment is well documented and linked with the rise of antimicrobial resistance. Conventional wastewater treatment plants cannot efficiently remove these contaminants and new solutions, such as solar-driven photocatalysis, need to be investigated. This study aimed at the synthesis of easily recoverable and reusable photocatalysts. For such a purpose, different routes were tested, and the resulting composites were evaluated to remove amoxicillin, sulfamethoxazole, and trimethoprim from water. The composites were synthesized by: (i) hydrothermal treatment, (ii) sonication & calcination, (iii) oxidative hydrolysis, (iv) co-precipitation, and (v) functionalization & coupling via the carbodiimide chemistry. The photocatalytic removal of the selected antibiotics using a solar radiation simulator was determined. Among the several routes, the co-precipitation provided consistent photocatalysts with high efficiency in antibiotic's removal, with the selected photocatalyst achieving removal % from 42.8 % to 95.7 %.

7.02. Reduction of bromate formation during wastewater ozonation

K.F. Guerrero-Granados, D. Schomers, J. Mante, M. Kolkmann, A. Boegers, S. Panglisch, J. Tuerk (Germany)

Micropollutants' effects on aquatic ecosystems and wastewater treatment plants as point sources are well-documented. Full-scale ozonation at WWTPs has shown high removal efficiencies. Depending on the catchment and bromide levels, concerns are growing about the formation of the carcinogenic transformation product bromate. At pilot and full-scale, an innovative Ozone Strong Water (OSW) system was investigated. Employing laboratory and pilot-scale experiments, chemical mitigation techniques against bromate formation combined with single and serial ozone dosages were tested. The effectiveness of monochloramine (NH₂Cl), ammonia (NH₃), and hydrogen peroxide (H₂O₂) in reducing bromate formation varied, in that order, at the OSW pilot plant, with further reduction observed by combining with a serial ozone dosage. The investigated mitigating procedures are promising strategies for a safe application of ozonation processes in wastewater in the case of significant bromide preloads to meet bromate target values.

7.03. Use of O₃, O₃/UV & O₃/H₂O₂ in the treatment of water containing antibiotics

H. Zúñiga-Benítez, S. Trujillo-Alzate, M. Araque-González, G. A. Peñuela (Colombia)

Today, the presence of different organic compounds in bodies of water is a problem affecting the natural balance of ecosystems and public health. In particular, the presence of antibiotics in the environment has caused the spread of resistant bacteria (bacterial resistance), which makes it difficult to control infections and limits the work of health services. Azithromycin (AZT) and cephalexin (CPX) are two of the most used antibiotics worldwide. Thus, their presence in different environmental compartments has been widely reported. One of the reasons these types of substances are found in water is that wastewater treatment plants are not appropriately designed to remove antibiotic residues. In this sense, this research sought to evaluate the efficiency of some ozone-based technologies (O₃, O₃/UV & O₃/H₂O₂) in the removal of AZT and CPX present in aqueous solutions. The results indicated that the activation of O₃, either by UV radiation or the presence of peroxide, favours the elimination of the contaminants. In addition, the generation of hydroxyl radicals (HO•) is promoted, increasing the system oxidation capacity.

7.04. The photocatalytic decolorization of arylazo pyridone dyes

M. Stojković, A. Mašulović, V. Dokić, V. Pavićević, J. Lađarević, D. Mijin (Serbia)

Wastewater treatment from the textile industry is challenging due to the presence of complex organic compounds such as dyes, where conventional purification methods are insufficient. Advanced oxidation processes, including heterogeneous photocatalysis, represent a good alternative for their removal from wastewater. Within this work, the possibility of using the TiO₂-photocatalytic process for the decolorization of an arylazo pyridone dye was investigated. To optimize this process, the influence of catalytic concentration and pH value were further examined. The optimal catalyst concentration of 2 g L⁻¹ was identified. Furthermore, the influence of pH values (pH=2, 3, 4, 7, 9, and 11) was examined. The decolorization efficiency was estimated to be over 99% during a time reaction of 35 minutes for an initial concentration of dye at 10 mg L⁻¹.

