PROCEEDINGS

of the
XVIII Postgraduate Summer School on Green Chemistry

6 July - 10 July 2026
Venice, Italy


Foto: Dorian Mongel / unsplash

Green Sciences For Sustainable Development Foundation

in collaboration with PhosAgro

COLLECTION OF ABSTRACTS

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International Postgraduate Summer School on Green Chemistry 2026

XVIII Edition

Organized by **Green Science for Sustainable Development Foundation** in collaboration with **PhosAgro**

6th-10th July 2026

Venice, Italy



Organizers:
Francesco Trotta Chairman
Fabio Aricò
Aurelia Visa
Mirabbos Hojamberdiev
Graziana Gigliuto
Aleksander Antonov

Topics:
Benign synthesis routes
Green catalysis
Alternative solvents
Renewable and green raw materials
Green chemistry for energy
Clean processes
Green Chemistry education
Sustainable Polymers

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The Editors would like to thank Graziana Gigliuto for her outstanding support in the creation of the Proceedings.

PROCEEDINGS of the

XVIII International Postgraduate Summer School on Green Chemistry,

6 July - 10 July 2026, Venice, Italy

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GREEN SCIENCES FOR SUSTAINABLE DEVELOPMENT FOUNDATION

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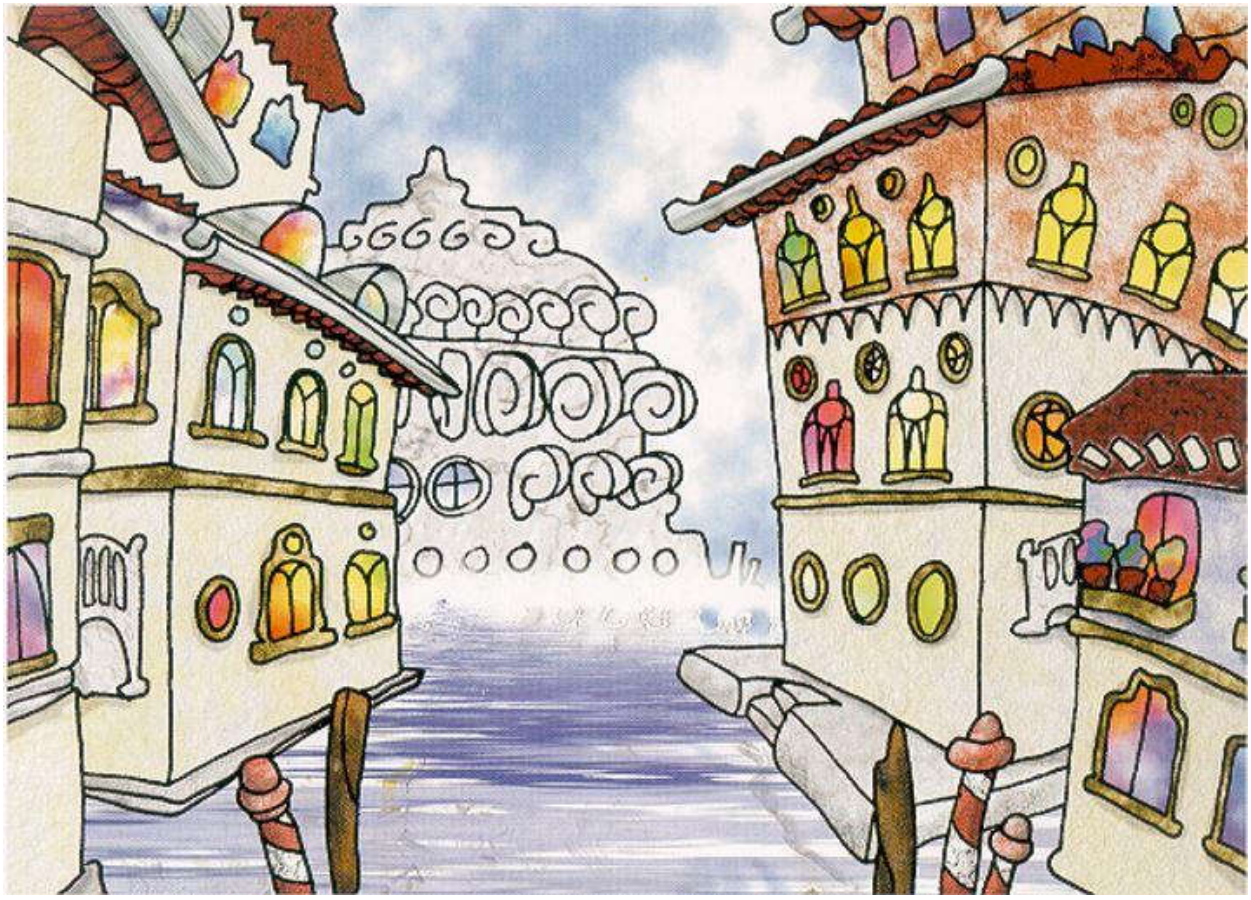
molecules

chemistry

polymers

GREEN SCIENCES FOR SUSTAINABLE DEVELOPMENT FOUNDATION

The Summer School was an international initiative organized and managed by the newly established ***Green Sciences for Sustainable Development (GSSD) Foundation*** *(www.gssd-foundation.org), a non-profit Foundation established in February 2020 and based in Venice, Italy.*



The Foundation was constituted, pursuant to Article 14 and in accordance with the Italian Civil Code, on February 17th, 2020.

The Foundation has legal personality, as it was registered with the Prefecture of Venice on May 28th, 2020, as a non-profit organization. Any proceeds, annuities, and profits deriving from the performance of the activities are used exclusively to pursue the purposes of the Foundation.

The Foundation is based in the Municipality of Venice. To pursue the statutory purposes, with the resolution of the Board of Directors, secondary offices, agencies, and branches may also be established abroad.

The Foundation facilitates the participation in its activity of public bodies and administrations and private subjects, developing and increasing the necessary network of national and international relations functional to achieve its goals.



PURPOSES:

The main aims of the Foundation are:

a) to encourage the development of scientific education and the dissemination of knowledge in the national and international fields of the sciences of chemical, physical and environmental order and of the disciplines that care and promote sustainability with particular regard to Sustainable and Green Chemistry and their applications;

b) to support and disseminate scientific, technological and cultural development in Sustainable Development in accordance with the 17 Goals of the United Nations, in the sectors of the use of renewable resources, energy saving, intrinsically clean processes and products, with low or no environmental impact, not harmful to health and green remedies for climate change;

c) to promote initiatives supporting the transfer of research results, the protection of intellectual property and the birth of new entrepreneurship;

d) to promote the involvement and collaboration of public or private, local, national, EU, foreign or international subjects in pursuing the aims of the Foundation itself;

e) to promote the internationalization of teaching and research activities through the management of specific services and participation in joint initiatives with other subjects, public or private, national, EU or international.



ACTIVITIES:

a) to organize and manage national and international Congresses and Conferences, education, specialization, and updating courses and other advanced training activities such as Summer Schools, Forums, and International Thematic Workshops, also in collaboration with other private and public institutions; the sub-Saharan African continent will be paid particular attention;

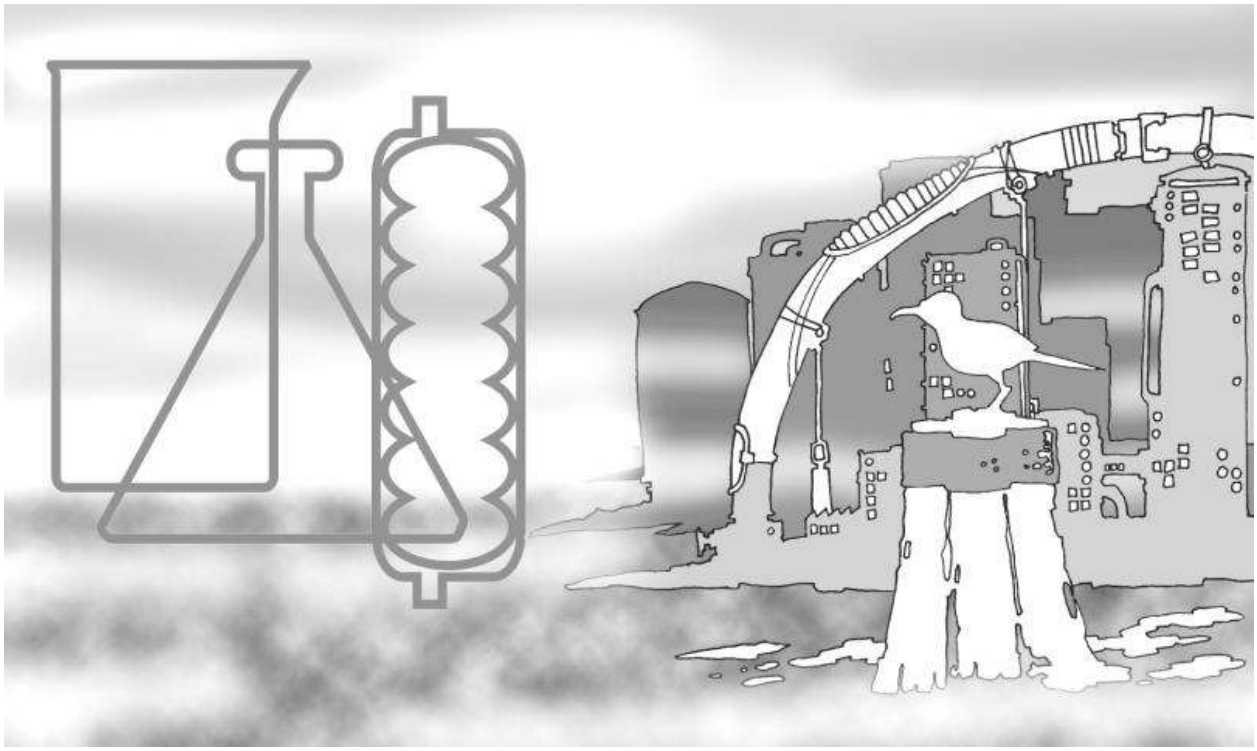
b) to publish books and magazines with their own ISBN;

c) to create and manage any laboratories or research centers also together with other public or private entities;

d) to participate in the operational management of scientific and/or technological structures of other foundations, structures, and research bodies;

e) to enter into agreements, contracts, agreements, or understandings with other subjects, public or private;

f) to promote and organize the collection of private and public funds and the request for local, national, European, and international public and private contributions to be used for the Foundation.



XVIII INTERNATIONAL POSTGRADUATE SUMMER SCHOOL ON GREEN CHEMISTRY

6 July - 10 July 2026

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WELCOME MESSAGE FROM THE CHAIR OF THE SUMMER SCHOOL



Dear Colleagues and Students,

I am Francesco Trotta, Full Professor of Industrial Chemistry at the University of Turin (IT) and President of the Green Sciences for Sustainable Development Foundation.

It is with great pleasure that I welcome you to the **18th edition of the Postgraduate Summer School on Green Chemistry (GCSS 2026).**

This year's edition marks a significant milestone, as it will be the first one not chaired by Professor Pietro Tundo, the founder of this esteemed Summer School, who sadly passed away last year. I had the honor of knowing Professor Tundo personally, as he was my PhD supervisor at the University of Turin, where I now lead my research group. His illustrious career as a professor and mentor left a lasting impact on many generations of students and scientists across the globe.

In recognition of his immense contributions, the board of the Green Science for Sustainable Development Foundation and I have decided to continue his legacy by organizing this highly regarded international Summer School. We aim to build on the success of previous editions by inviting distinguished educators, leaders from major chemical industries, and outstanding postgraduate students.

One of the key highlights this year was the generous support from our sponsors, which allowed us to offer scholarships to outstanding students from developing countries. These scholarships enabled participation, either on-site or virtually, ensuring that talented students had access to this unique learning and networking opportunity, regardless of cultural barriers. Many of these students will present their research during our Virtual and In-person Poster Sessions, contributing to vibrant and innovative discussions.

Postgraduate students will also have the chance to showcase their research in both virtual and in-person poster sessions. The best posters will be awarded during our Closing Ceremony.

GCSS 2026 will provide an exceptional platform for postgraduate students from various countries to interact with renowned scientists and educators in the field of Green Chemistry. It will offer students the chance to exchange ideas, build international research networks, and develop lasting friendships with peers from around the world.

At last but not least, I would like to thank all of the teachers who contributed to making the 18th Postgraduate Summer School on Green Chemistry such a memorable and impactful event. Your active participation, energy, and creativity ensured that this year's edition was not just a continuation of past success, but a step forward in advancing the important work that Professor Tundo started.

As we look to the future, I hope that the bonds formed during the Summer School will continue to strengthen, leading to future collaborations and advances in Green Chemistry. I encourage all of you to remain involved, to build on the knowledge and connections you've gained, and to be ambassadors for sustainable science in your own communities and institutions.

Thank you all once again for your dedication, and I look forward to seeing what we can achieve together in the future.

Francesco Trotta
Chair of the Summer School

FOREWORD BY THE HEAD OF INTERNATIONAL RELATIONS DEPARTMENT OF PHOSAGRO



Dear colleagues, lecturers, graduate students, and students!

On behalf of PhosAgro - one of the world's largest producers of phosphate fertilizers - I am pleased to welcome you to the 18th Session of the Summer School on Green Chemistry.

It is obvious, that interest in the Summer School continues to grow year after year! This year, over 100 young scientists and 25 lecturers from 30 countries worldwide participate in the 18th round of the School. The total number of Summer School participants has already reached 1,600 talented young researchers!

Our modern life is impossible without chemistry. Its products are used across all industries. However, the depletion of natural resources and the waste problem have led science to conclude: radical changes in industrial technologies are essential to preserve our planet. That is why green chemistry today serves as a key driver of technological progress.

At PhosAgro, we understand that supporting science is a long-term investment in the future of our planet. That is why we have long been engaged in productive collaboration with UNESCO and IUPAC, supporting young scientists from around the world.

Last year, we celebrated the 10th anniversary of the "Green Chemistry for Life" grant program. Over the years of its implementation, more than 1,000 applications from talented scientists have been reviewed, and 33 researchers from 55 countries have received grants.

Summer Schools on Green Chemistry represent another vital joint project by the Green Sciences for Sustainable Development Foundation, PhosAgro and IUPAC. This provides an excellent opportunity for talented scientists to gather together, exchange scientific ideas, demonstrate their leadership and scientific potential, and tackle global environmental challenges.

Finally, I would like to express my sincere gratitude to all organizers of the School—especially its Chairman and President of the Foundation, Professor Francesco Trota of the University of Turin for continuing to develop the remarkable legacy of the Summer School's founder, Professor Pietro Tundo.

Dear friends, I congratulate you on the 18th Session of the Summer School on Green Chemistry and wish all participants productive and engaging work!

Dr. Aleksander Antonov
Head of International Relations Department
PJSC PhosAgro

FOREWORD BY THE LOCAL ORGANIZING COMMITTEE IN VENICE



Dear students and teachers of the International Postgraduate Summer School on Green Chemistry 2026,

It is an honor for me to welcome you to this 18th edition of the school, which is once again held in the wonderful setting of Venice, which has been, and it is still nowadays a crossroads of peoples and cultures.

This is my tenth Summer School, my seventh one as part of the Organizing Committee representing Ca' Foscari University. I still vividly remember my first participation at the Summer School. It happened after returning from my experience abroad in America as a post-doctoral fellow, when I was invited by Prof Tundo - then director of the Interuniversity Consortium "Chemistry for the Environment (INCA) and creator of the event - to take part in the 2005 edition of the School held in San Servolo, a small island in the Venetian Lagoon. I remember the high quality of the teachers' presentations, the excitement of the young students, and the constant buzz of questions, laughter, and conversations about Green Chemistry. Most of the 2005 Summer School students are now grown-up scientists, teachers, and professors who still happily remember the School as an amazing opportunity to broaden their knowledge and create new collaborations and friendships for what has then become their future careers. Almost 20 years later, I still recognize in the students' eyes the same excitement and the desire to explore issues related to Green Chemistry and sustainability, nowadays even more intertwined with the world's social and economic growth.

This year's topics range from benign synthetic routes to green catalysts, alternative solvents, renewable and green materials, green energy, and green chemistry education. These topics have been selected as they encompass actual, new, or emerging issues related to the green and sustainable development of society and the scientific community.

As in every edition of the Summer School, each student had to present a scientific poster highlighting his actual research topic and interest. The number and the high quality of this year's poster presentations have been overwhelming, and I cannot wait to see how these young scientists will evolve in the future generation of scientific experts that will guide the world toward a greener future.

Fabio Aricò
Professor of Organic Chemistry Ca' Foscari University,
Member of the Organizing Committee of the
International Postgraduate Summer School on Green Chemistry 2026

SUMMER SCHOOL COMMITTEES

CHAIR OF THE SUMMER SCHOOL

• **Francesco Trotta,** *President of Green Sciences for Sustainable Development Foundation, Venice, Full Professor of Industrial Chemistry, University of Turin, Italy*

ORGANIZING COMMITTEE

- **Prof. Fabio Aricó**, Ca' Foscari University of Venice, Italy
- **Dr. Aurelia Visa**, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania
- **Prof. Mirabbos Hojamberdiev**, Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark
- **Dr. Graziana Gigliuto**, Green Sciences for Sustainable Development Foundation, Italy
- **Dr. Aleksander A. Antonov**, Director, Department of International Development & Projects, PhosAgro

INTERNATIONAL JURY FOR THE POSTER SESSIONS IN-PERSON AND ONLINE FOR THE *"Green Sciences for Sustainable Development Foundation Awards"*

Coordinator of the Poster Evaluation: Aurelia Visa, *Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry – Timisoara, Romania*

Alberto Figoli, Member of the Jury from Italy
Javier Garcia-Martinez, Member of the Jury from Spain
Jane E. Wissinger, Member of the Jury from USA
Luigi Vaccaro, Member of the Jury from Italy
Mirabbos Hojamberdiev, Member of the Jury from Denmark
Amy Cannon, Member of the Jury from USA
Macello Baricco, Member of the Jury from Italy
Jonathan Formann, Member of the Jury from USA
Giulia Fiorani, Member of the Jury from Italy
Christopher Brett, Member of the Jury from Portugal
Philip Jessop, Member of the Jury from Canada
Marco Sangermano, Member of the Jury from Italy
David A. Laviska, Member of the Jury from USA
Fabio Aricò, Member of the Jury from Italy
Youssef Habibi, Member of the Jury from Morocco
Alberto Cugnetto, Member of the Jury from Italy
Francesco Trotta, Member of the Jury from Italy
Giacomo Trapasso, Member of the Jury from Italy

SUMMER SCHOOL 2026

The School was held in collaboration with the academic institutions of Ca' Foscari University of Venice and the University of Turin.

The event was endorsed by the UNESCO Chair Aid4GEA, by the Gruppo Interdivisionale di Green Chemistry of Società Chimica Italiana (SCI), by the Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, by the Mads Clausen Institute, University of Southern Denmark, and Data-centric Environmental Studies Center.

The Summer School was sponsored by PhosAgro, the Organization for the Prohibition of Chemical Weapons (OPCW), the International Union of Pure and Applied Chemistry (IUPAC), the American Chemical Society (ACS), and the Multidisciplinary Digital Publishing Institute (MPDI).

Thanks to the participation of these Sponsors, 13 postgraduate students attending in presence and 28 online, coming from developing countries, have been awarded scholarships.

This year, the number of applications from students from developing countries was 150. During a strict selection process in March by the Organizing Committee, the scholarship applicants were evaluated based on their CVs, their list of publications, the recommendation letters from their Tutors, and their motivations to attend the Summer School 2026.

The total number of students attending the 18th IPSSGC 2026 was 104; 66 of them were in-person in Venice, and 38 students were online, coming from 32 different nationalities.

The rigorous selection of the participants contributed to forming a class of high-level students, who certainly find themselves at a point in their lives where they are ready to invest their talents and scientific know-how for their future professional careers maturely and responsibly. The top-level and diverse range of lectures offered at the Summer School provided them the chance to look around, exchange their scientific knowledge, and establish important links with other participants and professors for fruitful joint projects and research activities.

Green Chemistry has proven to be a compelling field for young scientists, as demonstrated by the Summer Schools held from 1998 to 2026, with over 1600 students participating. This interest is evident as some ex-alumni have returned as teachers, showing the program's significant impact on their careers and their commitment to the field. Green Chemistry's interdisciplinary nature provides a unique perspective, encouraging students to think creatively about sustainable solutions. The Summer Schools offer a valuable opportunity for students to explore various scientific disciplines and understand the importance of environmentally responsible practices.

The Summer School hosted 7 lecture sessions and 2 poster sessions on the following main topics:

- **Renewable and green raw materials**
- **Green Catalysis**
- **Alternative solvents**
- **Benign synthesis routes**
- **Sustainable Polymers**
- **Green chemistry for energy**
- **Clean Processes**
- **Green Chemistry Education**

After the Summer School, all participants received a certificate of attendance.

This Summer School was held in person and remotely; it was attended in person and online for those who could not come to Venice. We engaged the participants with the outstanding scientific quality of the teachers, involving themin the discussion of the lectures and, not less importantly, through the poster sessions.

From the outcomes of these hybrid Summer Schools, the GSSD Foundation has learned how to manage future events, which they hope will become a permanent feature in Venice due to their long-standing tradition and high scientific value.

Among various Summer Schools and similar educational events, the International Summer School on Green Chemistry in Venice stands out as a model of good practice for several reasons. First, the careful selection process ensures a class of top international students passionate about green chemistry and eager to contribute to its research. Second, the program attracts an exceptionally high caliber of teachers, including Nobel Prize winners and top-ranked global scientists. Third, the unique setting of Venice adds a profound dimension to the school, as the city itself is a symbol of sustainability and resilience, offering a fitting backdrop for discussions on environmental stewardship.

During the XVIII International Postgraduate Summer School on Green Chemistry in 2026, the teachers provided an in-depth overview of their current scientific work over the five days of the program. They also evaluated the students' research, offering valuable feedback and suggestions for improvement, further enhancing the educational experience.