7.05. Insights into the valorization of sewage sludge for enhanced water treatment

J. Nieto-Sandoval, R. Cavalcante, Z. Sun, J. Liu, P. Llopert, B. Bayarri, C. Sans (Spain, Brazil)

Advanced oxidation processes (AOPs) have shown promising results for the removal of emerging contaminants in water sources, including endocrine disruptors, pesticides, and pharmaceuticals, that poses significant environmental and health risks. Thus, the development of stable, active, economical, and environmentally friendly catalysts results crucial. This research explores the use of sewage sludge to synthesize hydrochar catalysts incorporating transition metals. Their efficiency has been evaluated for both Catalytic Wet Peroxide Oxidation (CWPO) and ozonation systems, achieving the complete removal of the primidone drug and bisphenol S endocrine disruptor in short times, demonstrating a sustainable and eco-friendly approach to water treatment.

7.06. Degradation and mineralization of lamotrigine in solution alone and in drug mixtures by catalytic ozonation

D. Montenegro, C.A.L. Graça, F. Machuca, O.S.G.P. Soares (Colombia, Portugal)

Lamotrigine (LTG) is an antiepileptic drug approved by the Food and Drug Administration (FDA) in 1994, and has been widely prescribed alongside carbamazepine (Ferrer et al., 2010). Only a fraction of these drugs are metabolized by the human body, being the remaining fraction excreted, ending up in the sewage system and contaminating water bodies. This fact makes it one of the most widely detected antiepileptic drugs in rivers and lakes around the world, along with other antiepileptics such as carbamazepine, gabapentin and primidone (Cardoso-Vera, 2021). This fact makes urgent the development and implementation of tertiary water treatment capable of removing this kind of pollutants. Catalytic ozonation appears as an excellent technology, in which the catalyst plays an important role because it can enhance the production and use of hydroxyl radicals. In this study, modified activated carbon was used as a catalyst to evaluate the degradation and mineralization of lamotrigine (LTG) and compare it with the degradation and mineralization of lamotrigine in a mixture with carbamazepine (CBZ) and ibuprofen (IBF). The catalytic ozonation reaction performed with modified activated carbon was revealed to be quite effective in the removal and mineralization of LTG, even when other pollutants are present in the mixture. The degradation time of LTG was slightly affected by the presence of other contaminants, as the degradation rate was 1.5 times slower, but an increase in TOC removal was observed in the solution mixture. During catalytic ozonation experiments, the following by-products were identified: oxalic acid (OXL), oxamic acid (OXM) and benzoquinone (BZQ).

7.07. Assessment of heterogeneous photocatalysis as disinfection step for reuse water: control of bacteria and protozoa

N. Larumbe, M.C. Hidalgo, N. Miguel, R. Torres-Palma, R. Mosteo (Spain, Colombia)

The presence of pathogenic microorganisms in waters is an issue of special concern due to the potential risk of waterborne diseases. Over the last years, advanced oxidation processes (AOPs) have gained importance in the treatment of water effluents. In this research work, different iron materials: BiFeO_3 , Fe_3O_4 and Fe_2O_3 based compounds, were synthesised for their study in heterogeneous photocatalysis for inactivation of bacteria and protozoa in water. All the systems were extensively characterised. The evaluation of the disinfection capacity on protozoa and gram-positive and negative bacteria of the photo-assisted advanced technologies based on iron materials was performed in saline solution and real urban treated wastewaters using *E. coli* and *E. faecalis* as indicators of the efficiency of the process, which shows a realistic approach and promising results for its application in water disinfection.

7.08. Toxicity Assessment of Nanosized Photocatalysts

A.V. Scalco, E.B. Figueiredo, P.G.M. Couto, C. Kreutz, A.M.C Ferrari, M.L. Gimenes, N.R.C. Fernandes (Brazil)

Heterogeneous photocatalysts are considered “green” and non-toxic materials for environmental remediation. Although nanosized photocatalysts can promote optimistic pollutants degradation rates, the assessment of its toxicity is highly recommended. In this work, NaY zeolite-supported Niobium oxides were synthesized by deposition, precipitation, and thermal hydration methods. Ecotoxicity tests with *Artemia salina* and phytotoxicity tests with *Lactuca sativa* were performed to evaluate the toxicity of the nanomaterials. Nb_2O_5 prepared by thermal hydration method was the lowest phytotoxic catalyst, but the most ecotoxic, with LC_{50} equal to 85 mg L^{-1} . The presence of NaY reduced the toxicity of the oxides. The 10% $\text{Nb}_2\text{O}_5/\text{NaY}$ material showed reduced toxicity and did not present an inhibition effect on the development of *Lactuca sativa* seeds. These findings suggest that the nanoparticles can have significant interaction with biological structures, emphasizing the importance of careful handling of this material, as is not completely absent of toxicity.