CEST TIME
(Central European Summer Time)

	MONDAY 6-July
9:00-11:00	Registration at the Summer School
11.00-12.00	OPENING CEREMONY
12:00-13:30	Lunch
13:30-15:15	John Warner
15:15-16:00	Amy Cannon
16:00 16:30	Coffee break
16:30-17:15	Katalin Kovacs

	TUESDAY 7-July
9:00-9:30	Phosagro
9:30-10:30	Philp Jessop
10.30-11:15	Peter Licence
11:15-11:35	Coffee Break
11:35-12:20	Alessandro Pellis
12:20-13:05	Youseff Habibi
13:05-14:30	Lunch
14:30-15:15	Chris Brett
15:15-16:00	Alberto Figoli
16:00-17:30	POSTER SESSION 1 ON SITE + Coffee break

	WEDNESDAY 8-July
9:00-9:30	ACS Green Chemistry Institute
9:30-10.30	Krzysztof Matyjaszewski -
10.30-11:15	David Laviska
11:15-11:35	Coffee break
11:35-12:20	Marco Sangermano
12:20-13:05	Marcello Baricco
13:05-13:35	MDPI - Presentation
13:35-14:45	Lunch
14:45-20:00	FREE TIME
20:00-21:30	SOCIAL DINNER

	THURSDAY 9-July
9:00-9:30	
9:30-10:30	Javier Garcia Martinez
10:30-11:15	Luigi Vaccaro
11:15-11:35	Coffee Break
11:35-12:20	Jane Wissinger
12:20-13:05	Alberto Cugnetto
13:05 - 14:30	Lunch
14:30-15:15	Giacomo Trapasso
15:15-16:15	Francesco Trotta
16:15-17:30	POSTER SESSION 2 ON SITE + Coffee break

	FRIDAY 10-July
9:00-9:30	IUPAC
9:30-10.30	Jonathan Forman/OPCW
10:30-11:15	Elena Semenzin
11:15-11:35	Coffee Break
11:35-12:20	Andrea Spolaor
12:20-13:00	CLOSING CEREMONY AND POSTER AWARDS

GREEN SCIENCES FOR SUSTAINABLE DEVELOPMENT FOUNDATION

18th Edition of the Green Chemistry Postgraduate Summer School 2026

THE SUMMER SCHOOL 2026 PROGRAMME

MONDAY 6 JULY MORNING

REGISTRATION AT THE EVENT

OPENING CEREMONY

Presenters:

Francesco Trotta, Chairman of the Green Chemistry Summer Schools and President of GSSD Foundation, University of Turin.
Dr. Aleksander A. Antonov, Director, Department of International Development & Projects, PhosAgro.
David A. Laviska, American Chemical Society, ACS Green Chemistry Institute.
Fabio Aricò, Board Member, GSSD Foundation, Ca' Foscari University of Venice.
Aurelia Visa, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara.
Mirabbos Hojamberdiev, Mads Clausen Institute, University of Southern Denmark, Sønderborg.

MONDAY 6 JULY AFTERNOON

1st LECTURE SESSION:

Moderator**:** Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
JOHN WARNER, *CEO & CTO, Technology Greenhouse, USA*
Green Chemistry: The Foundation of a Sustainable Circular Economy

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
AMY S. CANNON, *Executive Director & Co-Founder, Beyond Benign, USA*
From Classroom to Community: Green Chemistry Education for a Sustainable Future

2nd LECTURE SESSION:

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
KATALIN KOVACS, *Professor, School of Pharmacy, Faculty of Science at the University of Nottingham, United Kingdom*
Bioproduction of Chemicals from CO_2

TUESDAY 7 JULY MORNING

SPONSORS and INSTITUTIONS

PhosAgro Company

Presenter:

Alexander Antonov- Director, Department PJSC PhosAgro International Projects

3rd LECTURE SESSION:

Moderator: Aurelia Visa*, Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
PHILIP JESSOP, *Full Professor and Canada Research Chair of Green Chemistry at the Department of Chemistry, Queen's University in Kingston, Canada*
Using Life Cycle Assessment and Hotspot Analysis to Guide Your Research

Moderator: Aurelia Visa*, Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
PETER LICENCE, *Professor at The GSK Carbon Neutral Laboratories, School of Chemistry, The University of Nottingham, United Kingdom*
Green Chemistry: Seeing the Wood from the Trees!

Moderator: Aurelia Visa**,** *Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
ALESSANDRO PELLIS, *Professor at the Department of Chemistry and Industrial Chemistry, University of Genova, Italy*
Green Chemistry: Seeing the Wood from the Trees!

Moderator: Aurelia Visa**,** *Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
YOUSSEF HABİBİ, *Professor at University Mohammed VI Polytechnic, Sustainable Materials Research Center (SusMat-RC), (UM6P), Ben Guerir, Morocco*
Renewable Feedstock and Recycling

TUESDAY 7 JULY AFTERNOON

4th LECTURE SESSION:

Moderator*:* Mirabbos Hojamberdiev, *Professor at Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark*
CHRISTOPHER M.A. BRETT, *Professor at Department of Chemistry, University of Coimbra, Portugal*

Deep eutectic solvents for green electrochemistry. Application to polymer-coated electrodes for sensors and corrosion inhibition

Moderator: Mirabbos Hojamberdiev, *Professor at Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark*
ALBERTO FIGOLI, *Director of National Research Council – Institute on Membrane Technology "Enrico Drioli", Rende, Italy*
Concentration of clarified red dragon fruit juice using hydrophobic P(VDF-HFP) flat-sheet membranes: a comparison of osmotic, membrane, and vacuum membrane distillation

1st POSTER SESSION – 26 POSTERS

WEDNESDAY 8 JULY MORNING

SPONSORS and INSTITUTIONS

American Chemical Society, Green Chemistry Institute.
Multidisciplinary Digital Publishing Institute (MDPI).

Presenters:

David A. Laviska-American Chemical Society, ACS Green Chemistry Institute.
Lucía Gallego Aibar - Multidisciplinary Digital Publishing Institute (MDPI).
Haewon Song- Multidisciplinary Digital Publishing Institute (MDPI).

5th LECTURE SESSION:

Moderator: Francesco Trotta*, Full Professor at the University of Turin, Italy*
KRZYSZTOF MATYJASZEWSKI, *Professor at Carnegie Mellon University, Center for Macromolecular Engineering, Pittsburgh, United States*
Towards Green Atom Transfer Radical Polymerization

Moderator: Francesco Trotta*, Full Professor at the University of Turin, Italy*
DAVID A. LAVISKA, *Portfolio Manager for Green Chemistry & Sustainability in Education, ACS Green Chemistry Institute*
Thinking Green: How to Adopt a Systems Thinking Mindset in the Laboratory

Moderator: Francesco Trotta, *Full Professor at the University of Turin, Italy*
MARCELLO BARICCO, *Professor at the Department of Chemistry and NIS – INSTM, University of Turin – TORINO, Italy*
Hydrogen for Energy Transition

Moderator: Francesco Trotta, *Full Professor at University of Turin, Italy*
MARCO SANGERMANO, *Professor at Department of Applied Science and Technology, Politecnico di Torino, Italy*
Dynamic Polymer Networks: From Adaptive Covalent Chemistry to Reprocessable Vitrimers

WEDNESDAY 8 JULY AFTERNOON

FREE AFTERNOON

SOCIAL DINNER

THURSDAY 9 JULY MORNING

6th LECTURE SESSION:

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
JAVIER GARCÍA-MARTÍNEZ, *Professor at Laboratorio de Nanotecnología Molecular, Dpto. Química Inorgánica, Universidad de Alicante, Spain*
Reimagining Catalysis for a Greener Future: From Discovery to Commercialization

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
LUIGI VACCARO, *Professor at Laboratory of Green S.O.C., Dipartimento di Chimica, Biologia e Biotecnologie, Università di Perugia, Italy*
Green shades in organic synthesis and catalysis

Moderator**:** Aurelia Visa**,** *Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
JANE E. WISSINGER, *Professor at the Department of Chemistry, University of Minnesota, United States*
Advancing Green and Sustainable Chemistry Through Education and Outreach

Moderator: Aurelia Visa**,** *Senior Researcher Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry, Timisoara, Romania*
ALBERTO CUGNETTO, *Expert in Viticulture and Enology, Academy of Agriculture of Turin, Italy*
Modern Enology meets Green Chemistry: innovation across processes, analytics, and sustainability

THURSDAY 9 JULY AFTERNOON

7th LECTURE SESSION:

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
GIACOMO TRAPASSO, *Researcher at Department of Environmental Science Informatics and Statistics, Ca' Foscari University of Venice, Italy*
Metrics for green syntheses: two case studies in biorefinery

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
FRANCESCO TROTTA, *Full Professor at Department of Chemistry, University of Turin, Italy*
Exploitation of Renewable Resources in Polymer Chemistry

2nd POSTER SESSION- 27 POSTERS

FRIDAY 10 JULY MORNING

SPONSORS and INSTITUTIONS

Organisation For Prohibition of Chemical Weapons (OPCW)
International Union of Pure and Applied Chemistry (IUPAC)

Presenter:

Jonathan Forman- Science and Technology Advisor Threat Prevention and Resilience Group Pacific Northwest National Laboratory, OPCW
Javier Garcia Martinez- Laboratorio de Nanotecnología Molecular, Dpto. Química Inorgánica, Universidad de Alicante, International Union of Pure and Applied Chemistry (IUPAC)

8th LECTURE SESSION:

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
JONATHAN FORMAN, *Advisor at Science and Technology Advisor in the Global Security Technology and Policy Group under the National Security Directorate of Pacific Northwest National (PNNL), United States*
Atoms, Molecules, and Arms Control: Where Chemistry Meets Diplomacy

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
ELENA SEMENZIN, *Professor at Department of Environmental Sciences, Informatics and StatisticsUniversità Ca' Foscari Venezia, Italy*

Designing Safer and More Sustainable Chemicals: An Introduction to the European Safe and Sustainable by Design (SSbD) Framework

Moderator: Fabio Aricò, *Full Professor of Organic Chemistry, Ca' Foscari University of Venice, Italy*
ANDREA SPOLAOR, *Researcher at CNR-Institute for the Dynamics of Environmental Processes (IDPA), Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University, Venice, Italy*
Seasonal snow: where climate change meets natural chemistry

CLOSING CEREMONY AND POSTER AWARDS

Presenters:

Francesco Trotta, *President of Green Sciences for Sustainable Development Foundation, University of Turin, Italy*
Aurelia Visa, *Senior Researcher, Romanian Academy "Coriolan Drăgulescu" Institute of Chemistry – Timisoara, Romania*
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ABSTRACTS OF LECTURES

(according to the Summer School Programme Order)

Green Chemistry: The Foundation of a Sustainable Circular Economy

JOHN C. WARNER

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Chemistry has the power to create technologies that improve human well-being while protecting the environment. Green chemistry was established to provide scientists with the knowledge and design tools needed to achieve these goals, enabling the development of chemical products and processes that are inherently safer, less hazardous, and more sustainable throughout their lifecycle. This presentation will explore the early history of green chemistry, including the scientific and societal challenges that motivated the creation of the field and its development over the past three decades. It will examine how molecular design, reaction chemistry, and materials innovation can be guided by principles of sustainability without sacrificing performance or scientific rigor. The presentation will also describe the process of translating green chemistry ideas from the laboratory to the marketplace. Several illustrative examples will demonstrate how innovative chemistry can create both environmental and commercial value.

From Classroom to Community: Green Chemistry Education for a Sustainable Future

AMY CANNON

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What if chemistry education was redesigned from the ground up - with safety, sustainability, and social responsibility built in from the start? A growing community of educators, researchers, and advocates is making that vision a reality, transforming how chemistry is taught from primary and secondary classrooms to university curricula. In this session, we'll explore the green chemistry education movement, the work of organizations like Beyond Benign, and the many ways you - as graduate students and postdocs - can get involved. Whether through advocacy, outreach, teaching, or research, your expertise has a place in shaping the future of sustainable science.

Bioproduction of Chemicals from CO_2

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Copilot said: Fermentation-based bioprocesses that use one-carbon (C1) feedstocks, such as carbon dioxide (CO_2) and methane, offer significant potential for the sustainable production of chemicals, fuels, and pharmaceuticals from renewable resources. In addition, these approaches help mitigate greenhouse gas (GHG) emissions by valorising industrial waste gases from sectors including steel manufacturing, oil refining, anaerobic digestion, and coal or natural/shale gas processing.

Cupriavidus necator H16 (formerly *Ralstonia eutropha*) is a Gram-negative, non-pathogenic, facultatively chemolithoautotrophic bacterium capable of growing either on organic substrates or, under aerobic conditions, on hydrogen (H_2) and carbon dioxide (CO_2). Its ability to utilise CO_2 as its sole carbon source makes it a highly attractive chassis for sustainable production, enabling the synthesis of products ranging from polyhydroxybutyrate (PHB, a biopolymer) to alcohols, alkanes, alkenes, as well as precursors for biopolymers and pharmaceuticals.

We have successfully engineered *C. necator* H16 to produce 3-hydroxypropionic acid (3-HP), 3-HP–PHB copolymers, and mevalonate directly from various carbon sources and/ or CO_2. The strategies employed, along with the titres and yields achieved, will be presented.

Using Life Cycle Assessment and Hotspot Analysis to Guide Your Research

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Green chemistry researchers throughout the world, including the author, are motivated to use our research to benefit the environment, reduce harm, and help society become more sustainable. However, not all research projects are equally helpful to the environment. Assuming that harm reduction is the priority, we should prioritize projects that should maximize the benefit. Improving a process or product that causes very little harm is not an effective use of the time and resources of a green chemistry lab. However, it is not a trivial exercise to determine which processes, or which parts of processes, are causing significant harm. Several tools are available to green chemistry researchers to help us identify problems and therefore prioritize our research efforts.

Life cycle assessment (LCA) is a particularly powerful tool, because it not only allows us to compare different processes (or different products), but it also gives us detailed information about the hotspots. A hotspot is a part of a process (or an ingredient in a product) that causes more harm than other parts of the process/product. If we know the hotspots, then we can use our energy, creativity, and lab time to find better alternatives. That's much more effective than spending time greening a part of the process that isn't a hotspot.

Other tools include emissions databases that track chemical emissions from different industries, as well as impact-based metrics.

This presentation will describe how research chemists and chemical engineers can use LCA, emissions databases, hotspot analysis, and impact-based metrics to prioritize their research projects and maximize the resulting benefit to the environment.

Keywords: Life Cycle Assessment; Green Metrics; Research strategy

Green Chemistry: Seeing the Wood from the Trees!

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The translation of novel ideas, experiments or materials from the laboratory towards industry or into manufacturing at scale is a landmark event that should be recognised, celebrated and heralded as a prime indicator of success. However, realisation of this dream is not always easy, and when achieved, the pathway is often challenging or blocked by unsurmountable barriers that are not always obvious until far too late in the day!

This lecture will give an insight into 2 short vignettes – both of which are based upon the foundational teachings of Anastas and Warner's agenda setting book "Green Chemistry: Theory and Practice".[1] The Principles of Green Chemistry provide a rationale that underpinned the design of 2 distinct families of chemical process, one is historical,[2] the second contemporary.[3] I will use these Green Chemistry stories to explore some of the challenges and indeed opportunities that can be experienced along the path to application.

The discussion will explore the importance of ideas, the benefits of multidisciplinarity and the essential requirement for luck and serendipity. The conclusion of my talk is simple, for our chemistry to really make a difference, it must be put to work. We are not going to turn the tide on global scale challenges unless we deliver cleaner processes, smarter materials and better science today. Tomorrow will always be a day too late!

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Sustainable strategies for the processing of platform molecules to polymeric materials

ALESSANDRO PELLIS

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Renewable bio-based polyesters are one of the effective answers that the bioeconomy offers to solve the environmental emergency connected to fossil-based plastics. The next generation of plastics are expected to contribute to a massive reduction in the carbon footprint by the exploitation, in industrial productive processes, of renewable monomers such as polyols and dicarboxylic acids obtainable via biotechnological production. More specifically, there is a rising demand for advanced materials displaying new functional properties while meeting higher sustainability criteria. This talk will highlight new greener strategies for a more environmentally friendly synthesis of various polyester-based materials and their potential application.

Renewables Feedstock and Recycling

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In conjunction with the growing interest in developing circular economies through the substitution of fossil carbon with renewable one, green and sustainable chemistry sits at the cornerstone of this shift, with the use of renewable and recycled feedstocks as starting materials standing as one of its twelve foundational principles.

Indeed, interest in biomass and recycled feedstocks shows no sign of waning; if anything, it is expected to attract even greater attention during the so-called Fourth Industrial Revolution. With global biomass production estimated at 10^{13} tons and an annual growth of approximately 3×10^{11} tons, biomass stands out not only as abundant, renewable, and sustainable, but as a resource with the potential to supplant—or at minimum complement—fossil-based feedstocks at scale. Accordingly, the conversion of these resources into value-added chemicals, polymers, and materials is emerging as a credible response to the anticipated scarcity of fossil resources, addressing timely concerns of sustainability and ecological responsibility.

Plastic waste represents a parallel, and equally pressing, resource opportunity. Global plastic waste generation has grown nearly seven-fold over the past four decades, reaching close to 400 million tons annually, while recycling still accounts for less than 10% of global plastic waste management. This growing volume of discarded material, largely landfilled, incinerated, or left mismanaged in the environment, constitutes an underexploited feedstock stream whose valorization could simultaneously mitigate plastic pollution and reduce demand on virgin fossil resources.

The first part of this presentation will learn about the potential of using biomass as a vast and renewable resource for chemicals, polymers, and materials, framed within the biorefinery concept, covering the processing, fractionation, and full-component recovery strategies. These strategies enable conversion toward chemicals, additives, fillers, and diverse classes of polymeric materials across a wide range of applications. The second part will address the potential of plastic waste as this complementary resource stream, illustrating pathways for its valorization and exploitation as a feedstock in its own right. The final part will present holistic approaches that combine biomass-derived components with plastic-derived products into functional polymeric materials designed for more demanding applications.

Deep eutectic solvents for green electrochemistry. Application to polymer-coated electrodes for sensors and corrosion inhibition

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Deep eutectic solvents (DES) are a greener and lower-cost alternative to ionic liquids and conventional organic solvents, and are being investigated for use in a number of fields [1]. Strong interactions between a hydrogen bond acceptor (HBA) and one or more hydrogen bond donors (HBD) give an electrically conducting liquid solvent, simply by mixing solid components. The properties of DES will be reviewed, and compared with those of ionic liquids, including natural DES (NADES) and therapeutic DES (TADES). Applications of DES in polymer science as solvents or functional additives, in extraction, in metal processing (electrodeposition and electroless deposition), in nanomaterials science and in sensors [2,3] will be described. A recent survey on electrodeposition has highlighted improved anti-corrosion properties of metal coatings prepared by electrodeposition in DES [4].

The predominant HBA is the non-toxic choline chloride, vitamin B4, and amongst the HBD some of the most used are urea, ethylene glycol, glycerol and carboxylic acids. For electrochemical applications, ethaline (with ethylene glycol) has been most used owing to its relatively lower viscosity than most other DES, that enables easier diffusion of electroactive species.

Recent research on the preparation of electrochemical nanomaterial-polymer film sensors in binary and ternary (two HBD) DES will be illustrated. The search for HBDs less toxic than ethylene glycol whilst retaining the lower viscosity has led to the investigation of ternary DES (two HBD) as media for the preparation of polymer-modified electrodes, e.g. [5-7], especially including HBD with low eco-toxicity, the starting point being already-identified components of NADES. Future perspectives for the application of such electrochemical sensors and biosensors in monitoring of key analytes in the areas of health, foods and the environment will be illustrated and discussed. Application as corrosion inhibitor coatings will also be presented.

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Concentration of clarified red dragon fruit juice using hydrophobic P(VDF-HFP) flat-sheet membranes: a comparison of osmotic, membrane, and vacuum membrane distillation

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Poly(vinylidene fluoride-hexafluoropropylene) P(VDF-HFP) flat-sheet membranes were prepared via the non-solvent induced phase separation (NIPS) technique using polyethylene glycol (PEG) as pore former agent and Tamisolve® NxG as sustainable solvent [1]. The resulting membranes were used for the concentration of clarified red dragon fruit juice through both osmotic distillation (OD), membrane distillation (MD) and vacuum membrane distillation (VMD).

Membrane characterization revealed a thickness of 110 ± 7 μm, top and bottom contact angle values of 88 ± 2 ° and 107 ± 7 °, respectively, an average pore size of 0.14 μm, and a porosity of 79 ± 3 μm. In the MD process, conducted with a temperature difference (ΔT) of 25 °C, average evaporation fluxes of approximately 1 kg m^{-2} h^{-1} were obtained. In the OD process, performed at 25 ± 2 °C using a 60 wt% calcium chloride dihydrate solution as the stripping agent, average evaporation fluxes of about 1.4 kg m^{-2} h^{-1} were achieved. These values were slightly higher than those previously reported for the concentration of the same juice using commercial polypropylene hollow-fiber membranes [2]. The combined MD–OD process operated at a ΔT of 15 °C resulted in improved membrane performance, with average evaporation fluxes reaching approximately 1.7 kg m^{-2} h^{-1}. The highest productivity was obtained using a vacuum membrane distillation (VMD) setup, which achieved average evaporation fluxes of about 2.5 kg m^{-2} h^{-1} at 25 ± 2 °C.

Keywords
Membrane preparation; Membrane characterization; Osmotic Distillation; Vacuum membrane distillation.

Acknowledgements

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Towards Green Atom Transfer Radical Polymerization

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Fundamentals of ATRP (atom transfer radical polymerization) will be presented. Recently, by applying new initiating/catalytic systems, the Cu level in ATRP was reduced to a few ppm. To combat unavoidable radical termination, several techniques for the regeneration of the catalytic systems have been developed. They include various benign chemical reagents such as ascorbic acid or sugars but also external stimuli: electrical current, light, mechanical forces and ultrasound. ATRP was carried out without organic solvents, in bulk and in aqueous media under homogeneous conditions or in dispersed media. Reducing agents and enzymes permit the reaction without deoxygenation in the flasks open to the air. Some aspects of application of large language model to optimize ATRP will be discussed. The range of monomers for ATRP has been expanded to (meth)acrylates and acrylamides made from renewable resources. They have been used for the synthesis of well-defined polymers with precisely controlled molecular architecture with designed shape, composition, and functionality. Block, graft, star, hyperbranched, gradient and periodic copolymers, molecular brushes, and various hybrid materials or bioconjugates were prepared. Some examples of nanostructured multifunctional hybrid materials for applications related to environment, energy, and biomedicine will be presented.

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Thinking Green: How to Adopt a Systems Thinking Mindset in the Laboratory

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Most chemists (and scientists across all fields that require knowledge of chemical principles) were trained through a "reductive" teaching approach rather than from a broader systems perspective. A reductive mindset typically leaves students with a limited understanding of central concepts and varying levels of confusion. Even more critically, students are not trained to make important connections between concepts or think broadly about consequences of chemical principles beyond the laboratory. Where do reagents and feedstocks come from? Where do chemical products and waste go? What are the impacts outside the laboratory? The benefits of expanding from a reductive mindset to a systems approach to practicing chemistry extend far beyond greater mastery of foundational principles. Indeed, a systems mindset is what we need as chemists to succeed in research and industry and even more broadly, to address the many large-scale sustainability challenges we are facing across the globe. In this talk, I will provide encouragement and guidance on how to shift from a reductive mindset to a systems perspective in the laboratory. This is achievable for every scientist – no matter the career stage - and we must transform ourselves as a community of chemists before we can catalyze greater sustainability across the global chemistry enterprise.

Dynamic Polymer Networks: From Adaptive Covalent Chemistry to Reprocessable Vitrimers

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Polymer networks have traditionally been divided into two distinct classes: thermoplastics, which can be reshaped upon heating, and thermosets, which possess superior mechanical and chemical resistance but are permanently crosslinked and therefore difficult to recycle or reprocess. The emergence of dynamic polymer networks has challenged this paradigm by introducing reversible interactions that allow network rearrangement while preserving desirable material properties [1].

Dynamic polymer networks are constructed from reversible non-covalent or covalent bonds capable of undergoing exchange reactions under specific external stimuli, such as temperature, light, or chemical triggers. These reversible processes enable materials to continuously adapt their structure and properties, leading to functionalities such as self-healing, stress relaxation, weldability, and recyclability. The field originated from the concepts of supramolecular polymers and dynamic constitutional chemistry introduced by Jean-Marie Lehn and was later expanded through the incorporation of dynamic covalent bonds into crosslinked networks [2].

A major breakthrough was the development of Covalent Adaptable Networks (CANs), which combine the robustness of covalent crosslinks with the adaptability of reversible chemistry. CANs can be classified into dissociative and associative networks according to their bond-exchange mechanism. In dissociative systems, bonds break before reforming, resulting in a temporary reduction of crosslink density. In contrast, associative systems maintain a constant number of network connections through simultaneous bond formation and bond cleavage, enabling topology rearrangement without network degradation [3].

Among associative CANs, vitrimers represent one of the most important and rapidly growing classes of materials. Introduced by Leibler and co-workers in 2011, vitrimers are permanently crosslinked polymer networks that undergo dynamic covalent exchange reactions while preserving their overall crosslink density. This unique behavior allows them to flow at elevated temperatures like highly viscous liquids while retaining the solvent resistance and dimensional stability characteristic of thermosets. As a result, vitrimers bridge the gap between conventional thermoplastics and thermosets, offering unprecedented opportunities for sustainable materials design [4].

This lecture will provide an overview of the fundamental principles governing dynamic polymer networks, the mechanisms underlying covalent adaptable networks, and the distinctive characteristics of vitrimers. Particular attention will be devoted to the relationship between molecular exchange processes and macroscopic material properties, highlighting how dynamic chemistry enables the development of next-generation recyclable, repairable, and reprocessable polymeric materials for advanced technological applications.

After a general introduction some recent results on Uv-Cured dynamic Polymer neworks will be presented [5-6].

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Hydrogen for Energy Transition

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European investments plan to support hydrogen as a carrier in the energy transition. Hydrogen can be produced in different ways, often joined with its colour. Grey hydrogen is produced with the standard technology, which is based on the steam reforming of methane. Blue hydrogen is obtained when, after the production of grey hydrogen, CO2 is captured and stored. Green hydrogen is produced by electrolysis of water, by using renewable energy. After production and before the use in different applications, hydrogen may need to be purified, transported, compressed and stored, so suitable hydrogen handling approaches, based on low-cost, safe, highly efficient and sustainable systems and operating close to ambient temperature and pressure, are needed. Then hydrogen can be used as a feed of fuel cells, to produce electrical energy, or can be burned like a classical fuel, and in both cases water is the only product. Of course, hydrogen can be also use for the so called “hard to abate” production technologies, to promote the decarbonisation. An overview on the state of the art of current technologies for hydrogen production, handling and use will be provided. Some case studies using metal hydrides as hydrogen carrier will be presented. A small scale H2 refuelling station developed to provide hydrogen for a FC-driven drone will be described. The HyCARE project, funded by FCH JU - H2020 and focussed on the development of an efficient metal hydride-based system for the storage of renewables energies, with a quantity of about 50 kg of stored hydrogen, will be presented. The next step, linked to the REMEDHYS EU project, which aims to the development to low cost and low impacting production of hydrogen carrier, will be shown. The Life Cycle Assessment (LCA) methodology to evaluate the environmental impacts associated with developed systems will be shortly described. Finally, main open challenges linked to hydrogen technologies will be outlined, suggesting possible approaches for their overcoming.

Reimagining Catalysis for a Greener Future: From Discovery to Commercialization

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One of the major obstacles to achieving more sustainable and efficient chemical processes is our current inability to effectively and selectively convert complex, bulky molecules. This limitation stems largely from the narrow microporosity of conventional catalysts, such as zeolites, which restricts molecular transport, limits access to active sites and often leads to undesired side reactions. As a result, many important transformations suffer from low conversion, poor selectivity and rapid catalyst deactivation, posing a significant challenge to the advancement of green and sustainable chemistry.

In this lecture, I will present a new family of nanoengineered catalysts designed to overcome these fundamental constraints. By creating more accessible catalytic architectures, including self-pillared nanosheets, hierarchical mesoporous materials and hybrid frameworks obtained through interzeolite transformation, we have opened new pathways for the controlled transformation of bulky molecules. These materials combine the intrinsic shape selectivity and strong acidity of zeolites with improved pore accessibility, enhanced diffusion and tunable catalytic environments, resulting in high levels of activity, selectivity and stability.

I will discuss several of these architectures and the advanced characterisation methods used to understand their structure-property relationships, including electron microscopy, spectroscopy, diffraction and catalytic testing under relevant reaction conditions. I will also show how these insights allow us to move from catalyst discovery to rational design, connecting nanoscale structure with macroscopic catalytic performance.

The potential of these materials will be illustrated through industrially relevant processes such as alkylation, condensation, cracking and dehydration. For example, drug intermediates can now be synthesised up to six times more efficiently, enabling more effective pharmaceutical production. In methanol-to-hydrocarbon processes, these catalysts exhibit near-zero deactivation rates, significantly extending catalyst lifetime and reducing replacement costs. In the context of plastic waste upgrading, they enable remarkable reductions in reaction temperature, lowering energy consumption and CO_2 emissions while transforming waste into valuable fuels and chemicals.

Finally, I will reflect on the innovation journey from fundamental research to commercial impact. Through Rive Technology, the company I co-founded, these catalysts progressed from laboratory discovery to large-scale industrial deployment. This experience illustrates how advanced catalyst design can bridge scientific insight, technological development and commercialization, providing industry with powerful tools to make chemical production more sustainable, efficient and economically viable.

Keywords:
Catalysis, Green Chemistry, Zeolites, Mesoporous Solids, Hybrid Materials, Advanced Characterization Techniques, and Entrepreneurship

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Green Shades in Organic Synthesis and Catalysis

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Our approach to modern green chemistry is focused on the general idea that green/efficient processes are those designed to minimize the waste by the rational combination of different technologies and the use of specific metrics needed to quantify the advance in terms of sustainability.
Our research program is mainly committed to the definition of efficient and sustainable synthetic tools by combining the development of several crucial areas of investigation: i) use of safer reaction media, ii) preparation and use of nanostructured heterogeneous and reusable catalytic systems; iii) definition of continuous-flow reactors allowing a minimal waste production and high productivity; iv) applications of metrics and LCA to assess the overall sustainability of the results.[1]
Among the different projects, we are currently dedicated attention to the valorisation of waste for the preparation of recoverable catalytic systems and electrodes to define efficient protocols based on the use of continuous-flow reactors and electrochemistry.
In this contribution it will be presented an overview of our vision and ongoing research in the field.



Keywords:
Green solvents, continuous-flow technologies, heterogeneous catalysis

Acknowledgements:
Part of this work has been funded within the following programs, EU ECS00000041 – VITALITY; Marie Sklodowska-Curie entitled STiBNite (N_ 956923), PRIN-PNRR 2022 project "P2022XKWH7 – CircularWaste.

References
[1] Some recent examples L. Vaccaro et al: *Chem. Sci.* **2024**, *15*, 3831-3871; *Green Chem,* **2024**, *26,* 4871-4879; *Green Chem*, **2024**, in press, DOI: 10.1039/D4GC00830H, hot article; *Green Chem*, **2024**, in press DOI:10.1039/D4GC00699B, hot article and invited front cover; *Green Chem*, **2024**, 26, 6625–6633, DOI: 10.1039/D4GC00930D; *ACS Sus Chem. Eng.* **2024**, in press, doi.org/10.1021/acssuschemeng.4c02486.

Advancing Green and Sustainable Chemistry Through Education and Outreach

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According to recent findings from the Stockholm Resilience Center, human activities have pushed the Earth beyond seven of the nine planetary boundaries essential for maintaining safe operating conditions for the Planet. The chemical industry is one source of significant pressure on Earth's systems as pharmaceuticals, plastics, and agrochemicals, among other innovations, have become an integral part of society. But their benefits have come at a price of great harm through unintended consequences to human health and the environment.

The path towards a sustainable future lies with educating the next generation of chemical practitioners to understand the complexities of today's socio- and environmental challenges and equipping learners with the skills to find solutions. These skills include application of green chemistry principles, safe and sustainable by design strategies, and a systems thinking approach to new discoveries. This presentation will illustrate incorporation of green and sustainable chemistry into curriculum at all levels with the goal of training a workforce prepared to address these sustainability challenges. That is, to design chemicals and chemical processes that are safe, produce minimal waste, and are viable alternatives to today's petroleum-based products. Lecture content, case studies, and laboratory experiments that exemplify the use of renewable resources, green processes, cost-effective applications, and end-of-life options for sustainable polymers will be shared.

Both the United Nations Sustainable Development Goals and the 2025 Stockholm Declaration of Chemistry for the Future are all calls to action to chemists and chemical educators to be part of this transformative change in how we do chemistry responsibly for future generations.

Modern Enology meets Green Chemistry: innovation across processes, analytics, and sustainability

ALBERTO CUGNETTO

Socio ordinario dell'Accademia di Agricoltura di Torino, Italy

Here's a refined version of your abstract integrating the analytical innovation dimension while keeping a coherent green chemistry narrative. The wine sector represents a cornerstone of both the Italian and broader European agri-food economy, combining cultural heritage with significant economic value. Today, it is undergoing a profound transition driven by environmental constraints, evolving regulations, and increasing consumer demand for safer, more sustainable, and "clean-label" products. In this context, green chemistry provides a strategic framework to redesign enological processes by reducing inputs, minimizing waste, and improving efficiency, while also enhancing analytical control over product quality and safety. This lecture will explore the main challenges and opportunities for the wine industry through the lens of green chemistry. A primary focus will be the progressive reduction of traditional additives and processing aids, achieved through the adoption of alternative technologies and targeted enzymatic preparations. Enzymes such as urease, pectin methylesterase, polygalacturonase, β-glucosidase, proteases, and β-glucanases will be presented as key tools to enhance process selectivity, improve stability, and reduce reliance on chemical interventions. Alongside process innovation, increasing attention is being devoted to the development of advanced analytical methods for the detection of compounds of both technological and health relevance. These include volatile phenols (ethylphenols and vinylphenols), responsible for sensory defects; cork-related contaminants such as TCA and related haloanisoles; plastic-derived compounds including phthalates; and residues of plant protection products. The lecture will highlight how emerging analytical approaches—faster, more sensitive, and increasingly aligned with green chemistry principles—are becoming essential to ensure product quality, consumer safety, and regulatory compliance. Further attention will be given to the optimization of winery operations through the reduction of water consumption and the environmental impact of cleaning and sanitation practices. The use of innovative detergents, enzymatic formulations, and foam-based systems will be discussed as effective strategies to decrease water use while maintaining high hygiene standards. In parallel, winery wastewater management will be addressed, emphasizing green technologies for pollutant load reduction. Specific case studies will examine the mitigation of critical issues such as contamination from unwanted microbial activity or the accumulation of compounds like quercetin. Membranebased separation processes will be analyzed as promising tools to selectively remove undesired substances while preserving wine integrity. Finally, the lecture will address the rapidly growing field of partial and total dealcoholization. Current subtractive techniques, including membrane processes and spinning cone column technology, will be evaluated in light of regulatory frameworks, market trends, and technological constraints. Particular emphasis will be placed on their sustainability profile, especially in terms of water and carbon footprint, highlighting the trade-offs between innovation and environmental impact. Overall, the lecture aims to provide a comprehensive overview of how green chemistry principles, combined with advances in analytical science, can drive innovation in the wine sector, supporting its transition toward more sustainable, controlled, and resilient production systems.

Metrics for green syntheses: two case studies in biorefinery

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Green metrics is a relatively new concept in Green Chemistry. The application of rigorous green metrics must go along with the experimental validation of synthetic procedures; this is necessary to give precise guidelines so to define a green synthetic approach and avoid misunderstanding and pretentious claims originating from subjective rather than objective evaluations.

5-(hydroxymethyl)furfural (HMF) has been labelled as the "sleeping giant" of the bio-based platform-chemicals realm, due to its versatility and being the starting point for endless chemical transformations into novel monomers for producing bio-based polymers. Among HMF derivatives, 2,5-Furandicarboxylic acid (FDCA) has been extensively studied as monomer for the production of polyesters such as polyethylene furanoate (PEF), considered as one of the most valuable bio-based substitute of the petroleum-derived polyethylene terephthalate (PET). However, the sustainability of the synthetic procedures leading to HMF and its derivatives represent a key aspect that must be addressed in order to foster their entrance into the bio-based plastic market. In this scenario, green metrics such as the environmental factor (E-factor) and the process mass intensity (PMI) represent an useful tool towards this goal.1

From these premises, the present contribution reports an alternative synthetic procedure for the production of 2,5-furandicarboxylic acid dimethyl ester (FDME) starting from galactaric acid via dimethyl carbonate (DMC) chemistry. Both sulfonic resins and an iron-based Lewis acid showed to promote the one-pot formation of FDME. The pure product was retrieved as a white crystalline solid with an isolated yield of up to 70%. Based on the different intermediates identified, a possible reaction mechanism was proposed, which highlights the essential contribute of DMC in the product formation.2 This presentation is also focussing on some key points inherent to the IUPAC project 2017-030-2-041: Metrics for Green synthesis. Thus, the greenness of the herein discussed synthetic procedure was evaluated using the most common green metrics and compared with other available synthetic pathways.

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[2] G. Trapasso, M. Annatelli, D. Dalla Torre, F. Aricò, Green Chem., 2022,24, 2766-2771; G. Trapasso, B. Chícharo, T. Gherardi, D. Redolfi-Bristol, F. Aricò, Catalysts 2023, 13(7), 1114.

Acknowledgements:

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Exploitation of Renewable Resources in Polymer Chemistry

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To face severe environmental and health concerns, limit greenhouse effects and improve the management of the foreseeable depletion of fossil resources, over the last decades, chemistry has moved towards the use of renewable resources for the production of energy and the synthesis of chemicals. Unlike materials deriving from fossils, which are often concentrated in a limited part of the world, renewable raw materials can be produced and utilized theoretically everywhere. These renewable raw materials come from various value chains, such as vegetable oils, fats, cellulose, starch, wood and biomass. It is important to underline that, where possible, renewable raw materials coming from agricultural and forestry products should not be used for food or feed but expressly employed for the production of materials, heat, electricity or fuel. Today many products are made from renewable raw materials, which often require less energy consumption and use safer and eco-friendly synthetic routes. These include textiles, cosmetics, medicines, building materials, dyes, lubricants, intermediates and (bio)-polymers [1].

Of particular interest is the production of polymer materials using renewable resources. In fact, polymers have a wide range of applications and are of crucial importance in modern society. In 2015 a global production of 322 million tons of different polymers was recorded. However, only 1% is actually related to bio-polymers although a constant growth has been detected.

In this lesson I would like to share the results obtained over the last decades on the use of some starch derivatives i.e. cyclodextrins and linear dextrins to produce both cross-linked and branched polymers with an impressive number of applications [2]. Toxic solvent-free production and even solvent-free synthesis are possible,thus making these new materials particularly appealing.

References:

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Atoms, Molecules, and Arms Control: Where Chemistry Meets Diplomacy

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Harmful properties of chemicals have been exploited for weaponization throughout the history of warfare. Despite the introduction of international agreements (beginning from the year 1675) aimed at banning chemical weapons, chemical war was unleashed on an industrial scale during the First World War with a continued buildup of military toxic chemical stockpiles throughout the 20th century. In 1992 after nearly two decades of deliberation and negotiation, world states reached a landmark agreement on the complete elimination of chemical weapons. This agreement, the Chemical Weapons Convention (CWC), entered-into-force in 1997, obligating all States Party to the Convention (which numbers over 190) to declare and permanently destroy their chemical weapon stockpiles under international oversight. This presentation will look at some very "not green" chemicals, discuss the obligations world States have under the CWC, and the explore the history that led to an agreed comprehensive international ban on chemical weapons. The lecture also will examine the legal definition of a "chemical weapon" and how that translates from chemicals into international law, and how the concepts and outputs of Green Chemistry intersect with chemical disarmament effort, appreciating that even benign chemicals can be used in intentionally harmful ways.

Keywords:
Chemical Weapon, Chemical Weapons Convention, Stockpile Destruction, Declarations

Designing Safer and More Sustainable Chemicals: An Introduction to the European Safe and Sustainable by Design (SSbD) Framework

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The European Safe and Sustainable by Design (SSbD) framework supports the development of chemicals and materials that are safe for human health and the environment while ensuring sustainability throughout their life cycle. By integrating functionality, safety, environmental performance, and socio-economic aspects from the earliest stages of innovation, SSbD provides a structured framework to support the transition towards safer and more sustainable chemicals and materials.

This lecture introduces the principles and methodological structure of the SSbD framework, highlighting its role within the European Chemicals Strategy for Sustainability. Participants will gain an overview of the different assessment steps and the complementary methods used to evaluate safety and sustainability, including hazard and exposure assessment, risk assessment, Life Cycle Assessment (LCA), and socio-economic considerations.

The lecture will conclude with practical examples illustrating how the SSbD framework can support decision-making during research and innovation, enabling the identification and comparison of alternative chemicals and materials with improved safety and sustainability performance.

Seasonal Snow: Where Climate Change Meets Natural Chemistry

[1,2]ANDREA SPOLAOR, [1]ELENA BARBARO, [3]DAVID CAPPELLETTI, [1]FABRIZIO DE BLASI, [1]JACOPO GABRIELI, [4]JEAN-CHARLES GALLET, [4]ELISABETH ISAKSSON, [5]CATHERINE LAROUSE, [6]ALFONSO SAIZ-LOPEZ AND [1]FEDERICO SCOTO

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4Norwegian Polar Institute, Tromsø NO-9296, Norway
5University Grenoble Alpes, CNRS, INRAE, IRD, Grenoble INP, IGE, Grenoble, France
6Department of Atmospheric Chemistry and Climate, Institute of Physical Chemistry Rocasolano, CSIC, Madrid, Spain

Seasonal snow is a key component of the Earth's cryosphere, serving both as a sensitive indicator of climate change and as an active natural chemical reactor. In polar regions, variations in snow cover duration, accumulation, and physical properties provide valuable insights into the ongoing impacts of global warming. Changes in the snowpack influence the surface energy balance, ecosystem processes, and the exchange of water, energy, and chemical species between the atmosphere and the Earth's surface, making seasonal snow an important sentinel of environmental change.

Beyond its climatic significance, seasonal snow is a dynamic chemical environment where numerous heterogeneous and photochemical reactions take place. Its porous structure, large specific surface area, and interaction with solar radiation create favourable conditions for the transformation, storage, and release of a wide range of chemical species.

Among the most important processes occurring within the snowpack are those involving reactive halogen species, particularly bromine and iodine. Through a combination of chemical and photochemical reactions, seasonal snow promotes the activation and recycling of these reactive species, influencing atmospheric composition and contributing to complex atmosphere–snow interactions that remain the subject of active research.

As climate change continues to alter the extent, duration, and physicochemical properties of seasonal snow, its role as both a recorder of environmental change and a natural chemical reactor is expected to evolve. A better understanding of these coupled physical and chemical processes is therefore essential for improving our understanding of climate feedback and predicting the response of polar atmospheric chemistry to a rapidly changing cryosphere.