7.09. Development of eco-friendly catalytic membranes for ozone-driven water treatment

C.A.L. Graça, D.P. Ferreira, A.M. T. Silva, O.S.G.P. Soares (Portugal)

Heterogeneous catalysis is crucial to both the world's economy and the sustainable development of our society, being integral to 90% of chemical processes worldwide. Beyond industrial practice, heterogeneous catalysis is also a promising method for environmental remediation and disinfection, addressing key challenges such as pollution and water treatment. Catalysts are usually immobilized on an inert support, to facilitate their separation and recovery from the reaction medium. Nanostructured supports, such as nanofibers, are ideal for this purpose because they provide an extensive surface area for catalytic reactions while allowing fluid passage, thus functioning as both catalysts and membranes. The aim of this work is to create reactive membranes tailored for ozone-based water treatment, made entirely from environmentally compatible materials. This study focuses on the synthesis and performance evaluation of these innovative materials.

7.10. Graphitic Carbon Nitride Doping and Chemical Modification for PPCPs Mixture Degradation in Photocatalytic Ozonation

E. Fernandes, P. Mazierski, A. Zaleska-Medynska, R.C. Martins, J. Gomes (Portugal, Poland)

The development of feasible technologies for water reclamation is one of the major goals of the current generation. The increasing release of contaminants of emerging concern (CECs) into freshwater sources added to the inefficiency of current water treatment facilities presents a great danger to human and environmental health. The application of graphitic carbon nitride in photocatalytic water treatment appears a promising technology for the efficient elimination of a variety of pollutants. Herein, the highly adaptable $\text{g-C}_3\text{N}_4$ photocatalyst and its combined use in the photocatalytic ozonation degradation of a mixture of CECs will be studied. The use of cerium as a dopant and citric acid in the catalyst chemical modification was studied. The combination of both catalyst modifications (CeACCN) resulted in a great enhancement of the catalyst performance, achieving a faster complete removal of a mixture of six contaminants with significantly lower ozone consumption. The details of catalyst modifications, such as structure alterations, dopant optimum load, and other crucial parameters will also be further studied.

7.11. Multi-Barrier Approach for the Treatment of Secondary Urban Wastewater Targeting CECs Removal and Disinfection: Integration of Membrane Nanofiltration with UV-C/Persulfate Oxidation

C.S. Santos, S. Ribeirinho, R. Montes, R. Rodil, J.B. Quintana, O. Pastor, A.I. Gomes, V.J.P. Vilar (Portugal, Spain)

The combination of membrane filtration and advanced oxidation processes emerges as a remarkable strategy for improving the quality of municipal secondary effluent (MSE). This approach represents a promising solution for reusing MSE to address the challenges associated with water scarcity. This research seeks to explore a multi-barrier technology adapted to the treatment of MSE, to optimize the reduction of organic compounds. The study employs a pilot-scale tubular membrane photoreactor to promote UVC/peroxydisulfate (PDS) processes, improving the oxidation of micropollutants in MSE and concentrates generated from tertiary nanofiltration (NF) treatments. NF has shown remarkable effectiveness in producing high-quality permeate. The contaminant degradation results were promising, achieving over 80% degradation for 12 and 14 of the 19 organic compounds analyzed in MSE and in the NF concentrate, with 2.4 and 3.6 mM of PDS, respectively. Microbiological analyses corroborated the efficacy of the proposed system.

7.12. Valorization of CO₂ into Methane via Solar Photo-Thermocatalytic Hydrogenation over Plasmonic Metal-Semiconductor Nanocomposites

R.D.G. Matias, R.P. Rocha, O.S.G.P. Soares, R.A.R. Boaventura, A.F.P. Ferreira, V.J.P. Vilar, T.F.C.V. Silva (Portugal)