IN-PERSON POSTER PROGRAMME

XVIII International Postgraduate Summer School on Green Chemistry

Poster Session 1, Tuesday, 7th July 2026, **16:00-17:30**

Poster number	Name	Affiliation and country	Title
1	Gustavo Felix Bitencourt	Universidade Federal do ABC – UFABC, Centro de Ciências Naturais e Humanas, Brazil, University of Caen-Normandie, UNICAEN, ENSICAEN, CNRS, Laboratoire Catalyse et Spectrochimie, France	Metal-Free Aldehyde-Rich Covalent Organic Frameworks for Hydrogen Peroxide Production from Sunlight, Water and Air
2	Tabata Natasha Feijoó Zambrano	Renewable Energies and Environmental Sustainability Research Group, Institute of Chemistry, Federal University of Rio Grande do Norte, Lagoa Nova, CEP 59078-970, Natal, Rio Grande do Norte, Brazil	From Organic Matter to Energy: How Electrolyte Configuration Controls Hydrogen Production during Electrochemical Wastewater Treatment
3	María Victoria Velázquez Tundidor	Research Laboratory for Organic Polymers (RLOP), Departamento de Química Orgánica, Facultad de Química y Farmacia, Pontificia Universidad Católica de Chile	Two Novel Ionic Polyimides for Gas Separation Membranes: Synthesis, Characterization, and Gas Transport Properties
4	Jorge Alejandro Solis Portillo	Departamento de Química Orgánica, Escuela de Química, Facultad de Ciencias Químicas y Farmacia, Universidad de San Carlos de Guatemala, Guatemala	Integrating Green and Sustainable Chemistry into Undergraduate Teaching in Guatemala: A Comparison of Three Methods for the Removal of Orange G from Water
5	Felipe de Jesús Barraza Garcia	Instituto de Física, Universidad Autónoma de San Luis Potosí, San Luis Potosí, México	Green Sonochemical Synthesis of Naringin-Functionalized Bismuth Nanoadjuvants with Antimicrobial Activity
6	Fernanda Abigail Silva Melgarejo	Institute of Physics, Autonomous University of San Luis Potosi. 78295, SLP, Mexico	Sustainable Development of Bismuth-Based Nanostructures to Enhance the Effects of Radiotherapy
7	Hazel Joyce Ramirez	College of Education, University of the Philippines Diliman, Quezon City, The Philippines	Filipino Teachers' Praxis, Challenges, and Opportunities
8	Kamlesh Kumari	School of Chemical Sciences and Advanced Materials Research Center, Indian Institute of Technology Mandi, Kamand, Mandi 175075, Himachal Pradesh, India	Sustainable Chemical Depolymerization of Polylactic Acid via Solvolysis for Value-Added Product Recovery
9	Lawrence Sawunyama	Materials Science Innovation and Modelling (MaSIM) Research Focus Area, Faculty of Natural	From Waste to Photocatalyst: Sustainable Synthesis of α-Fe_2O_3-SiO_2

		and Agricultural Sciences, North-West University, Mafikeng Campus, Private Bag X2046, Mmabatho 2735, South Africa	Nanoparticles from Coal Fly Ash for Water Treatment
10	Catalin Chersan	"Petru Poni" Institute of Macromolecular Chemistry, Department of Polyaddition and Photochemistry, Iasi, 700487, Romania	A Tunable Boronic Acid–Choline Chloride Deep Eutectic Solvent for Advanced Cellulose-Derived Triple-Network Eutectogel Architectures
11	Callum Sinclair – Wright	School of Science & Technology, Nottingham Trent University, United Kingdom	A Collaborative Investigation on the Effects of Flue Gas on Sn-based Catalysts for Continuous CO_2 Electro-reduction to Formate
12	Evan Shelton	School of Chemistry, University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom	Non-thermal plasma for greener organic chemical synthesis
13	Gaia Pedevilla	University of Genoa, Department of Civil, Chemical and Environmental Engineering, Via Opera Pia 15, I-16145 Genoa, Italy	Chlorella vulgaris as a Sustainable Strategy for Polyethylene Microplastic Biodegradation
14	Mercé Mireia	Universitat Jaume I, Department of Inorganic and Organic Chemistry, Av. Vicent Sos Baynat, s/n, 12006 Castelló de la Plana, Castelló. Spain	Thiazolidine-Grafted Zeolite Imidazolate Frameworks: A Cysteine-Derived Route to Improved Metal Loading and Tune the CO2 Hydrogenation Efficiency
15	Francesca Mazzolini	Ca' Foscari-University of Venice, Department of Environmental Sciences, Informatics and Statistics, via Torino, 155, Mestre (VE), Italy	Sustainable biorefinery approach using NaDES for the extraction of high value-added compounds from Chlorella vulgaris biomass cultivated on molasses
16	Alessia Tonelli	MOST, Institute of Condensed Matter and Nanosciences, UCLouvain, NISM, Chemistry Department, UNamur	Carbon-based Lewis/Brønsted acid catalysts for 5-HMF one-pot production
17	Davide Dalla Torre	Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Scientific Campus Via Torino 155, 30170 Venezia Mestre, Italy	A library of lignocellulose-derived monomers from 5-(chloromethyl)furfural
18	Mayu Kamisono	Kyushu University, School of Engineering, Department of Applied Chemistry, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan	Deep Eutectic Solvent-Based Selective Recovery of Platinum Group Metals from Spent Automotive Catalysts
19	Maria Francesca Vigile	National Research Council of Italy-Institute on Membrane Technology "Enrico Drioli"	Production and Recovery of Cellulose Acetate Particles By Membrane-Based Processes: A Green Scalable Strategy

		(CNR-ITM), Via P. Bucci 17/C, 87036 Rende (CS), Italy	
20	Ioana-Sabina Trifan	"Petru Poni" Institute of Macromolecular Chemistry, Department of "Polyaddition and Photochemistry", "Grigore Ghica Voda" Alley, 41A, Iasi, Romania	Role of CNF Origin in Tailoring Floating CNF–Silane Hybrid Aerogels
21	Salah Chaji	Department of Drug Science and Technology, University of Turin, Via P. Giuria 9, Turin, Italy	Integrated biorefinery approach for palm leaves: Polyphenol eco-recovery and phosphorylated nanocellulose-based packaging film development
22	Matteo Mora	University of Genoa, Department of Civil, Chemical and Environmental Engineering, Via Opera Pia 15, Genoa, Italy	Carbon Dioxide Feeding Optimization in a Closed Microalgae Photobioreactor for Space Applications
23	Marco Chiocchini	Faculty of Engineering, Free University of Bozen-Bolzano, NOI Techpark - Bruno-Buozzi-Straße 1, 39100 Bolzano, Italy	Gasification of hydrochar for the valorization of wet waste biomass feedstocks
24	Shikha Gupta	University of Twente, Drienerlolaan 5, 7522 NB Enschede, The Netherlands	Fully recyclable wood coating using liquified woody biomass: An alternative to fossil-based plastics

IN-PERSON POSTER PROGRAMME

XVII International Postgraduate Summer School on Green Chemistry

Poster session 2, Thursday,9th July 2026, **16:15-17:30**

Poster number	Name	Affiliation and country	Title
1	Bryle Matthew Bacatan	Department of Chemistry, Faculty of Science, Chulalongkorn University, Thailand	Closed-Loop Upcycling of PET into Bimetallic MOF Adsorbents via a Neoteric Solvent-Mediated Route
2	Gabriela Sofía Paronetto	IIIA-UNSAM-CONICET, Instituto de Investigación e Ingeniería Ambiental, EHyS, UNSAM, 25 de mayo y Francia, 1650-San Martín, Argentina	Green biosynthesized iron-based microparticles: Performance and ecotoxicological evaluation for Cr(VI) remediation
3	María Florencia Azcoaga Chort	Instituto de Investigaciones en Catálisis y Petroquímica (INCAPE), UNL-CONICET, Argentina	Comparative Study of PtRe(3) Catalysts Supported on Functionalized Carbon Supports for DEFC
4	Elisa Ausili	University of Bologna, Department of Industrial Chemistry "Toso Montanari", Via Piero Gobetti 85, 40129, Bologna, Italy	In-Situ Electrochemical Generation of Initiator for Ionic Polymerization
5	Manuel Salgado Ramos	Research group in Innovative Technologies for Sustainable Food (ALISOST), Department of Preventive Medicine and Public Health, Food Science, Toxicology and Forensic Medicine, Faculty of Pharmacy and Food Science, Universitat de València (UV), Burjassot, Spain	Green extraction of lignin from tiger nuts by-products via process intensification technologies and bio-derived solvents
6	Rosa Nappi	University of Naples Federico II, Department of Chemical Sciences, I-80126 Naples, Italy	The role of catechin and of catechin-rich foods in the Maillard reaction: a chemical insight
7	Tamara Hotiet	Department of Chemistry, Faculty of Science, Beirut Arab University, P.O. Box 11-5020, Riad El Solh, Beirut 11072809, Lebanon	Agro-Waste Valorization into Copper Oxide Nanoparticles for Sustainable Water Remediation
8	Alessia Ruffolo	National Research Council – Institute on Membrane Technology "Enrico Drioli", via P. Bucci 17C, 87036, Rende (CS) – Italy	Concentration of clarified red dragon fruit juice using hydrophobic P(VDF-HFP) flat-sheet membranes: a comparison of osmotic, direct contact, and vacuum membrane distillation
9	Jose Luis Mendoza Quiala	Research Laboratory of Functional Polymer Systems, Faculty of Chemistry and Pharmacy, Pontifical Catholic University of Chile (PUC), Santiago de Chile (Chile)	Transparent lignocellulosic materials functionalized with coumarins for biobased luminescent solar concentrators (LSC)

10	Simona Angelino	Department of Chemical Sciences, University of Naples Federico II, I-80126 Naples, Italy	Sustainable Polyphenol-Based Coatings Enabled by Amine-Mediated Oxidative Polymerization
11	Maria Jose Calandri	Department of Chemistry and Industrial Chemistry, University of Genoa, via Dodecaneso 31, 16146, Genova, Italy	Enzymatic route to PET like polyesters via CaLB catalysis
12	Lavinia Pitari	Politecnico of Milano, Department of Chemistry, Materials and Chemical Engineering "G. Natta" Ed. 41, Via Edoardo Bassini 6, 20133, Milano MI, Italy	Heterogeneous Pd Catalysis in Confined Spaces: The Role of Soy-Protein Cryogels
13	Adelina Vukelaj	Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "G. Natta'' (Sede Bassini: Edificio 41, Via Edoardo Bassini 6, 20133) Milano, Italy	Circular Bio-Based Aerogels via Dynamic Imine Networks for Water Remediation and Heterogeneous Catalysis
14	Giovanni Marco Maria Chisari	Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "G. Natta" (Sede Bassini: Edificio 41, Via Edoardo Bassini 6 20133) Milano, Italy	Pd-Decorated Carbon Nanostructures for Sustainable Cross-Coupling Catalysis
15	Andrea Sanchez Monedero	Dpto. Ingeniería Química Industrial y del Medio Ambiente, ETSI Industriales, Universidad Politécnica de Madrid, C/ José Gutiérrez Abascal 2, 28006 Madrid, España	Integral valorization of olive leaves through ultrasound -assisted green-solvent extraction to obtain phenols and sugars
16	Leonardo Giribaldi	Università di Genova, DCCI, via Dodecaneso 31, 16146 Genova, Italy	Design of Green Covalent Adaptable Network Materials: From Bio-Based Feedstock to Recyclable and Biodegradable Crosslinked Materials
17	Francesco Brenda	University of bologna, Department of Industrial Chemistry "Toso Montanari", via P. Gobetti, 85, 40129 Bologna, Italy	Life Cycle Assessment of an Innovative Ammonia Production Process via Electrochemical Reduction of Nitrates
18	Marco Mearelli	Laboratory of Green SOC, Dipartimento di Chimica, Biologia e Biotecnologie Università degli Studi di Perugia Via Elce di Sotto 8, Perugia 06123, Italy	Cyclooctyne Synthesis for SPAAC Applications: an alternative route to the Palladium-catalyzed Sonogashira Reaction
19	Naomi Toplis	University of Nottingham, Nottingham, UK	Extraction and Characterisation of Keratin Associated Proteins
20	Xing Wei	Laboratory of Green SOC, Dipartimento di Chimica, Biologia e Biotecnologie Università degli Studi di Perugia Via Elce di Sotto, 8, 06124 Perugia, Italy	Development of Green Electrocatalytic System for Selective Phenol-to-Cyclohexanone Conversion
21	Maithili Majithia	Department of Chemistry, University of Massachusetts	Mechanistic investigation and sustainable method development for the

		Boston, 100 William T. Morrissey Boulevard Boston, MA 02125, United States of America	synthesis of quinoxalines and benzimidazoles using Saccharomyces cerevisiae as a biocatalyst
22	Mattia Marinelli	Laboratory of Green SOC, Dipartimento di Chimica, Biologia e Biotecnologie, Università degli Studi di Perugia, Via Elce di Sotto, 8, 06124 Perugia, Italy	Biowaste-derived catalyst promotes the pH-controlled reduction and reductive formylation of nitroarenes using formic acid as LOHC
23	Julián Eduardo Sánchez Velandia	Supramolecular and Sustainable Research Group, Departamento de Química Inorgánica y Orgánica, Universidad Jaume I, Castellón, España	A Sweet Flow: HMF Production and in-situ Valorization into Valuable Nitrile-containing Compounds via Telescopic Flow Chemistry
24	Juan Enrique Chiva Celades	Department of Inorganic and Organic Chemistry, Jaume I University, Av. Vicent Sos Baynat, s/n, 12071, Castelló de la Plana, Spain	Design of novel amino acid-derived macrocyclic organometallic complexes with applications in sustainable chemistry
25	Álex Fernández Martínez	Universitat Jaume I, ESTCE, Av. Vicent Sos Baynat, s/n, Castelló de la Plana, Spain	Structure–activity Relationship of CaLB Supported on Zeolitic Imidazolate Frameworks: a Systematic Approach

ONLINE POSTER PROGRAMME

XVII International Postgraduate Summer School on Green Chemistry

Poster number	Name	Affiliation and country	Title
1	Propa Sarker	Department of Chemistry, University of Dhaka, Dhaka 1000, Bangladesh	Garlic (*Allium sativum*) as a Sustainable Bio-adsorbent for Selective Hg^{2+} and Pb^{2+} Removal from Water
2	Emanuel A. Nkotya	National Institute of Materials Physics, Laboratory 80 - Catalytic Materials and Catalysis Atomistilor, 405A, Magurele, Romania	Understanding Metal–Support Effects in CO_2 Hydrogenation to Methanol through Data-Driven Analysis
3	Linh Truong	Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark	β-TaON Photocatalysts for Enhanced Photoelectrochemical Water Splitting via Phase Control and Vanadium Doping
4	Sara El Moujahed	Laboratory of Applied Organic Chemistry, Faculty of Sciences and Technologies, Sidi Mohamed Ben Abdellah University, Imouzzer street, B.P. 2202, Fez, Morocco	Bioinspired Collagen Films Reinforced with Waste-Derived Polyphenols for Sustainable Bioactive Packaging
5	Sara Iziki	Laboratory of Materials and Environment, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco	Optimized PANI/Biomass Composite as Eco-Friendly Adsorbents for Dye Removal
6	Martina Cozzani	Università di Genova, Dipartimento di Chimica e Chimica Industriale, Via Dodecaneso 31, 16146, Genova, Italy	Green solvent-based upcycling of poly(lactic acid) into functional branched oligomers for sustainable film production
7	Fatima Jmaito	Ibn Zohr Uiversity, Faculty of Sciences, Agadir, Morocco	Ceramic Membrane Functionalization for Water Purification
8	Rayen Ben Aoun	Center of Biotechnology of Borj Cedria, Hammam-Lif – Tunisia, Laboratory of Olive Biotechnology, University of Tunis El Manar, Tunisia	From Waste to Sustainable Solutions: Green Extraction of Chitosan with Deep Eutectic Solvents for Food Coating and Plant Stress Tolerance
9	Fatima Ennafaa	Energy, Materials and sustainable Development Team, CERN2D, Higher School of Technology Salé, Mohammed V University, Rabat8007, Morocco	Study of the Relationship Between Antioxidant Activity and the Electrochemical Behavior of Ecological Steel Corrosion Inhibitors
10	Abdelkader Dabagh	Laboratory LACAPE, Faculty of Science, Ibn Zohr University, Hay Dakhla, Agadir, Morocco	Integration of artificial intelligence in leaf extract-mediated biosynthesis of copper oxide nanoparticles for multifunctional applications: wastewater remediation, phytotoxicity test, and antioxidant activity

ABSTRACTS OF STUDENTS

(alphabetical order of surnames)

Development of $CaCl_2$-crosslinked Gelatin–alginate Films Enriched with Thyme Essential Oil for Food Biopackaging Applications

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The growing concern over synthetic materials in food packaging emphasizes the pressing demand for eco-friendly and biodegradable alternatives. In this study, gelatin–alginate composite films crosslinked with calcium chloride ($CaCl_2$) and enriched with thyme essential oil were developed for food biopackaging applications. Various gelatin–alginate ratios (75:25, 50:50, and 25:75 (v:v)) were investigated to determine the optimal film formulation. The obtained films were immersed in a 1.5% $CaCl_2$ solution to evaluate the effect of crosslinking on film solubility. In parallel, six essential oils were screened for their antimicrobial activity. Among them, thyme essential oil exhibited the highest antibacterial activity and was therefore incorporated into the film-forming solution at concentrations of 3%. The antimicrobial activity of the developed films was subsequently evaluated against different bacterial strains. The obtained results revealed that the gelatin–alginate ratio of 75:25 provided the optimal film formulation. Furthermore, $CaCl_2$ crosslinking significantly reduced film solubility from 98.98% for the non-crosslinked film to 56.36% for the crosslinked film, indicating improved water resistance. Regarding antimicrobial activity, the films enriched with 3% thyme essential oil exhibited inhibitory effects against the tested bacterial strains, with inhibition zone diameters ranging from 18 to 32 mm. These findings suggest that gelatin–alginate films enriched with thyme essential oil represent a promising natural and biodegradable packaging alternative for preserving food quality.

Keywords*: Antimicrobial activity, Calcium chloride ($CaCl_2$), Gelatin-alginate films, Thyme essential oil.*

Mixed Group I & II Metal Amide–Imide Catalysts for Ammonia Decomposition

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Ammonia is attracting increasing interest as a carbon-free hydrogen carrier for sustainable energy systems owing to its high energy density and ease of storage and transport.[1-3] However, the development of efficient and thermally stable catalysts for ammonia decomposition remains a major challenge, as conventional Ru- and Ni-based systems are costly and often require high operating temperatures. Metal amides and imides have emerged as promising alternatives due to their strong basicity and potential for reversible hydrogen chemistry. Here, we report the synthesis and mechanistic investigation of a mixed Group I–Group II catalyst, sodium–calcium amide ($NaCa(NH_2)_3$), designed to combine the high reactivity of alkali metal systems with the enhanced stability of alkaline-earth frameworks. Structural analysis reveals strong similarities with lithium–calcium analogues, [1,2] while thermal studies under inert conditions demonstrate a distinct decomposition pathway involving stepwise transformation to imide-rich phases via a transient amide–imide intermediate, $NaCa(NH)(NH_2)$. Catalytic testing identifies this intermediate as the active phase for ammonia decomposition. The incorporation of transition metals, particularly Ru and Mn, lowers the onset temperature for amide–imide conversion, enabling earlier formation of the active phase and significantly enhancing low-temperature activity and high catalytic activity (77% NH_3 conversion at 519°C and 74.8% at 522°C). Overall, the results demonstrate that the Na–Ca amide system functions as a thermally stable catalytic framework in which TMs promote earlier formation of the active imide phase, thereby enabling enhanced ammonia activation and improved hydrogen release kinetics at reduced temperatures.

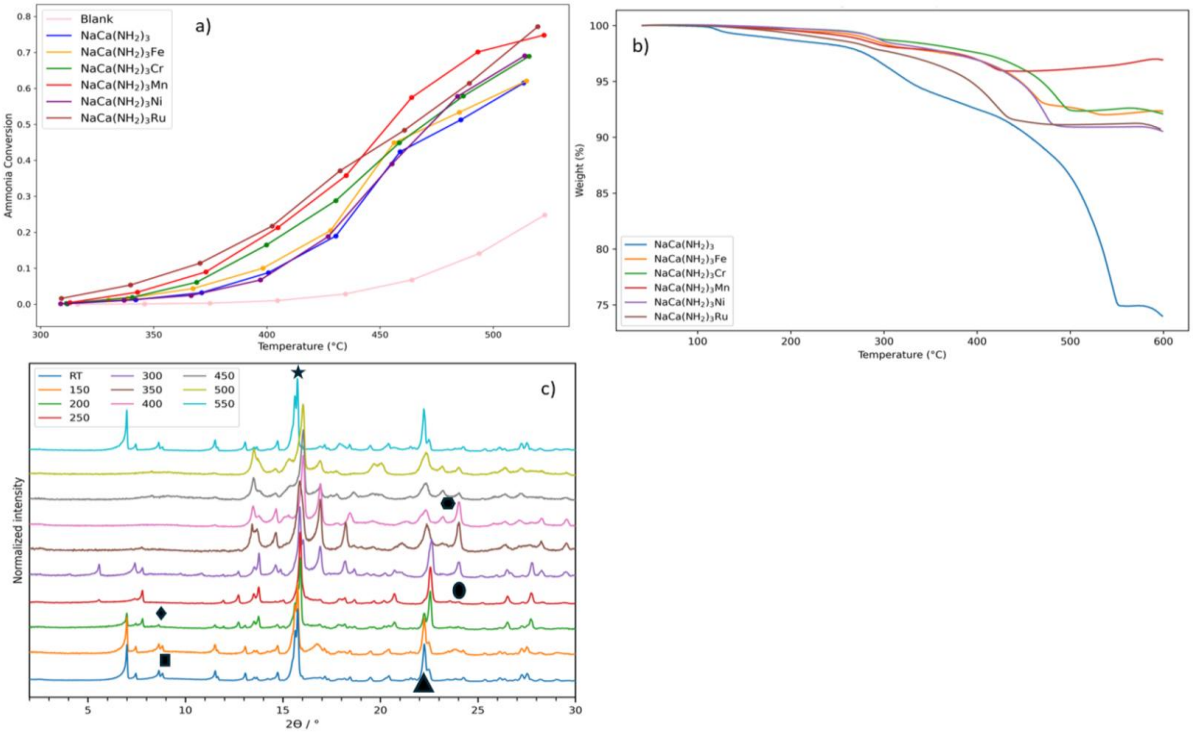


Figure 1. a) Ammonia conversion as a function of temperature, showing the intrinsic catalytic activity of $NaCa(NH_2)_3$ and the enhanced performance observed upon transition metal addition. b) Thermogravimetric analysis (TGA) profiles recorded under N_2, demonstrating the thermal stability and decomposition behaviour of the $NaCa(NH_2)_3$ with TMs within the temperature range relevant to ammonia decomposition. c) X-ray diffraction (XRD) patterns of the thermal evolution of $NaCa(NH_2)_3$ under Ar under relevant temperature range, $NaCa(NH_2)_3$, $Ca(NH_2)_2$, $NaNH_2$, CaNH ($Fm\bar{3}m$), CaNH ($Fm\bar{3}$), $NaCa(NH)(NH_2)$

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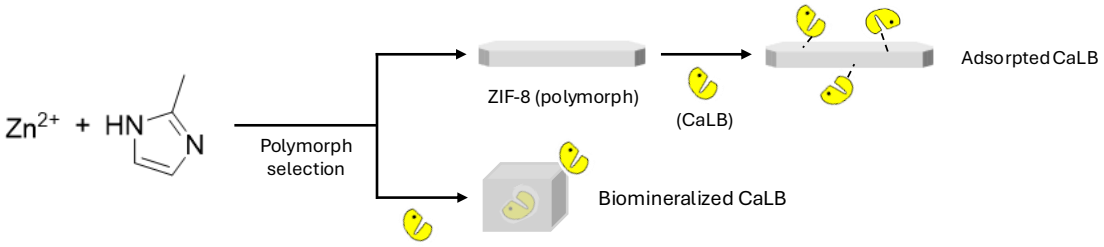
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Structure–activity Relationship of CaLB Supported on Zeolitic Imidazolate Frameworks: a Systematic Approach

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Rising ecological concerns have driven a paradigm shift in both the chemical industry and academia towards the sustainable production of chemicals. Subsequently, new and greener ways to perform chemical transformations must be developed under the framework of the 12 Principles of Green Chemistry.[1] In this context, immobilized biocatalysis offers key advantages due to its unparalleled selectivity and enhanced stability, making it a robust and powerful tool for green organic synthesis.[2]
In this regard, this work focuses on the study of structural and biocatalytic features of the resulting biocomposites from the combination of the readily tunable supporting materials zeolitic imidazolate frameworks (ZIFs) and the biocatalyst Candida antarctica lipase B (CaLB). Enzyme immobilization was achieved by following two main strategies: adsorption and entrapment (biomineralization). Biocomposite structures were characterized by ATR-FTIR and PXRD measurements and SEM imaging. Catalytic performance was evaluated by performing two model transesterification reactions using either non-chiral and chiral substrates (geraniol and (±)-1-phenylethanol, respectively) and an activated ester (vinyl propionate). Furthermore, enzyme structural integrity was examined by ATR-FTIR amide I band analysis.
Results show that the highest immobilization yields were obtained from using low concentrations and molar relationships of ZIF precursors in solution whereas buffered media at pH 8.5 and tris buffer presence at low concentrations promotes biocomposite formation and CaLB structural preservation. High thermal stability is also achieved with great activity retention upon incubation in cyclohexane at 80ºC.



Scheme 1. CaLB immobilization approaches in ZIF phases.

Keywords: *ZIFs · CaLB · adsorption · biomineralization · thermal stability*

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Sustainable Polyphenol-Based Coatings Enabled by Amine-Mediated Oxidative Polymerization

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Polyphenols are emerging as versatile building blocks for multifunctional coatings, owing to their intrinsic antioxidant, anti-inflammatory, and antimicrobial properties. Following the discovery of the remarkable wet adhesion properties of polydopamine (PDA)—a black, insoluble eumelanin-like material inspired by the robust adhesion of catechol- and amine-rich mussel byssal proteins—recent studies have highlighted how the interplay between catechol and amine functionalities promotes both covalent (e.g., Michael addition and Schiff base reactions) and non-covalent interactions, thereby enhancing film formation.[1] In this context, new opportunities have derived from the discovery that long-chain aliphatic diamines—most notably hexamethylenediamine (HMDA)—can impart strong film-forming ability when used as additives during the oxidation of *o*-diphenolic compounds not adhesive *per se*, such as caffeic acid, gallic acid or eumelanin precursors.[2] In this study this strategy is extended to a broader class of polyphenolic substrates and we investigated in detail the oxidative polymerization of phloroglucinol (PG) (**Figure 1A**), the major biosynthetic precursor of algal phlorotannins,[3] in the presence of HMDA. Aerial oxidation of phloroglucinol at 10 mM in carbonate buffer at pH 9 in the presence of two molar equivalents of HMDA led to the formation of insoluble yellowish-brown material (PG-HMDA) capable of forming robust and hydrophobic coatings on quartz and glass substrates immersed in the mixture over 24 h (**Figure 1B**). Mechanistic analyses conducted by HPLC and LC-MS revealed characteristic dimeric/oligomeric species, including an intermediate at **$[M+H]^+$= m/z 347** suggestive of a dimer of the type shown in **Figure 1C**. The resulting PG–HMDA coating was characterized by UV–vis spectroscopy, FT-IR, XPS, zeta-potential, and water contact angle measurements, revealing a nanostructured morphology and a chemical composition consistent with polyphenol–amine networks. Remarkably, the coating demonstrated excellent cytocompatibility and strong antioxidant properties, both in chemical assays and in cellular model. On the other hand, antibacterial activity was limited, although a reduction in bacterial adhesion and aggregation was observed. Given these promising results and inspired by the increasing interest in sustainable and bio-derived building blocks for functional coatings, we explored the use of naturally occurring amines as mediators of film formation. Herein we also introduce the use of **agmatine**, [4] a biogenic diamine containing a guanidinium group, as an efficient mediator of film formation from both low-molecular-weight polyphenols (e.g., caffeic acid, catechin, pyrogallol, phloroglucinol) or polymeric polyphenols like condensed tannins (**Figure 2**). Preliminary results on tannin-based coatings indicate a significant antioxidant activity, as confirmed by DPPH, FRAP, and CUPRAC assays. The biologically relevant properties of the resulting coatings including antibacterial activity will be described. Overall, this work opens the doorway to a new polyphenol–amine strategy for the development of bioinspired multifunctional coatings, highlighting agmatine as a promising alternative to aliphatic diamines for applications in tissue engineering and wound care.

Keywords: *polyphenols, hexamethylenediamine, polyphenol-based coatings, agmatine, antioxidant properties, cytocompatibility.*

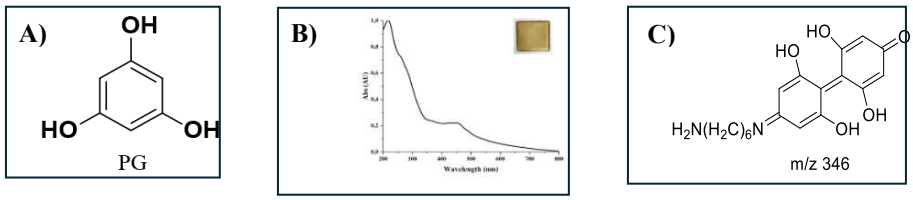


Figure 1. A) Structure of PG, **B)** UV-vis spectrum of the quartz substrate after 24 h immersion in the FG/HMDA mixture at pH 9.0, and **C)** Proposed **s**tructure of a dimer component of the mixture.

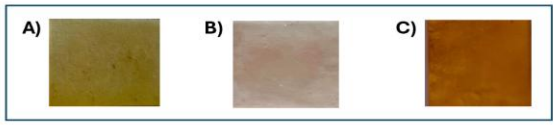


Figure 2. Pictures of the glass substrates after 24 h immersion in the mixture of agmatine and PG (**A)**, quebracho tannin **(B)** and catechin**(C)** at pH 10.

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In-Situ Electrochemical Generation of Initiator for Ionic Polymerization

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The use of lithium-based compounds as initiators is well established in industrial polymerization processes; however, their application is increasingly questioned due to safety issues, environmental concerns, and high costs. In this context, the development of alternative initiation strategies represents a relevant challenge in polymer chemistry.
Electrochemical methods provide an attractive approach for the generation of initiating species directly in situ, avoiding the use of highly reactive organolithium reagents [1]. The possibility to modulate the applied potential allows a fine control over the formation of reactive intermediates, opening new perspectives for the initiation of living ionic polymerizations.
This work focuses on the electrochemical generation of initiators from α-olefins and polycyclic aromatic hydrocarbons (PAHs) [2]. A laboratory-scale electrochemical and spectroelectrochemical setup has been developed to investigate the reduction processes under controlled conditions. The formation of the active species is achieved via potentiostatic electrolysis and monitored by amperometric techniques, enabling the study of the early stages of the initiation process.
The proposed approach highlights the potential of electrochemistry as a safer and more sustainable alternative to conventional lithium-based systems, contributing to the advancement of more environmentally responsible polymerization methodologies.

Keywords: *Electrochemical initiation, Living ionic polymerization, Lithium-free polymerization*

Acknowledgements: This research is part of a PhD project co-funded by Versalis S.p.A., which is gratefully acknowledged.

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Comparative Study of PtRe(3) Catalysts Supported on Functionalized Carbon Supports for DEFC

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Direct ethanol fuel cells (DEFCs) are attractive energy conversion devices due to the renewable nature, low toxicity, and high energy density of ethanol. However, ethanol electrooxidation remains challenging because of its complex mechanism and the formation of strongly adsorbed intermediates. In this work, PtRe(3) catalysts supported on HNO_3-functionalized mesoporous carbon (MC-HNO_3), urea-functionalized activated carbon derived from rice husk (HTC-urea), and carbonized polyaniline/carbon nanotube composites ($PANI_{50}$-NT_{50}) were comparatively evaluated to investigate the influence of support properties on ethanol electrooxidation.

The supports were synthesized and functionalized to tailor their textural and electronic characteristics. At the same time, the catalysts were prepared by the polyol method with Pt and Re loadings equal to 20 and 3 wt.%, respectively. Physicochemical and structural characterizations were carried out, and the electrocatalytic activity was mainly studied in a half-cell configuration, together with performance evaluation in prototype direct ethanol fuel cells.

The supports exhibited distinct physicochemical characteristics; for example, MC-HNO_3 showed an ordered mesoporous structure and high conductivity. In contrast, HTC-urea presented the highest surface area and microporosity due to the formation of nanowindows and the incorporation of nitrogen-containing groups. $PANI_{50}$-NT_{50} displayed intermediate textural properties and enhanced conductivity provided by the nanotube network.

Electrochemical studies revealed significant differences in catalytic behavior. PtRe(3)/HTC-urea exhibited the highest oxidation currents, lower poisoning effects, and superior stability, which were attributed to the combination of high surface area and nitrogen functionalities that favored metal dispersion and ethanol oxidation kinetics. PtRe(3)/MC-HNO_3 also showed remarkable activity owing to its ordered mesoporosity and conductivity, while PtRe(3)/$PANI_{50}$-NT_{50} presented intermediate performance.

The trends observed in half-cell experiments were consistent with prototype DEFC tests. PtRe(3)/HTC-urea achieved the highest power density and overall performance, demonstrating that the combination of enhanced microporosity and nitrogen functionalities provides the most favorable environment for ethanol electrooxidation.

Overall, the comparative analysis demonstrated that the support properties strongly determine the electrochemical and fuel cell performance of PtRe(3) electrocatalysts. Although all three catalysts exhibited promising activity toward ethanol electrooxidation, PtRe(3)/HTC-urea showed the best overall behavior in both half-cell and prototype DEFC studies, highlighting the key role of nitrogen-functionalized biomass-derived carbons in the development of efficient and sustainable electrocatalytic systems.

Keywords: *PtRe electrocatalysts, Carbonaceous materials, Chemical functionalization, DEFC.*

Acknowledgements: Authors acknowledge Universidad Nacional del Litoral, CONICET, and Universidad Católica de Santa Fe for their financial support.

Closed-Loop Upcycling of PET into Bimetallic MOF Adsorbents via a Neoteric Solvent-Mediated Route

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Plastic-to-MOF upcycling is an emerging strategy for converting post-consumer PET waste into functional metal-organic frameworks.[1,2] Nonetheless, the conventional synthesis approach relies on reprotoxic DMF, which faces increasing regulatory restrictions under EU REACH.[3] Herein, the use of a neoteric deep eutectic solvent (DES) offers a clean alternative to DMF while facilitating the mild and efficient bimetallic MOF synthesis. In this work, post-consumer PET waste was upcycled into terephthalic acid (H_2BDC) and subsequently used to synthesize a Fe-Cu bimetallic MOF via a DES-mediated route. Alkaline hydrolysis was optimized using a Box-Behnken design, achieving a conversion of >90% under optimal conditions. This linker was utilized for the DES-mediated MOF synthesis, where an iron(III) metal source was doped with 10% copper(II) in Reline (a choline chloride/urea DES) to yield a Fe-Cu bimetallic framework. The resulting material exhibits a topology that closely resembles the well-known iron-MOF structure typically obtained via conventional solvothermal routes. The upcycled bimetallic framework achieved a high As(V) adsorption capacity comparable to conventionally synthesized MOFs (exceeding 250 mg/g) and a norfloxacin adsorption capacity exceeding 400 mg/g. The plastic waste-derived material, in cadence with the elimination of toxic DMF and the reduction of thermal requirements, yielded a improved Path2Green score compared to the negative value in the solvothermal method. This works demonstrates a neoteric solvent-mediated approach for upcycling plastic waste into functional bimetallic adsorbents.

Keywords: *PET upcycling, Bimetallic MOFs, Deep eutectic solvent, Adsorption, Arsenic, Path2Green*

Acknowledgements: This work was funded by Chulalongkorn University's Scholarship for ASEAN and Non-ASEAN Countries and the 90th Anniversary of Chulalongkorn University (Ratchadaphiseksomphot Endowment Fund). In addition, the support of Green Chemistry Philippines, Pinoy Chula (Philippine Community in Chulalongkorn University), Sherwin Lu, and the Environment Analysis Research Unit for their technical and community support.

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Green Sonochemical Synthesis of Naringin-Functionalized Bismuth Nanoadjuvants with Antimicrobial Activity

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This study reports the green sonochemical synthesis, physicochemical characterization, and antimicrobial evaluation of naringin-functionalized bismuth-based nanoadjuvants. The nanostructures were obtained by ultrasonic reduction of bismuth(III) nitrate at 25 kHz using a naringin extract as a bio-reducing and stabilizing agent.

The resulting nanoadjuvants were characterized by UV–vis spectroscopy, dynamic light scattering, Z-potential analysis, Fourier-transform infrared spectroscopy, Raman spectroscopy, and scanning electron microscopy. These analyses confirmed the formation of stable, semi-spherical nanoparticles with an average diameter of approximately ≈80 nm and a negative surface charge. FTIR results verified the functionalization of the nanoparticle surface with naringin, while Raman spectroscopy provided additional information on the molecular structure associated with the naringin source.

The antimicrobial activity of the nanoadjuvants was evaluated against *Escherichia coli* and *Staphylococcus aureus* using disk diffusion assays and microdilution methods in LB medium. The bismuth-based nanostructures showed dose-dependent antimicrobial effects, with inhibition zones observed in solid media and up to 60% bacterial growth inhibition at moderate-to-high concentrations in liquid media.

Overall, these results demonstrate the potential of eco-friendly, naringin-functionalized bismuth nanoadjuvants as antimicrobial platforms. Their stability, surface functionality, and biological activity suggest promising applications in antimicrobial strategies and drug delivery systems where biocompatibility and controlled surface properties are essential.

Acknowledgments: The author acknowledges the support provided by the Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI) through the postdoctoral fellowship (CVU 861451, incidence modality) under the project titled *"Pilot study of the environmental risk of nanoadjuvants designed for biomedical applications."* Financial support from CONAHCYT-MEXICO through project CF-2023-I-1196 is also gratefully acknowledged.

Keywords: *Bismuth nanoparticles, Naringin, Antimicrobial nanoadjuvants*

From Waste to Sustainable Solutions: Green Extraction of Chitosan with Deep Eutectic Solvents for Food Coating and Plant Stress Tolerance

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Chitosan, one of the most abundant natural biopolymers, has attracted considerable interest owing to its biodegradability and biocompatibility. This study presents a sustainable framework for the extraction, characterization, and multifunctional valorization of chitosan derived from marine sources (shrimp and crab shells) and insect biomass (Black Soldier Fly pupae). A green extraction strategy based on deep eutectic solvents (DES) was developed alongside an optimized deacetylation process using reduced NaOH concentrations. Comprehensive physicochemical characterization via FTIR, XRD, SEM, TGA, DSC, NMR, and rheological analysis confirmed that DES-based extraction preserves key structural and functional properties, including degree of deacetylation and crystallinity index.

In the food sector, chitosan-based edible coatings applied alone or enriched with olive leaf extract (OLE) significantly extended the shelf life of tomatoes over 10 days of ambient storage, reducing microbial growth, limiting physicochemical degradation, and enhancing antioxidant capacity. Molecular docking analysis further revealed strong binding interactions between chitosan and key phenolic compounds, notably oleuropein, and microbial enzymes implicated in fruit spoilage, particularly cellulase and endopolygalacturonase, suggesting a mechanistic basis for the inhibition of enzymatic cell wall degradation and the delay of fruit deterioration.

In agricultural applications, chitosan is used as a seed-priming agent for tomato under stress conditions, enhancing antioxidant enzyme activity, reducing oxidative stress markers (H_2O_2 and lipid peroxidation), and improving chlorophyll content. Chlorophyll fluorescence analysis revealed increased quantum yields Y(II) and Y(I), along with higher electron transport rates ETR(II) and ETR(I), collectively indicating improved light-use efficiency across both photosystems (PSI and PSII) and enhanced protection against oxidative damage.

Taken together, these findings establish DES-based extraction as a viable green alternative for producing high-quality, functionally active chitosan, and demonstrate its dual potential as a natural food preservative and plant biostimulant. This work contributes to the development of scalable, bio-based solutions for food preservation and agricultural resilience within a circular bioeconomy framework.

Keywords: *Chitosan; Deep eutectic solvents; Green extraction; Edible coatings; Seed priming; Biopolymers*

Metal-Free Aldehyde-Rich Covalent Organic Frameworks for Hydrogen Peroxide Production from Sunlight, Water and Air

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Hydrogen peroxide (H_2O_2) is one of the most important and environmentally friendly oxidants used by modern industry, with applications spanning water and wastewater treatment, disinfection, pulp bleaching, and green chemical synthesis. Because its only by-product is water, H_2O_2 is itself a key reagent for clean technologies. Paradoxically, the way it is currently manufactured is far from green. The dominant anthraquinone process relies on a multi-step, energy-intensive cycle that consumes hydrogen gas and noble-metal catalysts and uses large volumes of organic solvents, generating considerable waste and CO_2 emissions.[1] The product must then be concentrated, stabilized, stored, and transported, raising further safety and environmental concerns. A truly sustainable route would instead produce H_2O_2 on demand from only water, air, and sunlight. Covalent organic frameworks (COFs) make this possible. These metal-free, crystalline, porous polymers can be tailored at the molecular level, making them attractive light-harvesting materials for solar H_2O_2 synthesis.[2] Here we show that engineering the chemical environment inside the pores of a COF can dramatically improve its performance. Using a sub-stoichiometric condensation strategy, we prepared two closely related COFs: PDA-TTA-COF, in which reactive aldehyde groups are periodically retained along the pore walls, and a fully condensed analogue, PDA-BPDA-COF, lacking those groups. Under simulated sunlight, the aldehyde-rich PDA-TTA-COF produced nearly seven times more H_2O_2 (11.03 mmol g^{-1}) than its fully condensed counterpart (1.60 mmol g^{-1}), together with higher quantum efficiency and excellent stability. Mechanistic, spectroscopic, and computational studies revealed why: the combination of the donor–acceptor architecture and the retained aldehyde groups improves the separation of photogenerated charges and favours a selective two-electron oxygen-reduction pathway. The triazine units of the framework act as dynamic proton relays, stabilizing reaction intermediates and enabling efficient H_2O_2 release, whereas the analogue lacking these features degrades non-selectively. Beyond this specific material, the work establishes a simple and general design principle — tuning the pore microenvironment of metal-free polymers — to make solar-driven H_2O_2 production more efficient. By replacing a fossil-based, waste-intensive industrial process with one powered only by sunlight, water, and air, it contributes directly to the green and sustainable manufacturing of a chemical that is itself a cornerstone of clean technology.

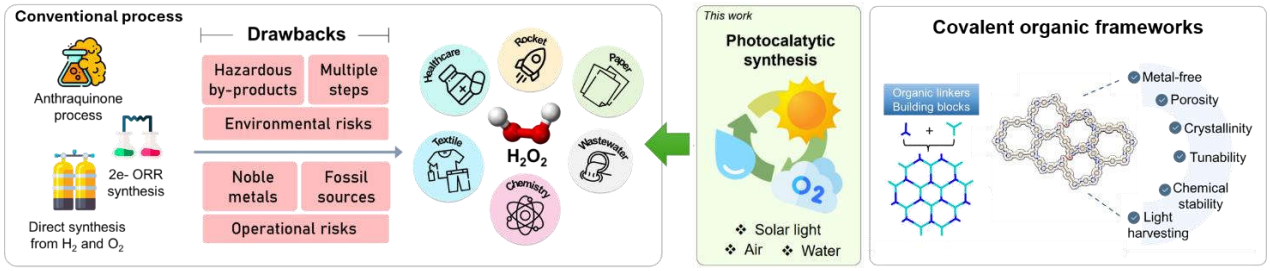


Figure 1. Schematic of the greener hydrogen peroxide production by COFs idealized in this work.

Keywords: *Hydrogen peroxide, photocatalysis, solar simulated sunlight, defects, artificial photosynthesis, oxygen reduction reaction*

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Life Cycle Assessment of an Innovative Ammonia Production Process via Electrochemical Reduction of Nitrates

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Nowadays, ammonia is one of the most common chemical products (150 Mt produced worldwide annually) as it is mainly employed as an intermediate to produce nitrogen fertilizers (around 85% of the total).[1] Alternative technologies to the energy-intensive Haber-Bosch process are gaining recent interest among researchers, e.g., the Nitrate Reduction Reaction (NO_3RR) aimed at synthesising ammonia via electrochemical reduction of nitrates, a widespread waste product and water pollutant. In this study, Life Cycle Assessment (LCA) methodology is applied to evaluate the environmental profile associated with a laboratory scale NO_3RR technology. The aim is to assess the environmental feasibility of the process by identifying hotspots—materials and processes that significantly contribute to the system's overall burdens—and to support upscaling in line with ecodesign principles. The analysis was subdivided in two levels, to focus both on the production of the flow cell (level I, FU=1 cell) and on the production of NH_3 (level II, FU=10 mg NH_3). Results indicate that polytetrafluoroethylene and iridium (a CRM) used in the assembly of cell components are the primary contributors to the total environmental impacts of the electrochemical cell. Regarding the laboratory reaction, data reveal that higher electricity consumption, driven by longer reaction times, results in increased cumulative impacts associated with the system. These insights are essential for a sustainable technology development. This work is in line with the 6th Principle of Green Chemistry, as the assessed process operates under ambient temperature and pressure.[2]

This project received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No. 948769, project title: SuN$_2$rise).

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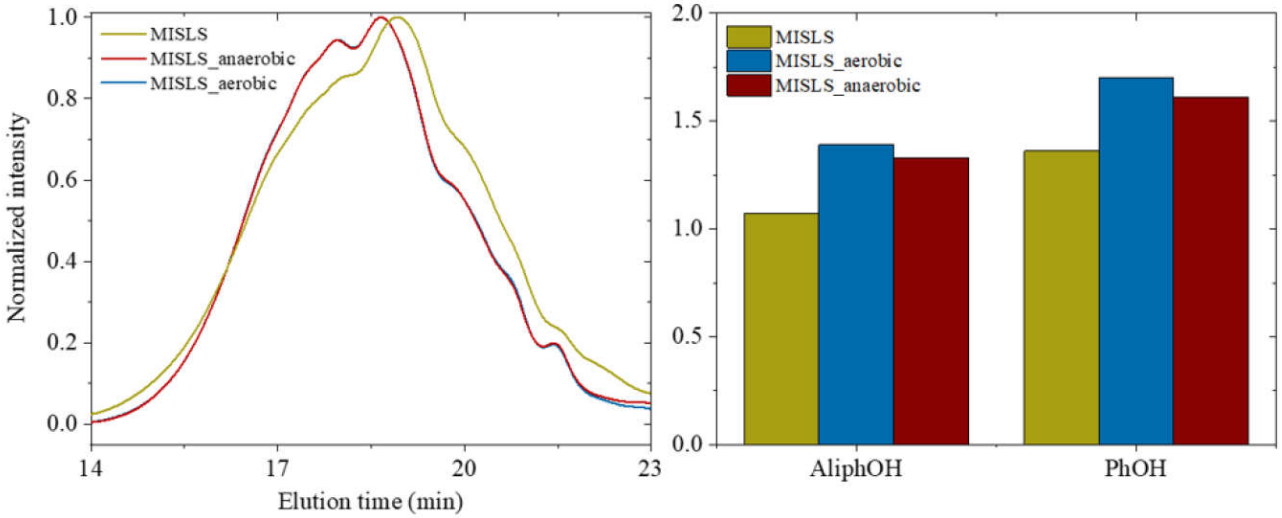
Microbial Upgrading of Technical Lignins by *Rhodopseudomonas palustris*

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Transitioning to a greener economy requires innovative strategies for recycling industrial waste and transforming it into high-value products. Technical lignins (TL), abundant byproducts of pulp and paper processes and modern biorefineries,[1] are currently mostly incinerated for energy generation. The LUCE Project combines biotechnology and materials science to transform TL into advanced biomaterials, promoting an efficient bioeconomy strategy.