This research aimed to develop a highly active and selective catalyst for CO₂ photo-thermal methanation under simulated sunlight at moderate temperatures, utilizing a plasmonic metal impregnated into the wide band gap TiO₂ semiconductor. The nanocomposite's performance was investigated in a batch-mode photoreactor, considering several factors, such as plasmonic metal type, TiO₂ form, catalyst preparation method and composition, and reaction temperature. Through comprehensive characterization techniques, the catalyst properties were analyzed. A highly efficient and 100% methane-selective photo-thermal catalyst was successfully synthesized by impregnating ruthenium (Ru) into PC500 TiO₂ using the solvothermal method. The 7.5 wt.% Ru/TiO₂ nanocomposite led to a 73% CO₂ conversion within 15 min at a moderate temperature of 160 °C, along with a maximum methane (CH₄) yield rate of 23.4 mmol·g⁻¹·h⁻¹. These results underscore the significant potential of the developed catalyst for CO₂ utilization and sustainable energy production.

Session 8. Advanced wastewater treatment

8.01. Applications of Ozone and Advanced Oxidation in Indirect and Direct Potable Reuse Treatment

A. Ried (Germany)

In the past years Water Scarcity limits the availability of water sources to fulfill the needs for regional water management of municipalities and cities. Water stress and competition on Use is leading to a Gap between demand and availability of water. This situation requires a new water source management. Existing available water sources building on the natural water cycles can often no longer support the increasing regional needs of water supply for e.g. urban irrigation, agricultural use, industrial use and drinking water use.

8.02. Ozone in Operation – Long-term Benefits of Combining Ozone and Activated Carbon for Micropollutant removal

A. Murillo, C. Bopp, L. Dinkloh, L. De Franceschi (Switzerland, Germany)

Many full-scale treatment plants for the removal of micropollutants rely on ozone or the use of activated carbon. The WWTP Altenrhein is operating a combination of ozone followed by granular activated carbon (GAC) that reliably reaches the 80% removal required by the Swiss regulation. Compared to plants that operate only one of the technologies, the applied ozone dosage of 0.1 to 0.2 g O₃/g DOC is significantly lower and the lifetime of the GAC is significantly increased at Altenrhein. In this presentation, we will compare data from Altenrhein with similar combination plants and draw conclusions on the long-term technical and economic benefits and drawbacks. These insights will be valuable to support optimal technology selection for the implementation of the upcoming EU regulation on micropollutant removal.

8.03. Enhancing Ceramic Microfiltration Flux and Water Quality through Ozonation in Surface Water Treatment and WWTP Effluent Reuse

M. Spruijt, J. Zheng, H. Shorney-Darby (The Netherlands)

To produce drinking water from surface water and to treat wastewater for reuse, it is necessary to remove suspended and biological colloidal matter. Ceramic microfiltration provides an absolute barrier against particles larger than its pore size. Integrating ozonation with ceramic microfiltration not only creates a robust barrier against pathogens but also significantly enhances flux rates. In this study, pilot-scale results from two case studies in Australia are presented, demonstrating the effectiveness of combining ozonation with ceramic microfiltration for surface water treatment for drinking water production and advanced treatment of WWTP effluent for reuse. In the first case study, reservoir water was treated for drinking water production, with primary treatment objectives focusing on reducing microbiological risks and controlling seasonal taste and odor. Maintaining the feed at a neutral pH and employing a moderate ozone dosage can keep bromate levels below the Australian Drinking Water Guidelines limit. The second pilot case study focused on treating WWTP secondary effluent for reuse, with ceramic microfiltration as a pre-treatment for reverse osmosis (RO). In summary, ozonation stands out as an effective approach in enhancing water quality and ensuring sustainable flux rates of ceramic membranes. These advancements are applicable not only in the treatment of surface water for drinking water production but also in reuse schemes.

8.04. Integration of membrane bioreactor with ozonation for the quaternary treatment of urban wastewaters

C.S. Santos, K. Rodrigues, P. H. Marrocos, A. Narcizo, R. Montes, R. Rodil, J. B. Quintana, A. I. Gomes, V.J.P. Vilar (Portugal, Spain)

The changing state of water resources is a global concern, and the reuse of urban wastewater (UWW) offers a promising solution to water scarcity. The combination of membrane bioreactor (MBR) and ozonation can be an effective multi-barrier strategy to achieve high-quality water for reuse. In this study, a sidestream injection system for ozone (O₃) using a novel micro/mesostructured pressurized static mixer (NETmix) for gas(O₃)-liquid(water) mixing was applied to post-MBR effluent, targeting disinfection and removal of contaminants of emerging concern (CECs), enabling its safe reuse for agricultural purposes. The MBR effluent has the highest quality (class A) of recycled water. Although the water's physical-chemical characteristics after ozonation showed negligible changes, the decrease in absorbance at 254 nm (UV₂₅₄) suggests potential CECs removal (data will be available soon).