To achieve the project goals, softwood lignosulfonate was selected as a prime candidate due to its excellent water solubility. To reduce structural heterogeneity and eliminate low-molecular-weight contaminants or free sugars, the technical lignin was fractionated using methanol. The resulting methanol-insoluble fraction (MISLS) was supplied to the purple bacterium Rhodopseudomonas palustris under both aerobic (MISLS_aerobic) and anaerobic (MISLS_anaerobic) conditions. The subsequent changes in MISLS macromolecular structure after incubation were evaluated through advanced analytical techniques, including 2D HSQC, ^{31}P NMR spectroscopy and GPC, providing insights into the utilization of MISLS by the microbial strain. Specifically, GPC analysis revealed a clear shift in the molecular weight distribution, showing an increase in the number-average molecular weight (M_n) of both MISLS_aerobic and MISLS_anaerobic (3900 g/mol) compared to the pristine MISLS (2900 g/mol). This was accompanied by a narrowing of the dispersity, which decreased from 7.9 to 6.1, suggesting that the low-molecular-weight fraction were preferentially consumed. Concurrently, quantitative 31P NMR analysis highlighted a significant variation of the content of OH functionalities, as an enrichment in aliphatic hydroxyls (from 1.07 to ~1.36 mmol/g) and total phenolic hydroxyls (from 1.36 to ~1.65 mmol/g), was observed.



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Acknowledgements: This study was carried out in the framework of the LUCE PRIN Project (CUP N. H53C24000740006) (Mission 4 Component 2 Investment 1.1) funded by the European Union Next-Generation EU – National Recovery and Resilience Plan (NRRP).

Enzymatic route to PET-like polyesters *via* CaLB catalysis

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This study focuses on the enzymatic polymerization of a set of disubstituted aromatic monomers mediated by *Candida antarctica* lipase B (CaLB), to produce homopolymeric esters. The concurrent presence of an alcoholic functionality and an ester group on the aromatic ring allows the formation of homopolymers, materials that are highly appealing yet only marginally investigated in enzymatic catalysis. All monomers exhibit the same *para*-regiochemistry but differ in their functional groups, comprising aromatic alcohols (phenols), linear aliphatic alcohols, and phenolic/benzoic carboxylic esters applied in all possible combinations. This structural diversity constitutes the primary factor dictating their reactivity. Beyond substrate structure, the reaction medium was systematically assessed, while maintaining constant operational parameters such as enzyme loading, applied vacuum, and reaction duration. Furthermore, several solvents were compared during the polymerization, more specifically the conventional DPE, the bio-based alternatives Cyrene and Cygnet 2, and, when possible, solvent-free conditions. Likewise, the effect of monomer concentration was also investigated. The findings indicate that the most decisive variable is the nature of the alcoholic group, while others parameter have minimal influence on the degree of polymerization (DP). Phenolic substrates display no reactivity, whereas masking the aromatic hydroxyl group with an alkyl substituent markedly improves conversion. Overall, the resulting polymers show moderate chain lengths, in line with enzymatic polymerizations involving aromatic substrates. For most monomers containing non-aromatic alcohol residues, the isolated polymers reach degrees of polymerization around DP ≈ 15. Bulk reactions afford lower values (approximately DP ≈ 8), suggesting that although a solvent is not strictly required, its presence provides a beneficial effect. It was demonstrated that the substitution of conventional solvents (DPE) with bio-based alternatives, such as Cyrene and Cygnet 2, is possible for certain monomer polymerizations. This replacement constitutes a relevant advancement toward more sustainable polymerization methodologies.

Key words: *Enzymatic process, sustainable, aromatic homopolyester.*

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Mechanochemical Amidation Mediated by 1,1′-Oxalyldiimidazole for the Synthesis of Agrochemicals

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Amide bond formation is among the most frequently performed transformations in the synthesis of pharmaceuticals and agrochemicals, yet it traditionally relies on hazardous or poorly sustainable activation chemistry, chlorinating agents that release corrosive gases, or uronium and phosphonium coupling reagents that generate large amounts of waste and complicate purification. Mechanochemistry offers a greener route to amide bond formation, avoiding bulk solvent while often improving reaction rates and accessing reactivity unavailable in solution. Within this framework, 1,1′-carbonyldiimidazole (CDI) is an attractive, affordable acyl transfer agent with which the only by-products obtained are imidazole and CO_2, and it has already been used for mechanochemical amidation.[1] CDI, however, becomes inefficient with poorly nucleophilic, electronically deactivated carboxylic acids.
Here we introduce 1,1′-oxalyldiimidazole (ODI),[2] a more reactive analogue of CDI, as an activating agent for the mechanochemical synthesis of amides, to the best of our knowledge, never explored so far.[3] We applied the method to three marketed antifungal agrochemicals (*i.e.* Mepronil, Flutolanil and Fluxapyroxad) at gram scale and extended the scope to a library of ten amides to benchmark CDI- against ODI activation method. Reactivity was examined in both vibrating (VBM) and planetary (PBM) ball mills, and across two planetary devices of different geometry and acceleration.
To place the comparison on a quantitative footing, a publicly available kinematic tool[4] was used to separate the cumulative energy delivered over the milling run from the energy of a single impact. Greater energy input did not translate into higher conversion, underscoring that mechanochemical optimization is multifactorial, balancing chemical reactivity, rheology and process parameters. Real-time temperature and pressure measurements, with CO_2 evolution as a kinetic marker, were interpreted with a dedicated kinetic model.[5] The profiles were sigmoidal and strongly substrate-dependent, with reactivity decreasing in the order Fluxapyroxad > Flutolanil > Mepronil, and an early, mechanically driven stage giving way to a reaction-controlled regime.
ODI outperformed CDI for the deactivated (fluorinated) acids of Flutolanil and Fluxapyroxad. All targets were recovered by precipitation in water and filtration, and the greenness of the mechanochemical reactions[5] was assessed by CHEM21[6] and DOZN™ 3.0 toolkits[7] showed that, for Flutolanil and Fluxapyroxad, both mechanochemical routes surpass their solution counterparts despite lower yields, driven by solvent avoidance and a benign work-up.
The results establish ODI as a valid alternative to CDI for mechanochemical amide synthesis, particularly for the electronically demanding substrates that are common in the agrochemical industry.

Keywords: *Mechanochemistry, Ball-milling, 1,1'-oxalyldiimidazole (ODI), 1,1'-carbonyldiimidazole (CDI), Amide bond, Agrochemicals, Reaction kinetics, Green metrics*

Acknowledgements: A.C. is grateful to Campus France and Tallinn Technological University (TalTech) for the Ph.D. fellowship (co-tutelle de thèse France-Estonie). E.C. and A.N. are grateful to Campus

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Integrated biorefinery approach for palm leaves: Polyphenol eco-recovery and phosphorylated nanocellulose-based packaging film development

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The development of integrated biomass valorization approaches using its valuable components have emerged as a promising strategy to achieve zero-waste objectives. The aim of this work is to develop a holistic approach focusing on the recovery of the phenolic fraction of palm leaves, an abundant agricultural residue, and subsequently using the remaining solid residues to prepare nanocellulose fibers (CNF) with the aim to develop biobased packaging films (Figure 1). To this end, ultrasound-assisted extraction (UAE) of phenolic compounds was optimized and the CNF obtained using the remaining solid residue was phosphorylated (Ph-CNF) and incorporated into 1% polyvinyl alcohol (PVA) polymeric solution at 2.5, 5, 10 and 20% with respect to the PVA content. The optimal film formulation was identified based on its mechanical performance and thermal behavior and further comprehensively characterized with respect to its structural, morphological and thermal features. The findings revealed that UAE proved to be an efficient and rapid method for the recovery of phenolic compounds in comparison with conventional dynamic maceration, with optimal conditions identified at 40% ethanol, a solid-to-liquid ratio of 1:20 (w/v), and particle size below 0.50 mm, while pulsed UAE at 40 °C and high amplitude maximized extraction yields (35.2 mg gallic acid equivalent/g dry weight (DW) for total phenolic content and 7.3 mg kaempferol equivalent/g DW for total flavonoids). The incorporation of Ph-CNF into PVA improved the properties of the resulting films in comparison to neat PVA, particularly in terms of mechanical and thermal stability and flameretardant properties, due to enhanced intermolecular interactions and char-forming ability. In particular, an optimal balance between mechanical properties (strength and flexibility) and thermal stability was achieved at 10% Ph-CNF loading. These outcomes highlight the potential valorization of residual biomass to produce bioactive extracts intended for food and health-related applications, as well as functional fractions suitable for the development of bio-based packaging films with enhanced mechanical and thermal performance, thereby supporting zero-waste strategies.

Keywords: Biomass valorization; phenolic compounds; cellulose; phosphorylation; biofilms; food packaging.

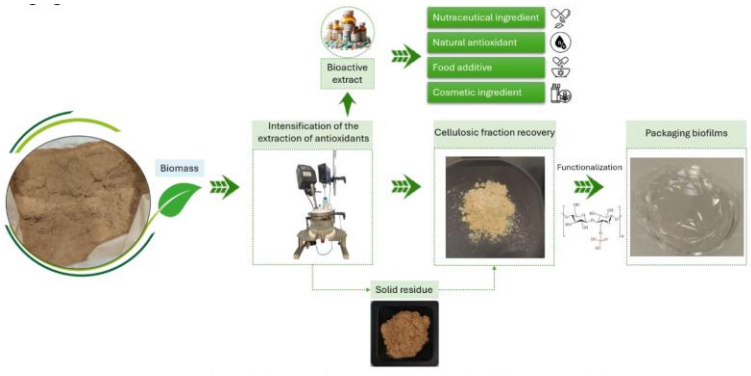


Figure 1. General workflow of the proposed palm leaf biomass valorization.

A Tunable Boronic Acid–Choline Chloride Deep Eutectic Solvent for Advanced Cellulose-Derived Triple-Network Eutectogel Architectures

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Deep eutectic solvents (DES) are a new class of green solvents related to ionic liquids, obtained by mixing hydrogen bond donors (HBD) and hydrogen bond acceptors (HBA) in specific molar ratios. The resulting hydrogen-bonding network leads to a significant depression of the melting point relative to the individual components [1]. Cellulose is a naturally abundant and renewable polysaccharide with a highly structured hydrogen-bonding network, providing excellent mechanical properties and structural integrity. Its biocompatibility, chemical versatility and its ability to form promising gel systems with other natural or synthetic polymers makes it an attractive candidate for hydrogel and eutectogel development [2]. This study aims to design and fabricate a triple-network eutectogel composed of poly(vinyl alcohol), dialdehyde-functionalized nanofibrillated cellulose, and a polyamine derived from polyacrylonitrile, employing a novel deep eutectic solvent based on choline chloride and 4-carboxyphenylboronic acid as the reaction and structuring medium. The resulting eutectogel is anticipated to exhibit enhanced mechanical robustness, autonomous self-healing capability, and significant ionic conductivity, thereby demonstrating strong potential for advanced applications in healthcare technologies and soft robotic systems. A choline chloride-4-carboxyphenylboronic acid DES was successfully prepared via lyophilization of a mixture of two solutions: choline chloride in water and 4-carboxyphenylboronic acid in DMF, at an optimal molar ratio of 1:1. The obtained DES was characterized using FTIR spectroscopy, NMR, thermal analysis techniques, and microscopic methods.



Figure 1. Appearance of the ChCl:4-CPhB DES mixtures in different molar ratios after lyophilization.

Keywords: cellulose, deep eutectic solvents, DES, eutectogel, green solvents, soft robotics

Acknowledgment: This work was supported by a grant of the Ministry of Education and Research, CNCS – UEFISCDI, project number PN-IV-P1-PCE-2023-0558, within PNCDI IV.

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Gasification of hydrochar for the valorization of wet waste biomass feedstocks

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The consumption of fossil fuels in the energy sector led to a frightening increase in greenhouse gas (GHG) emissions causing the climate change, making it essential to find alternative renewable energy sources [1]. In this context, waste biomass can be valorized into renewable energy through sustainable biorefinery approaches [2]. For instance, gasification is a thermochemical treatment which allows for the conversion of carbonaceous solids into a combustible gas, but it requires feedstocks with proper fuel properties (i.e. high calorific value, low moisture and low ash content) [3]. However, waste biomass, such as sewage sludge, food waste and municipal solid waste, are typically characterized by poor fuel properties (e.g. high moisture content, low calorific value). In this perspective, hydrothermal carbonisation (HTC) can be an effective pre-treatment to improve waste biomass for gasification purpose, converting directly the wet biomass into a carbonaceous solid (known as hydrochar) with improved fuel properties and higher hydrophobicity [4], [5]. Even if the two thermochemical treatments have been widely studied in scientific literature, only few studies focused on their integration for waste biomass valorization. In this work, a literature review of the topic was carried out to assess the effectiveness of this technology and the existing research gaps, highlighting that most of the studies about hydrochar gasification investigated it using batch laboratory scale configurations. On the other hand, the only few studies which investigated gasification of hydrochar using continuous configurations did not focus on exploring the impact of HTC conditions on gasification performance. In this regard, the future experimental activity will consist of producing hydrochars from different HTC conditions using 1 L Parr reactor starting from sewage sludge as biomass feedstock, followed by gasification of the hydrochars using an updraft fixed-bed continuous gasifier (1 kg/h), evaluating the properties of the produced gas. Therefore, this research work will focus on the integration of HTC and gasification for the valorization of waste biomass, with the aim of assessing the trade-offs of this biorefinery approach.

Keywords: Hydrothermal carbonisation, Gasification, Waste biomass, Renewable energy.

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Pd-Decorated Carbon Nanostructures for Sustainable Cross-Coupling Catalysis

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The development of efficient, recoverable and sustainable catalytic systems remains a key challenge in modern synthetic chemistry. In this work, we report the preparation of Pd-decorated carbon nanostructures obtained through a pyrrole-based functionalization methodology, a simple, versatile and environmentally friendly approach that enables the covalent grafting of Janus pyrrole derivatives onto sp^2 carbon allotropes via domino reactions (Fig.1) [1] [2]. This functionalization strategy enables the controlled anchoring of palladium species onto the carbon surface [3], bridging homogeneous and heterogeneous catalysis by combining high catalytic performance with recoverability.

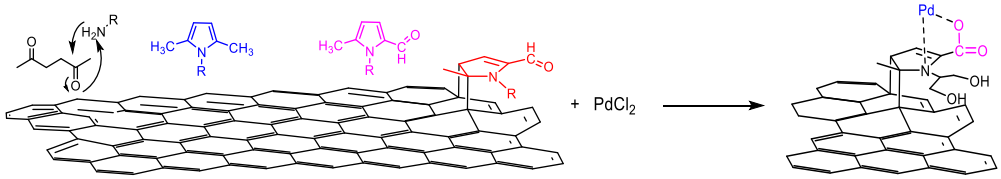


Fig.1: Carbon allotropes functionalization with pyrrole compound and anchorage of Palladium

The resulting materials were characterized by FTIR, TGA and XRD, supporting successful grafting and Pd incorporation. Their catalytic performance was evaluated across a broad range of C–C cross-coupling reactions, including Suzuki–Miyaura, Heck and Sonogashira transformations. Under optimized conditions, the catalysts delivered high yields, up to 99%, even with very low Pd catalyst loading, 0.1 mol%, short reaction times, as low as 5 min at 80 °C, and benign solvent mixtures. Recyclability tests demonstrated excellent stability and reusability, with minimal loss of activity over multiple cycles. Taken together, these results highlight a robust, scalable and sustainable platform for the development of high-performance Pd-based catalysts, offering a promising route toward greener and more efficient cross-coupling methodologies.

Keywords: Pyrrole grafting; Pd–carbon catalysts; Sustainable cross-coupling

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We acknowledge the Circular Economy Lab for Life Sciences-CELLS within the MUSA –Multilayered Urban Sustainability Action –project, funded by the European Union –NextGenerationEU, under the National Recovery and Resilience Plan (NRRP) Mission 4 Component 2 Investment Line 1.5: Strenghtening of research structures and creation of R&D "innovation ecosystems", set up of "territorial leaders in R&D".This research was funded by Made in Italy–Circular and Sustainable (MICS) Extended Partnership funded by the European Union Next-Generation EU (Piano Nazionale di Ripresa e Resilienza (PNRR)–Missione 4, Componente 2, Investimento 1.3–D.D. 1551.11-10-2022, PE00000004) for financial support.

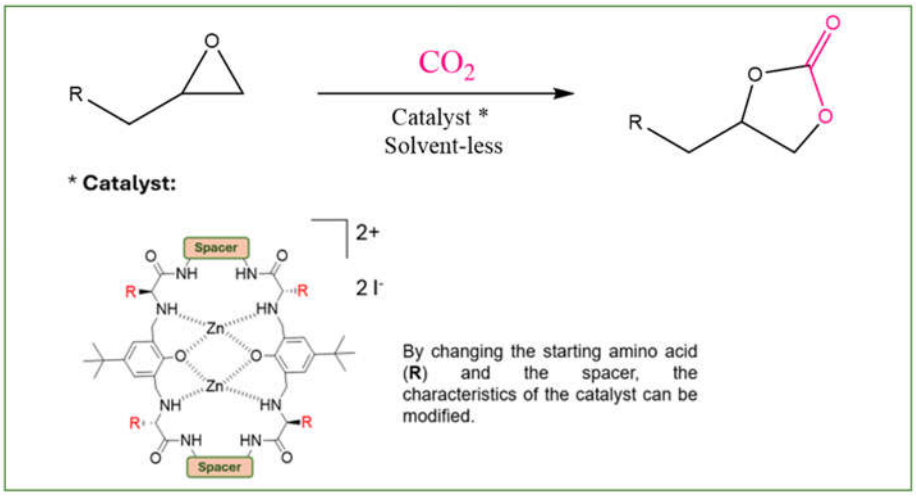
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Design of novel amino acid-derived macrocyclic organometallic complexes with applications in sustainable chemistry

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The continuous increase of carbon dioxide emissions into the atmosphere has intensified research efforts aimed at its capture, activation, and transformation into value-added chemicals.[1] Within the range of available strategies for CO_2 utilization, the development of efficient catalytic systems for the production of cyclic carbonates has attracted significant attention.[2] Our group has previously shown that these complexes exhibit outstanding catalytic performance under mild reaction conditions in the cycloaddition of CO_2 to epoxides, without the need for additional co-catalysts (Scheme 1).[3]
Based on these results, this study proposes the modification of the organometallic catalyst to improve its catalytic performance, as well as the exploration of new green chemistry model reactions in which these catalysts could be applied.



Scheme 1. Zn-based macrocyclic catalysts for the cycloaddition of CO_2 to epoxides

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FROM RENEWABLE AROMATICS TO HIGH-PERFORMACE THERMOSETS: Synthesis, Performance, and Toxicity Screening of Novel Biobased Diamines for Epoxy Curing

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Aromatic diamine hardeners are critical for high performance epoxy thermosets, yet renewable aromatic diamines remain scarce, and conventional hardeners raise health concerns. Here we report three aromatic diamines prepared from aromatic amino-acid-derived feedstocks via (i) diketopiperazine dimerization followed by a nitration-reduction reaction to give Cyclo(4-amino-Lphenylalanine-4-amine-L-phenylalanine) (ADKP), (ii) a pathway from p-coumaric acid to 1,3-diamino-4-ethylbenzene (EBDA), and (iii) nitration-reduction of phenylethylamine to 4-(2-aminoethyl)- aniline (AEA). The diamines were used as curing agents for biobased epoxy resins and benchmarked against fossil-derived toluene diamine (TDA) and 4,4′-methylenedianiline (MDA) and a biobased 4,4′- diaminostilbene (AS). The resulting thermosets reached glass transition temperatures (Tg) up to 78 °C and exhibited Young's moduli of ~1.7−2.1 GPa with a low soluble fraction (<0.1%). To address safety-by-design, the biobased diamines were screened in OECD-align in vitro assays for eye/skin irritation, skin sensitization (KeratinoSens), and bacterial mutagenicity (Ames). ADKP showed the most favorable preliminary hazard profile, motivating further validation. These results broaden the design space for renewable aromatic hardeners for epoxy thermosets.

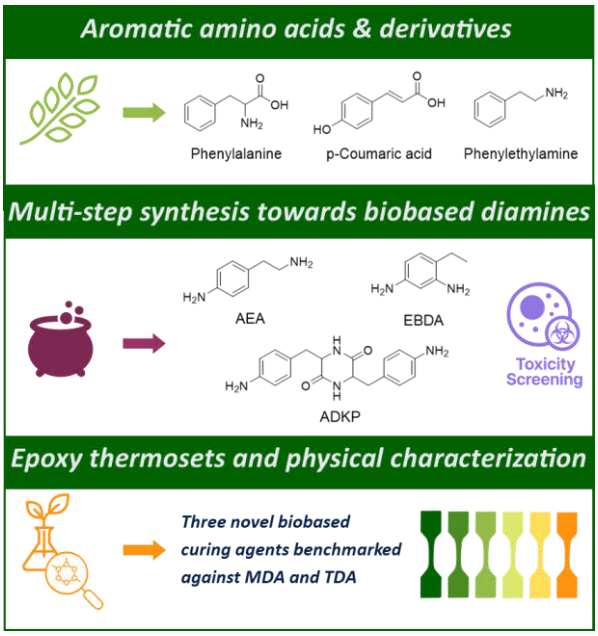


Figure 1 Sustainable design strategy: renewable aromatic compounds are converted into biobased diamines for epoxy curing, integrating synthesis, thermoset performance evaluation, and early-stage in vitro toxicity screening to enable safer, high-performance materials.

Keywords: Biobased amines, Toxicity assessment, Curing agents, Biobased epoxy thermosets, Sustainable organic synthesis

Acknowledgements
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Green solvent-based upcycling of poly(lactic acid) into functional branched oligomers for sustainable film production

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The transition towards a circular plastics economy requires sustainable strategies that allow the valorization of the end-of-life of bioplastics, while minimizing the environmental impact of recycling processes. [1]
In this work, a green and scalable upcycling approach for post-consumer poly(lactic acid) (PLA) was developed through alcoholysis in dihydrolevoglucosenone (Cyrene®), a bio-based solvent derived from cellulose. [2] The reaction was carried out using pentaerythritol as a polyalcohol and zinc stearate as a catalyst, two low impact reagents suitable for sustainable polymer processing, yielding highly functional branched PLA oligomers.
A key feature of the proposed methodology is the direct use of the reaction medium without purification of the alcoholysis products. Indeed, high-molecular-weight PLA was added into the same reaction mixture and processed into porous films via Non-solvent Induced Phase Separation (NIPS). This strategy did not require additional separation and purification steps, thereby reducing waste generation, solvent consumption and overall process complexity. Structural characterization confirmed the formation of branched oligomers with significantly reduced molecular weight and hydroxyl functionalities. When incorporated into PLA-based porous films, these upcycled additives enhanced the functional properties, increasing water uptake, improving the retention of a model cationic compound and accelerating enzymatic degradation under mild conditions.
To further improve process sustainability, Cyrene® was successfully recovered from the water/solvent mixture that had been generated during the film production step through simple distillation and was then reused without detectable loss of purity, thus enabling a closed-loop approach.
Overall, this work demonstrates how green solvent technology, waste valorization and solvent recycling can be integrated into a single circular strategy for PLA upcycling, transforming biopolymers into high-value functional materials while respecting the key principles of green chemistry and sustainable materials design.

Keywords
PLA upcycling – Green solvent – Circular economy

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Integration of artificial intelligence in leaf extract-mediated biosynthesis of copper oxide nanoparticles for multifunctional applications: wastewater remediation, phytotoxicity test, and antioxidant activity

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This study presents the green synthesis of copper oxide nanoparticles (CuO-NP) utilizing an extract from *Carpobrotus edulis* leaves, and evaluates their effectiveness in the removal of phosphate ions (PO_4^{3-}) and Malachite Green (MG) dye from aqueous solutions. The CuO-NP were subjected to physicochemical characterization, which indicated that the redox processes were carried out effectively. Furthermore, the material exhibited promising properties for the removal of both types of pollutants such as numerous adsorption groups (carbonyl groups, phenolics, and other reducing agents), high specific surface area (301.2 m^2/g), and SEM presented the pore of various sizes. The percentage of elimination from the best combination of variables of the adsorption process is obtained using a two- step optimization, namely, the Taguchi experimental design (TED) followed by response surface methodology (RSM). The findings results indicate that the two-step optimization approach, incorporating both TED and RSM, achieves superior removal performance compared to the single-step process. The kinetic values were consistent with the pseudo-second order model with higher R^2 and lower χ^2 and APE values. The maximum adsorption capacity of PO_4^{3-} and MG was determined by the equilibrium study, with 807.76 and 668.07 mg/g, respectively, and the experimental values were most consistent with the Freundlich model. After five regeneration cycles, the regeneration efficiency remained at 75.44% for PO_4^{3-} and 63.98% for MG, indicating sustained performance. These results underscore the viability of synthesizing CuO-NP using *C.edulis* extract and demonstrate their potential for applications in phytotoxicity assessment, antioxidant activity, and environmentally sustainable treatment of municipal wastewater.

Keywords: Biosynthesis, Copper oxide nanoparticles, Phosphate ions and MG dye removal, Adsorption mechanism, Design of experiments, Multifunctional applications.

Aromatic diamine hardeners are critical for high performance epoxy thermosets, yet renewable aromatic diamines remain scarce, and

A library of lignocellulose-derived monomers from 5-(chloromethyl)furfural

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The ultimate goal of the Biorefinery is to move away from a fossil-based business towards a more sustainable industry centered on the use of renewable feedstocks, capable of respecting the principle of the circular economy [1]. Among the various furan-derived compounds obtained from carbohydrate-rich feedstocks, 5-(chloromethyl)furfural (CMF) has recently attracted increasing attention.[2] CMF has largely been regarded as an impurity and has consequently been removed during downstream purification or discarded in side streams without further valorization.[3] Only in recent years this molecule has gained recognition as a valuable Bio-Based platform chemical due to its stability, hydrophobicity, and easier extractability compared to 5-hydroxymethylfurfural (HMF).[4] In this work, CMF was successfully employed as a versatile biomass-derived platform molecule for the synthesis of a library of lignocellulosic (LC) monomers. The optimal conditions involved the reaction of CMF and vanillin in a 1.0:1.0 molar ratio in the presence of K_2CO_3 (1.0 eq. mol) in acetonitrile, affording the desired product (Fur-Van monomer) in only 2 h. These conditions were subsequently extended to a range of lignin-derived monomers bearing aldehyde, ketone, ester, and allyl functionalities, demonstrating the broad applicability of the methodology. The protocol was successfully scaled up to 5.0 g of CMF while maintaining high isolated yields. Furthermore, the LC monomers were readily converted into the corresponding (di)ol derivatives through a straightforward reduction, affording a complementary library of LC diol monomers in high yields. All compounds were comprehensively characterized by spectroscopic and thermal analyses, including DSC and TGA, demonstrating their suitability as monomers for polycondensation processes leading to highmolecular-weight polymeric materials.

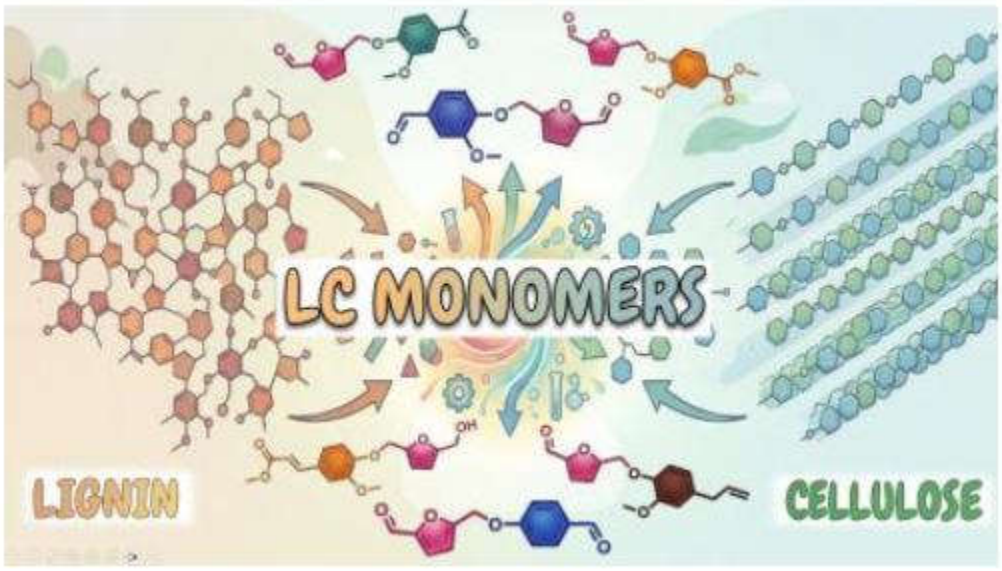


Figure 1. CMF: a gateway to a library of lignocellulose-derived monomers.

Keywords
Bio-Based platform chemicals, 5-(chloromethyl)furfural (CMF), lignin-derived monomers, lignocellulosic monomers, waste valorization.

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Bioinspired Collagen Films Reinforced with Waste-Derived Polyphenols for Sustainable Bioactive Packaging

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The increasing demand for sustainable and biodegradable materials has intensified interest in the development of bio-based alternatives to conventional petroleum-derived packaging. Among natural polymers, collagen represents a promising candidate due to its biodegradability, biocompatibility, and excellent film-forming properties. Nevertheless, its poor physicochemical stability and high water sensitivity limit its practical application. In this work, a bioinspired approach was developed to reinforce collagen films using tannins extracted from pomegranate peel waste as natural polyphenolic crosslinking agents. This strategy combines green material engineering with agro-industrial waste valorization within a circular bioeconomy framework.

The current investigation used six cross-linker extracts from six different pomegranate varieties. Collagen films containing different tannin concentrations were successfully prepared and characterized using UV–Vis spectroscopy, TEM microscopy, Fourier transform infrared spectroscopy (FTIR), swelling and solubility measurements, and thermogravimetric analysis (TGA). FTIR analysis confirmed the establishment of intermolecular interactions between collagen and tannins through polyphenol-mediated crosslinking. The incorporation of tannins significantly improved film stability by reducing water solubility and swelling behavior compared to non-crosslinked collagen films. Nanoscaled observations confirmed the tannins polymerization degree effect on the cross-linking density via the overlap sequences on the fibril. In addition, the films exhibited improved opacity and UV-barrier properties, which are highly desirable features for active and sustainable packaging applications.

The obtained results demonstrate that waste-derived tannins can act as efficient natural stabilizing agents for collagen-based materials while simultaneously imparting functional properties relevant to bioactive packaging systems. Beyond replacing synthetic crosslinkers, this work proposes an environmentally friendly route for transforming agricultural residues into high-value functional biomaterials with potential applications in sustainable packaging and advanced green materials.

Keywords: Bioinspired materials, Agro-waste valorisation, Polyphenols, Crosslinking, Collagen films, Sustainable Packaging.

Study of the Relationship Between Antioxidant Activity and the Electrochemical Behavior of Ecological Steel Corrosion Inhibitors

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The development of environmentally friendly corrosion inhibitors has attracted increasing attention as an alternative to conventional toxic inhibitors. This study investigates the relationship between the antioxidant activity and the electrochemical performance of a plant extract as a green corrosion inhibitor for C38 steel in 1 M HCl solution. The plant extract was obtained by hydroethanolic extraction and characterized through the determination of total polyphenol and flavonoid contents. Corrosion inhibition performance was evaluated using potentiodynamic polarization (PDP), electrochemical impedance spectroscopy (EIS), and scanning electron microscopy (SEM).
The results revealed that the extract is rich in phenolic compounds, which are responsible for its remarkable antioxidant activity. Electrochemical measurements demonstrated that the inhibition efficiency increased with extract concentration. Potentiodynamic polarization indicated that the extract acts as a mixed-type inhibitor, while EIS measurements showed a significant increase in charge transfer resistance, confirming the formation of a protective adsorbed layer on the steel surface. SEM observations further confirmed that the inhibitor effectively reduced surface deterioration by forming a compact protective film.
These findings demonstrate a strong correlation between the antioxidant properties of the plant extract and its corrosion inhibition performance. Therefore, the investigated extract represents a promising, sustainable, and eco-friendly alternative for protecting steel in acidic environments.

Keywords: Green corrosion inhibitor; Plant extract; Antioxidant activity; Electrochemical impedance spectroscopy; Potentiodynamic polarization; C38 steel; 1 M HCl.

From Organic Matter to Energy: How Electrolyte Configuration Controls Hydrogen Production during Electrochemical Wastewater Treatment

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The integration of wastewater treatment and renewable energy generation is a key challenge for the development of sustainable technologies. Electrochemical oxidation offers a promising approach for both organic pollutant degradation and the simultaneous generation of H_2 and O_2, two energy carriers with potential applications in fuel cell systems [1]. In this study, glucose (0-100 ppm) was used to evaluate the influence of electrolyte configuration on organic matter degradation and H_2 production during electrochemical treatment using boron-doped diamond (BDD) and Ti/RuO_2-IrO_2-Sn_2O_3 (DSA) anodes. Three sulfuric acid (H_2SO_4) and perchloric acid ($HClO_4$) electrolyte configurations were investigated in a divided electrochemical cell, while gas evolution was monitored in real time by Differential Electrochemical Mass Spectrometry (DEMS). The results revealed that both electrode material and electrolyte configuration significantly influenced glucose oxidation and gas evolution. More importantly, H_2 production strongly depended on the electrolyte arrangement between anodic and cathodic compartments (Fig. 1), indicating that the electrolyte selected for the anodic compartment can significantly influence cathodic H_2 generation, providing a strategy to balance selective anodic oxidation with enhanced energy recovery. These findings highlight electrolyte configuration as a key design parameter for coupling wastewater treatment and energy recovery in electrochemical systems.

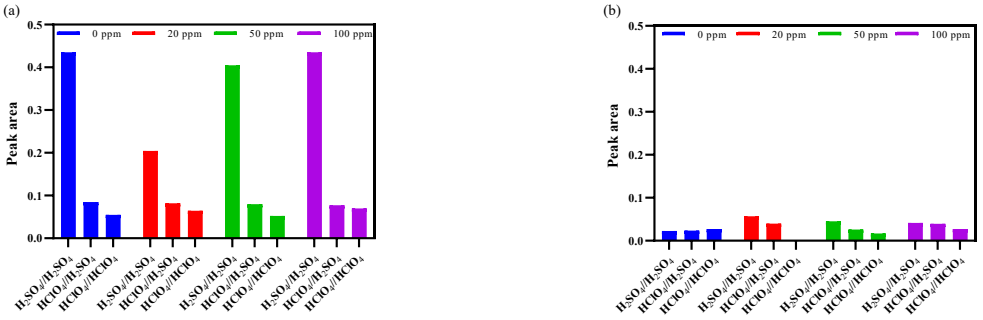


Figure 1. Hydrogen production measured by a DEMS with (a) BDD and (b) DSA electrodes.

Keywords: wastewater treatment, hydrogen production, resource recovery, electrolyte configuration, DEMS.

Acknowledgements

Financial support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) is gratefully acknowledged.

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Transient Solvent Ramp Experiments for the Determination of Kinetic Parameters in Flow

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Keywords: reaction kinetics, transient flow, solvent mixtures

The composition of solvent mixtures greatly influences reaction kinetics. Multiple studies have investigated this, optimising product yields by varying solvent compositions.[1,2] Transient flow experiments using autonomous flow equipment allow for solvent mixtures to be varied continuously across one experiment, rapidly generating large quantities of data suitable for machine learning (ML).[3,4] In this work, the data generated by transient flow ramps is used to calculate key reaction parameters such as reference rate constants (k) and activation energies (E_a) for a pharmaceutically relevant amidation reaction.

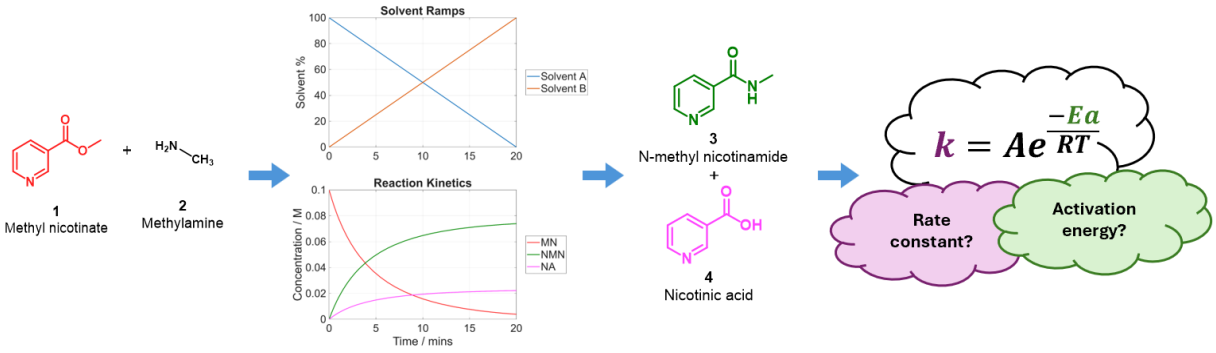


Figure 1: *Solvent ramps of a binary mixture for an amidation reaction.*

Utilising this methodology, relationships between the kinetic parameters and the composition of the solvent system (across 4 solvents) can be derived from fewer experiments than traditional batch while using less reaction material than conventional steady-state experiments. With initial insights from binary solvent systems, further work will explore tertiary and quaternary mixtures, and the application of the data produced in ML algorithms for the prediction of optimal solvent compositions for similar reactions.

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Design of Green Covalent Adaptable Network Materials: From Bio-Based Feedstock to Recyclable and Biodegradable Crosslinked Materials

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This work focuses on the design of materials that adhere to the principles of green chemistry, starting from the selection of renewable feedstocks and benign preparation methods, down to ensuring recyclability and complete biodegradation at their end of life. To achieve these sustainability goals, two bio-based building blocks were chosen, specifically epoxidized soybean oil acrylate (ESOA) and cystamine (Cys). These building blocks react to form a covalent adaptable network (CAN) by aza-Michael addition, performed in bulk and without a catalyst. Two different formulations were investigated by changing the molar ratio of [acrylate]/[amino] groups (1/1 in ESOA-Cys_1:1 and 2/1 in ESOA-Cys_2:1). The curing reaction was carried out at 30, 50 and 100°C and monitored by FTIR spectroscopy, which revealed two different reaction kinetic orders depending on the moiety ratios. For the 1:1 formulation, the abundant primary amino groups quickly react, consuming all acrylate groups and forming mono β-amino esters as crosslinks. Conversely, in the 2:1 formulation, lower concentrations of primary amino groups during the network formation led to the reaction between the newly formed β-amino esters and another acrylate group, forming bis-adducts as linkages. A complete polymeric network was formed after 6 hours for every considered temperature and formulation, as indicated by the 100% gel fraction (GF%) results. By studying the reaction at 100 °C, it was possible to observe the increase of the glass transition temperature (T_g) over time, reaching a value at 40 minutes differing only by 1 °C from the plateau value obtained at 48 hours of curing, indicating that the reaction was fast and almost complete after only one hour. The differences in network architecture of the two formulations were evaluated by DMTA and rheological measurements, revealing a higher crosslink density and rigidity of ESOA-Cys_2:1, compared to ESOA-Cys_1:1. The possibility of rearrangement of the network was demonstrated via stress-relaxation tests, thus establishing that the materials are indeed CANs. This was further confirmed by the successful mechanical recycling of the materials at 180 °C via compression molding, highlighting their circularity potential. Finally, the benign end of life of the materials was demonstrated by complete biodegradation via enzymatic hydrolysis using *Humicola insolens Cutinase* (HiC) in buffered pH 8 solutions, after 60 days.

Keywords: Biobased, Covalent Adaptable Network, Sustainability

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Coal–Bamboo Biomass Co-Combustion: Characterisation of Torrefied *Gigantochloa levis* for Sustainable Energy Applications

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The transition towards sustainable energy systems has intensified interest in biomass as a renewable alternative to fossil fuels. However, the direct utilization of lignocellulosic biomass is constrained by its high moisture content, low energy density, and poor physicochemical stability. Although bamboo has emerged as a promising biomass feedstock due to its rapid growth and high productivity, the fuel characteristics of *Gigantochloa levis*, a native bamboo species in Sabah, Malaysia, remain insufficiently understood following torrefaction treatment. This study aims to evaluate the influence of torrefaction on the physicochemical, morphological, and thermal properties of *Gigantochloa levis* to determine its suitability as a renewable solid fuel for future coal–biomass co-combustion applications.

Torrefaction was conducted at temperatures ranging from 200 to 300°C under an oxygenlimited atmosphere. The torrefied samples were comprehensively characterised using proximate analysis, ultimate analysis, higher heating value (HHV), scanning electron microscopy (SEM), and thermogravimetric analysis (TGA). The results demonstrated that increasing torrefaction severity significantly enhanced the fuel quality of bamboo by decreasing moisture, volatile matter, oxygen, and hydrogen contents while increasing fixed carbon, elemental carbon, and calorific value. Morphological analysis revealed the development of a more porous surface structure following torrefaction, whereas TGA confirmed enhanced thermal stability compared with untreated bamboo. Although mass yield declined with increasing torrefaction temperature because of devolatilisation, the energy yield remained relatively high, indicating effective energy retention. The highest enhancement factor of 1.18 was obtained at 300°C, corresponding to an approximately 18% increase in energy density relative to raw bamboo.

These findings demonstrate that torrefaction is an effective pretreatment strategy for upgrading *Gigantochloa levis* into a carbon-enriched and energy-dense solid biofuel with improved thermal characteristics. The study provides fundamental insights into the valorisation of Sabah's indigenous bamboo resources and establishes a scientific basis for the subsequent development of torrefied bamboo–coal pellets for co-combustion, thereby supporting the transition towards low-carbon and sustainable energy systems.

Keywords: *Gigantochloa levis*; torrefaction; biomass upgrading; thermogravimetric analysis; scanning electron microscopy; higher heating value

Fully recyclable wood coating using liquified woody biomass: An alternative to fossil-based plastics

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The increasing demand for sustainable materials has accelerated research into the valorisation of lignocellulosic biomass, a promising renewable carbon source due to its abundance, low cost [1,2]. The objective of this research project is to develop sustainable, circular and cost-effective thermoplastic composites or coatings from woody biomass. This study investigates the properties of heavy fraction of liquefied biomass (HLW), as potential sources for bio-based composite and coating precursors [3]. It further studied the properties of bio-based coatings produced using heavy fraction as polyol.
The lignocellulosic biomass was subjected to direct liquefaction using guaiacol at 300 °C for 30 minutes in a batch autoclave reactor. After removing the solid char, the resulting bio-crude were vacuum-distilled to separate lighter fractions, yielding a tar like heavy fraction (HLW). The HLW was comprehensively characterized using elemental analysis, gas chromatography (GC) for yield determination, and gel permeation chromatography (GPC) for molecular weight profiling. To determine structural features, advanced spectroscopic techniques including FTIR, ^{1}H-NMR, DOSY, ^{13}C-NMR, HSQC, and ^{31}P-NMR were employed.
The liquefaction process resulted in bio-crude yield exceeding 85 C% (based on dry feed), of which approximately 30–40 wt% constitutes the heavy fraction, as determined by GPC (Mw > 1000 Da). NMR and FTIR analyses revealed the presence of aromatic hydroxyl groups, lignin-derived structures, and few aliphatic functionalities in HLW. These chemical features underpin their application-specific potential use as hardeners or curing agents in thermosetting resins.
Utilizing the hydroxyl group, HLW was crosslinked with bio-based epoxy glycerol diglycidyl ether (GDE) in the ratio of 1:1 and was coated on wood substrate. The thermo-mechanical properties such as hardness, toughness, thermal heat resistance index, hydrophobicity were studied and compared with the commercial amine based epoxy coating and coating prepared after one recycle batch. The fresh and recycled coating showed excellent properties comparable to that of commercial ones [4]. These insights establish a foundation for ongoing efforts to tailor biomass-derived HLW into sustainable, high-performance material platforms [5].

Keywords: Lignocellulosic biomass, Biomass liquefaction, Recyclable materials

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Agro-Waste Valorization into Copper Oxide Nanoparticles for Sustainable Water Remediation

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The increasing deterioration of water quality caused by industrial and anthropogenic activities has intensified the demand for new sustainable environmental remediation approaches. In this study, pineapple waste was valorized as a renewable biogenic resource for the green synthesis of copper oxide nanoparticles. Pineapple peel extract (PPE) acted as both reducing and stabilizing agent enabling nanoparticle formation without the use of harmful chemicals. The synthesis parameters were optimized. Structural, morphological, thermal and optical properties were comprehensively evaluated using UV-Vis, SEM, TEM, DLS, XRD, FTIR, TGA, PL and EDX analyses. The results demonstrated the formation of polydisperse, spherical nanoparticles consisting of mixed CuO/Cu2O phases and surrounded by a dense organic coating originating from PPE. Beyond successful synthesis, the obtained PPE-CuONPs exhibited multifunctional properties with promising catalytic and antimicrobial applications. Their catalytic performance was demonstrated through the degradation of a diverse set of dyes ranging between cationic and anionic, including methylene blue, trypan blue, safranin O, orange G, methyl orange and Congo red, with degradation efficiency ranging between 70.08% and 98.12%. Additionally, the nanocatalystys retained their activity with effective performance up to 10 cycles. Antimicrobial assessment revealed broad spectrum activity against seven bacterial and fungal strains with inhibitory concentrations ranging between 0.62-9.95 mg/mL supported by kinetic time kill assay. Collectively, these findings demonstrate the potential of agro-waste derived nanoparticles as sustainable cost-effective multifunctional nanomaterial addressing water pollution, promoting waste valorization and advancing circular economy bioeconomy principles.