8.05. Ozone advanced treatment for pathogen elimination and disinfection by-product management in potable water reuse

L.R. De C. Costa, L. Li, K.R. Pagilla, L.A. Féris (Brazil, USA)

Reclaimed water poses environmental and human health risks due to residual organic micropollutants and pathogens. Ozonation emerges as an important step in advanced water treatment. This study aims to explore ozonation conditions employing a plug flow reactor (PFR) to attain proficient pathogen inactivation while mitigating the formation of bromate and N-Nitrosodimethylamine (NDMA). The pilot-scale study employed three ozone doses using real reclaimed water (Reno, NV, USA). The treatments resulted in ozone CT values ranging from 1.60 to 13.62 mg.min/L, leading to substantial reductions in pathogens and indicators. Specifically, reductions of 2.46-2.89, 2.03-2.18, 0.46-1.63, 2.23-2.64, and >4 log were observed for total coliforms, *E. coli*, PMMoV, ToBRFV, and HNoV, respectively. However, bromate and NDMA concentrations increased post-ozonation, reaching levels between 2.8 -12.0 µg/L and 28 - 40.0 ng/L, respectively, suggesting the need for control in subsequent treatment steps, particularly with higher ozone dosages.

8.06. Assessment of TiO₂ ceramic membranes performance for winery wastewater treatment

V. Mendes, F. Pereira, B. Esteves, C.V. Miguel (Portugal)

The agricultural sector is directly affected by increasing droughts and limited access to water in many regions. Water scarcity and increased frequency of heat waves are serious threats to winemaking business, particularly in southern European countries like Portugal. This study evaluates the performance of TiO₂ membranes for winery wastewater treatment envisaging its reuse. Initially, the research involved membrane screening, where permeate analysis proved that ultrafiltration (UF) was adequate to comply with water quality requirements for reuse in irrigation in vineyards. Subsequently, a detailed study using UF membranes with different pore sizes was conducted, wherein the quality of the permeate flux and quality were considered to select the most suited membrane for this application. The membrane with a pore size of 10 nm successfully reduced chemical oxygen demand (COD) by 76 %, turbidity by 96 % and *E. coli* by 100%, enabling the treated water to be reused for irrigation according to Portuguese legislation (Decree-law no. 119/2019).

8.07. The operating temperature influence on the structure of the bacterial community and the abundance of antibiotic resistance genes in secondary treated wastewater

S. Ribeirinho-Soares, V. Braga, S. Cabral, V.J.P. Vilar, C.M. Manaia, O.C. Nunes (Portugal)

Concerns about growing water scarcity and the spread of infections brought on by antibiotic resistant bacteria are intensifying due to climate change. Therefore, during wastewater treatment, it is essential to comprehend how temperature changes affect the prevalence and abundance of antibiotic-resistant bacteria and their genetic determinants (ARB&ARGs). Two pilot conventional activated sludge treatment (CAS) installations were installed and run continuously for 147 days at a host UWWTP in northern Portugal in order to accomplish this goal. The test CAS was run at 10 °C (days 1–56), 5 °C (days 57–91), 15 °C (days 92–113), and 28 °C (days 114–147). CAS was kept at around 20 degrees Celsius. The Test CAS and Control CAS counterparts had all other operating parameters set to the same values. The fecal contamination markers, *int1* and *qnrS*, *bla_{IMP}* and *bla_{KPC}* antibiotic resistance genes were more effectively removed by test CAS running at 5°C, indicating that low-temperature operation may reduce the danger of ARB&ARGs propagating in the urban water cycle.

Session 9. Advanced wastewater treatment

9.01. Production of reclaimed water for reuse: a case study at Gaia Litoral WWTP

J. Vilaça, L. C. Lopes, I. Baptista, R. Jorge, L. Marinheiro, S. Löblich (Portugal)

Wastewater reuse is an innovative and sustainable approach that could help address the growing challenges of drought and water scarcity that have been intensifying in recent years in Portugal. This project aimed to investigate and compare the production of reclaimed water (ApR) using different treatment technologies in various combinations to produce ApR with different quality levels, suitable for the various applications specified in the Portuguese regulation Decree-Law N.º 119/2019. The trials were conducted at the Gaia Litoral wastewater treatment plant on both a pilot and industrial scale, applying technologies such as filtration, membrane separation, disinfection, and ozonation. ApR with different quality levels was produced for irrigation and urban uses. The application of membrane separation and ozonation technologies allowed to produce high-quality ApR suitable for irrigation. The nitrogen content and microbiological quality were the parameters that most influenced the classification and uses of the obtained ApR.

9.02. Innovative control strategies for advanced water treatment by ozonation

A. Ried, U. Hübner, A. Wieland (Germany)

Ozonation is a well-known effective water treatment process. Treatment goals for ozonation are the reduction of chemicals of emerging concern (CECs) and disinfection. For the oxidation process it is key to control the ozone dose to achieve the treatment goals and prevent generation of by-products. Since direct measurement of CEC elimination and disinfection is difficult, concepts for dose adjustment based on surrogate parameters e.g., Ozone:DOC ratios, decrease of UV absorbance or fluorescence, are investigated. The ozone dose can be optimized by involving on-line sensors measuring the surrogate parameters integrated in a control algorithm. The right selection of on-line sensors, their positioning in the process and integration in a control concept are essential. Selected case studies are demonstrating the value of different implemented controls. A new approach combining existing control algorithm with AI-models is investigated and reported.

9.03. Ozone in Operation – Insights from 10 years of micropollutant treatment at ARA Neugut

C. Bopp, N. Hubaux, A. Murillo, L. Dinkloh, L. De Franceschi (Switzerland, Germany)

In 2014, the first Swiss full-scale micropollutant treatment plant using ozone in a WWTP began operation at ARA Neugut, Switzerland. Since then, the plant reliably achieves at least 80% removal of micropollutants as required by the Swiss regulation. This pioneering project has given valuable insights into ozone dose control, handling of rain events, reactor maintenance, and prevention of bromate formation for the construction of similar plants in Switzerland and beyond. For this anniversary, we revisited ARA Neugut. Here, we update the latest operational figures and present insights on CAPEX and OPEX developments over the last 10 years. The use of treated offgas for aeration of the biological tanks is discussed under technical and economic aspects. As ARA Neugut continues to optimize their operations, more valuable lessons can be learned that will be crucial for the implementation of the upcoming EU regulation on micropollutant removal.

FURTHER CONTACT

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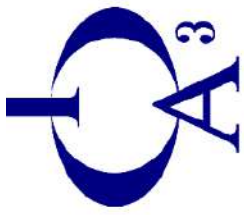
27TH IOA OZONE WORLD CONGRESS AND EXHIBITION

Dates: August 25-28, 2025

Location: Atlanta, GA (USA)

Venue: Omni Atlanta Hotel at Centennial Park





International Ozone Association

- Association created in 1973
- Mission
Answer the needs of the industry and research community in the fields of ozone and related oxygen oxidants
- Purpose
 - Education
 - Science
- Scope
 - Collection and dissemination of information
 - Promotion of research

Any and all aspects of ozone and related advanced oxidation technologies



Ozone and its applications

When effective oxidizing action is required

On

- Natural substances
- Manufactured products

To achieve

- Disinfection
- Pollutants removal
ODS, acids, CO₂, H₂S, metals, micro-pollutants, such as endocrine disruptors
- Conversion
- Purification
- Therapy

- Mineral
- Inorganic
- Organic
- Biological

- Solid
- Liquid
- Gas

1785	First detected Van Marum
1840	Discovery Schönbein
1857	First generator Von Siemens
1897	1 st Doctorate Researches on ozone Otrio
1904	1 st drinking water plant
1973	IOA
1973	First IOA World Congress
1979	First Issue of Ozone: Science & Engineering

Numerous applications developed over more than a century

IOA Activities

- Publications
 - Ozone Science and Engineering Journal
 - Ozone News
- Events
 - World Congress
 - Regional events
- Research programs
- Quality assurance
 - Ozone Engineering Group
- Regulations
- ..



Focus Point

IOA profile

- Strength
 - 1 000 members
 - Diversity in background and disciplines
- Organisation in 3 regional groups

Worldwide representation