Keywords: Environmental Nanotechnology, Waste valorization, Circular economy

Optimized PANI/Biomass Composite as Eco-Friendly Adsorbents for Dye Removal

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The development of sustainable and low-cost adsorbents from renewable resources has become an effective strategy for the treatment of dye-contaminated wastewater. In this study, an eco-friendly polyaniline PANI/biomass composite was synthesized through *in situ* oxidative polymerization, and evaluated for the adsorption of Orange G dye from aqueous solution. The composite was characterized by Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy (SEM-EDS), confirming the successful grafting of PANI onto the biomass surface and revealing the morphological and elemental modifications after polymerization. The adsorption performance was investigated under different operating conditions to determine the optimum parameters. Maximum dye removal efficiency of 99.47% was achieved using only 0.2 mL of aniline under optimal conditions (pH = 6, contact time = 90 min, and initial dye concentration = 20 mg L^{-1}). Equilibrium data were best fitted by the Langmuir isotherm model, while adsorption kinetics followed the pseudo-second-order model, indicating monolayer adsorption dominated by chemisorption. In addition, the composite demonstrated excellent stability and reusability, maintaining high adsorption efficiency over four consecutive adsorption-desorption cycles. These findings highlight the potential of the optimized PANI/biomass composite as an efficient, cost-effective, and environmentally friendly adsorbent for wastewater treatment applications.

Keywords: Polymer-based composites; Polyaniline; Biomass; Adsorption; Environmental applications

Ceramic Membrane Functionalization for Water Purification

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Rising levels of ionic pollutants—nitrates and heavy metals in particular—make sustainable water treatment solutions necessary. Cordierite/zirconia ceramic membranes are highly resistant to chemical and thermal stress, yet their modest natural adsorption and tendency to foul limit their overall effectiveness. In this study, the membranes are enhanced by incorporating a solid biomaterial (BMIS) derived from the Moroccan plant Carpobrotus edulis, which is abundant in carboxyl, hydroxyl, and amine functional groups. The modification process, involving BMIS infusion and controlled drying, creates a 1µm active layer, as confirmed by Scanning Electron Microscopy. Performance testing indicates that this change enhances ion retention by about six times compared with unmodified membranes. The experimental results further corroborate substantial adsorption capacities for lead (174.6 mg/g) and nitrates (124.4 mg/g). A critical trade-off is identified, as the modification reduces initial water flux from 350 to approximately 280–300 $L \cdot h^{-1} \cdot m^{-2}$, indicating that the biomaterial layer introduces meaningful hydraulic resistance. Furthermore, multi-ion assessments reveal that while nitrates and orthophosphates occupy distinct adsorption sites, heavy metal cations compete for the same functional groups, which is vital for treating complex effluents. This sustainable approach leverages locally available biologically derived resources to develop affordable hybrid purification systems that successfully combine adsorption with filtration.

Deep Eutectic Solvent-Based Selective Recovery of Platinum Group Metals from Spent Automotive Catalysts

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Platinum group metals (PGMs) are widely used in various industrial products due to their exceptional properties. In particular, platinum, palladium, and rhodium are employed in automotive catalysts for the purification of exhaust gases. However, PGM resources are unevenly distributed and reserves are limited; consequently, an efficient recycling process for spent automotive catalysts is essential. In this study, hydrophobic deep eutectic solvents (DESs) with high PGM leaching selectivity were designed and synthesized to develop an innovative recycling process for spent automotive catalysts. PGM extractants and long-chain carboxylic acids were used as DES components to enhance PGM affinity. By employing these DESs in place of the strong acids conventionally used for catalyst leaching, we aim to develop an efficient and environmentally friendly recycling process [1].

Two types of DES were prepared using trioctylmethylammonium chloride ($N_{8881}Cl$) or trihexyltetradecylphosphonium chloride ($P_{66614}Cl$) as the hydrogen bond acceptor and decanoic acid as the hydrogen bond donor. The leaching results of spent automotive catalysts using conventional inorganic acids and the two DESs are presented in **Fig. 1**. While highly concentrated inorganic acids achieved efficient PGM leaching, they also caused extensive dissolution of Al, La, and Mg. In contrast, these DESs with additives enabled selective PGM dissolution while significantly suppressing the leaching of Al, La, Mg, and other base metals. Two possible explanations have been considered. First, the hydrophobicity of the DES may contribute to the observed selectivity; metals with high charge densities, which readily form complexes with water, are poorly leached in hydrophobic media containing only trace amounts of water, such as La, Al, and Mg. Second, the metal-coordinating properties of $N_{8881}Cl$ and $P_{66614}Cl$ may also play a role. These components act as efficient extractants for PGMs due to their strong coordination affinity, enabling stabilization of PGM species within the hydrophobic DES phase.

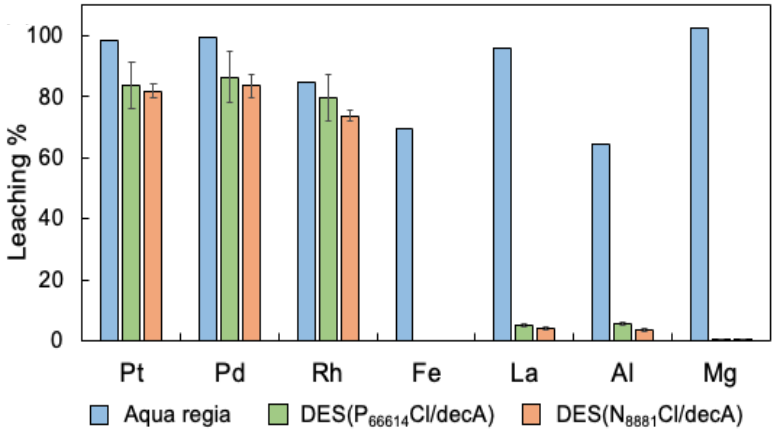


Fig.1 Leaching of Waste Automotive Catalysts

Keywords
Deep Eutectic Solvent, Platinum Group Metals, Selective Leaching, Spent Automotive Catalyst
Acknowledgements
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Sustainable Chemical Depolymerization of Polylactic Acid via Solvolysis for Value-Added Product Recovery

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The rapid accumulation of plastic waste poses a significant environmental challenge, necessitating the development of sustainable recycling strategies to enable a circular plastics economy. Among the available approaches, chemical depolymerization has emerged as an effective method for converting plastic waste into valuable monomers and chemicals. Polylactic acid (PLA), a widely used biodegradable polymer in applications such as packaging, agriculture, and 3D printing, has experienced increasing consumption, leading to substantial waste generation and the need for efficient recycling solutions. In this study, catalytic chemical depolymerization of PLA was investigated via both methanolysis and glycolysis pathways to selectively produce value-added products. The reactions were carried out using metalsupported catalysts under optimized and relatively mild conditions, resulting in high efficiency with excellent product selectivity and yields. Mechanistic insights into the depolymerization pathways were obtained using spectroscopic analysis. The developed protocols were further validated through gram-scale experiments, demonstrating their practical applicability. The sustainability of the processes was evaluated using green metrics, including environmental factor, energy efficiency, and environmental impact parameters. Additionally, the catalysts exhibited good stability and recyclability over multiple cycles. Overall, this work presents a sustainable, environmentally friendly, and scalable approach for the chemical recycling of PLA via methanolysis and glycolysis, contributing to resource recovery and advancing a circular plastics economy.

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From Waste to Photocatalyst: Sustainable Synthesis of α-Fe_2O_3-SiO_2 Nanoparticles from Coal Fly Ash for Water Treatment

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The disposal of coal fly ash in landfills and ash dams remains a major environmental challenge, particularly in developing countries where coal continues to play a significant role in energy production1,2. In this study, α-Fe_2O_3-SiO2 nanocomposites were sustainably synthesized from coal fly ash through a combination of magnetic separation and mechanochemical treatment. The synthesized materials were calcined at 500, 550, and 600 °C and subsequently characterized using SEM-EDX, FTIR, XRD, PL spectroscopy, UV–visible spectroscopy and point of zero charge (pHpzc) analysis.
Characterization confirmed successful magnetic enrichment of iron-rich phases with minor Si and the formation of crystalline α-Fe_2O_3-SiO2 nanocomposite within the nanoscale range. The fabricated material was evaluated for photocatalytic degradation of methylene blue (10 mg L^{-1}) at natural pH (6.4) and a catalyst loading of 0.4 g L^{-1}, achieving up to 85% removal efficiency. Kinetic analysis revealed an apparent rate constant (k_{app}) of 0.01502 min^{-1}, indicating strong photocatalytic performance. The observed activity could be attributed to enhanced visible-light absorption and to trace impurity elements that act as dopants, thereby improving charge-carrier dynamics and overall photocatalytic efficiency. These findings demonstrate a sustainable pathway for converting coal fly ash into functional nano photocatalysts for wastewater treatment, addressing both industrial waste management and water pollution challenges through green chemistry and circular economy principles.

Keywords
Coal fly ash valorization; Photocatalysis; Wastewater treatment

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Mechanistic investigation and sustainable method development for the synthesis of quinoxalines and benzimidazoles using *Saccharomyces cerevisiae* as a biocatalyst

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Benzimidazoles and their derivatives have been utilized in the pharmaceutical industries since 1960's as anthelmintic, agricultural fungicides, pharmaceutical scaffolds, angiotensin receptor blockers and emerging studies even show promising anti-cancer properties.[1] Quinoxalines, while showcasing vast applications in the pharmaceutical industry, also find their use in material sciences in solar cell components, OLEDs, dyes amongst many.[2] Current synthesis methods rely on catalysts that are metal-catalyzed/mediated, bentonite K-10 and nano catalysts, and microwave-assisted protocols. These add cost, use of excess solvents, and reduced ability to scale.[3] We developed a one-pot yeast mediated biocatalytic method as an economical, non-toxic, sustainable, and green alternative to conventional metal-based catalysts, thereby eliminating the need for hazardous reagents' disposal and multi-step processes. Successful optimization and comprehensive scope resulted in yields up to 90% confirmed by GC-HRMS and NMR. Mechanistic studies were carried out to understand the biocatalytic role of *S. cerevisiae*, highlighting the involvement of intracellular metabolites synthesized during the glycolytic pathway that facilitate product formation. Furthermore, we successfully developed selective synthetic routes for quinoxalines and benzimidazoles from the same starting material by altering the reaction conditions.

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Biowaste-derived catalyst promotes the pH-controlled reduction and reductive formylation of nitroarenes using formic acid as LOHC

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To advance the development of alternative and low-impact synthetic pathways, we defined a waste-minimized protocol for the selective reduction and reductive formylation of nitro compounds. A heterogeneous tailor-made Pd-based catalyst, obtained from the valorization of urban biowaste pine needles (PiNe), was employed in combination with formic acid as a safe H-source. The employment of a recyclable catalyst derived from an upcycling strategy [1] and the replacement of molecular hydrogen, which is associated with serious concerns regarding storage and use, with an on-demand alternative H-source contribute to reducing the impact of the protocol.[2]

Using water as a safe reaction medium offers, in addition to its environmental and economic advantages,[3] the possibility of fine-tuning pH to control the reaction selectivity towards the formation of the amino and the formamide products. The high selectivity allows the definition of a simple work-up protocol, leading to good, isolated yields for a wide spectrum of nitro-compounds, further associated with waste minimization. It is worth noting that key intermediates for the synthesis of active pharmaceutical ingredients can also be isolated in high yield.

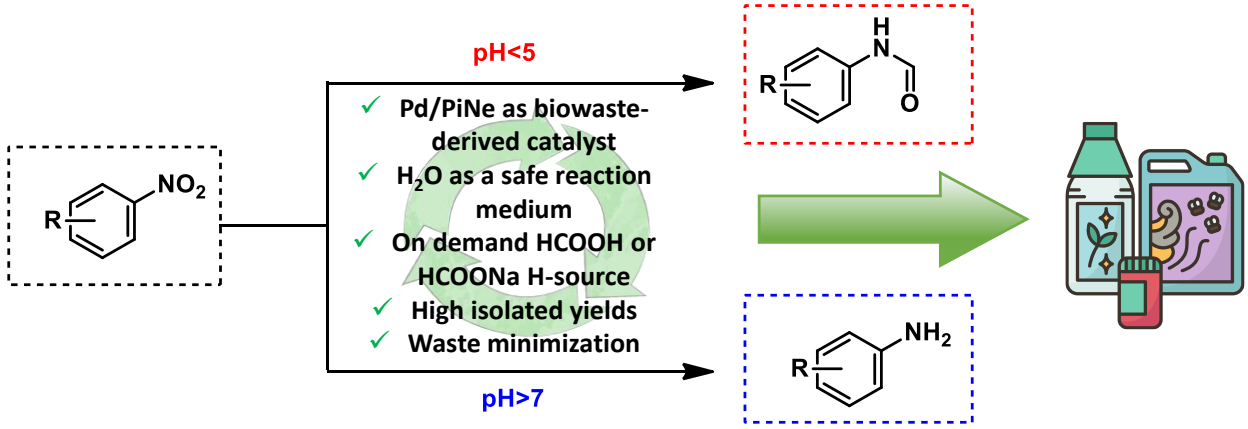


Figure 1. pH-controlled reduction of nitro-compound

Keywords
pH-controlled selectivity, safe H-source, biowaste derived catalyst

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We acknowledge the University of Perugia and the National PhD Program in Catalysis and Energy. MUR is also thanked for PRIN–PNRR 2022 project "P2022XKWH7 – CircularWaste"

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Sustainable biorefinery approach using NaDES for the extraction of high value-added compounds from *Chlorella vulgaris* biomass cultivated on molasses

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The development of sustainable biorefinery processes for microalgae biomass is gaining increasing interest, especially the extraction of high-value added compounds [1, 2]. A circular biorefinery approach was implemented by employing molasses, an agro-industrial waste, as an organic carbon source for microalgae biomass production [3], together with a Natural Deep Eutectic Solvent (NaDES) composed of betaine and lactic acid (BET:LA) for the biomass extraction. In this system, betaine, that is present in beet molasses at concentrations ranging from 3 to 12%, is potentially recoverable directly from molasses, further enhancing process sustainability [4].

The microalgae biomass was extracted using the NaDES to recover compounds exhibiting bioactivity as a more environmentally friendly procedure compared to traditional solvent such as chloroform, hexane, dichloromethane, and methanol. NaDES are particularly interesting because of their biodegradability and high safety profile (Hilali et al., 2024). The extracts obtained from the NaDES treatment were chemically characterized to understand their chemical composition in terms of polyphenols, proteins, lipids, and carbohydrates (Figure 1). Additionally, their potential functionalities were evaluated. Finally, the biological activities of such extracts were tested.

The results demonstrated that the selected NaDES system is an effective extraction medium, enabling significant recovery of compounds compared to water extraction used as control. For evaluation of the biostimulant effect of the extracts, different amounts of NaDES extract from 0.01 to 1%w/w were used for Vigna radiata seeds. There was no evidence of the presence of biostimulant effect at the lower concentration range, while the higher concentration caused high biological variation between the seeds. Overall, this study highlights the potential of integrating low-cost substrates and green solvents within a circular biorefinery framework to valorize microalgae biomass, contributing to more sustainable agricultural and industrial applications.

Figures

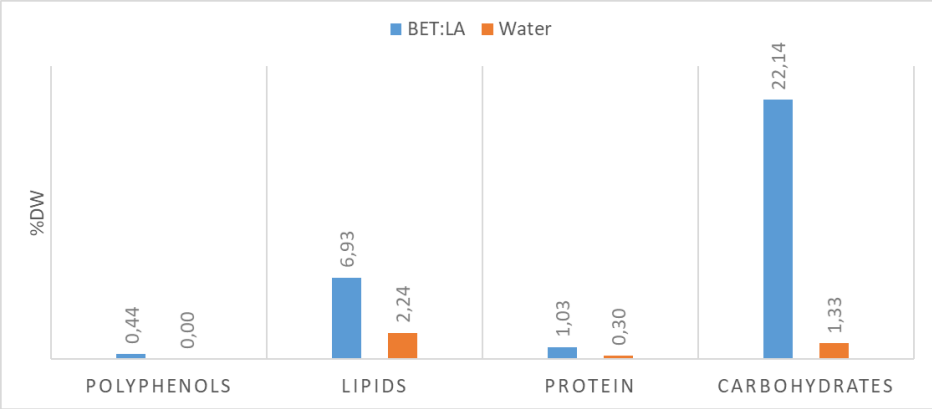


Figure 2. Biomass extract composition using NaDES BET:LA (blue) and water (orange).

Keywords
Microalgae; Molasses; Betaine; NaDES; Bioactivity

Acknowledgements
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Cyclooctyne Synthesis for SPAAC Applications: an alternative route to the Palladium-catalyzed Sonogashira Reaction

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Since its introduction by C. Bertozzi and co-workers in 2004, the strain-promoted azide–alkyne cycloaddition (SPAAC) has emerged as a crucial click transformation, especially owing to its application in bio-orthogonal chemistry. [1] Building on the click chemistry concept introduced by K. Barry Sharpless, SPAAC exploits the ring strain of cyclooctyne derivatives to react quickly and selectively with azides under mild conditions without the need for a copper-based catalyst. This feature overcomes the toxicity issues associated with copper-catalyzed azide–alkyne cycloaddition (CuAAC), making SPAAC particularly useful for biological environments. [2]
However, its large-scale application is hampered by the high cost and difficult synthesis of strained cyclooctyne reagents. A well-established strategy for the synthesis of dibenzoazacyclooctynes (DIBACs), a key class of strained cyclooctynes, is based on a debromination/elimination sequence. [3] More recently, an efficient alternative route was developed, based on novel cobalt-mediated complexation and decomplexation steps. However, a life cycle assessment (LCA) study, carried out within our research group, revealed that, between the two total synthesis routes, the cobalt complexation/decomplexation pathway exhibits the highest environmental impact. Particularly, the Sonogashira cross-coupling step was identified as the main contributor to the overall environmental footprint. This result is mainly attributed to the use of palladium, which, despite its catalytic efficiency, possesses a significant environmental and economics cost. [4] Based on these findings, the aim of this work is to develop a more sustainable synthetic strategy by reducing the environmental impact of the Sonogashira reaction through alternative catalytic systems.

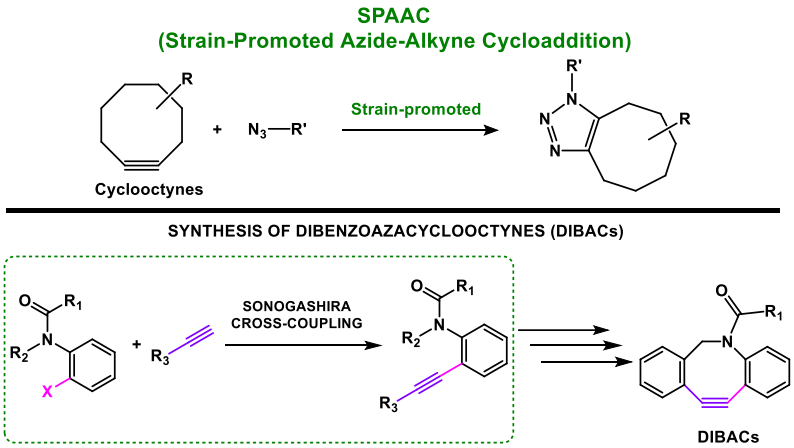


Figure 1. Sonogashira reaction for cyclooctyne synthesis for SPAAC applications

Keywords: LCA, SPAAC, Sonogashira reaction.

Acknowledgements
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Transparent lignocellulosic materials functionalized with coumarins for biobased luminescent solar concentrators (LSC)

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Keywords: *transparent wood, chitosan, coumarins*

Luminescent solar concentrators (LSC) represent a promising technology for integrating photovoltaic systems into urban architectures. However, developing sustainable, highly efficient, and transparent matrices remains a challenge. This work reports the development of a novel material based on a transparent wood functionalized with a highly fluorescent coumarin derivative (TW - HMCA), which can be utilized as an efficient LSC.

Balsa wood was successfully delignified using a chemical bleaching process that fully preserved its natural porous hierarchical microstructure, as confirmed by SEM analysis. Concurrently, chitosan was chemically functionalized with a coumarin derivative via stable imine bonds (Schiff base reaction) to serve as the luminescent phase. The functionalized chitosan was subsequently infiltrated into the delignified wood template. By matching the refractive index of the polymer with the cellulosic matrix, light scattering was minimized, yielding a composite with optical transparency (~ 75%) in the visible range.

Characterization by FT-IR, UV-Vis spectroscopy, and thermogravimetric analysis confirmed the structural integrity and thermal stability of the composite. Photophysical studies demonstrated that the TW-HMCA system functions as an efficient LSC, absorbing the UV-blue region and emitting green fluorescence at 520 nm. Notably, the system exhibits a Stokes shift (~ 53 nm), which is crucial for minimizing self-absorption losses during waveguiding. Furthermore, photostability assays showed excellent endurance, maintaining strong emission intensity across typical solar operating temperatures (20 °C – 46 °C). Contact angle measurements also revealed a more hydrophobic character (WCA of 48.8 °) compared to unmodified matrices. These results highlight the potential of functionalized lignocellulosic architectures as sustainable platforms for the next-generation solar energy harvesting.

Thiazolidine-Grafted Zeolite Imidazolate Frameworks: A Cysteine-Derived Route to Improved Metal Loading and Tune the CO_2 Hydrogenation Efficiency

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The covalent functionalization of ZIFs with sulfur-containing ligands is an effective strategy for controlling active metal centers in heterogeneous catalysis. Herein, ZIF-8/90 materials functionalized with thiazolidine groups derived from L-cysteine were synthesized via post-synthetic condensation of aldehyde functionalities on the imidazolate linker. X-ray diffraction (XRD), N_2 physisorption, thermogravimetric analysis (TGA), and nuclear magnetic resonance (NMR) confirm successful functionalization. The introduction of S/N donor sites significantly enhances metal uptake, achieving up to threefold higher Pd loading compared to the non-functionalized ZIF. The cysteine-functionalized ZIF catalyst shows improved resistance to metal leaching and nanoparticle aggregation during CO_2 hydrogenation to formic acid at room temperature, preserving Pd nanoparticles of 1–3 nm after catalytic cycling.[1]

Keywords
CO_2 conversion; adsorption; amino acids; catalysis; metal capture; metal organic frameworks.

Acknowledgements
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Carbon Dioxide Feeding Optimization in a Closed Microalgae Photobioreactor for Space Applications

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In long-duration space missions, regenerating essential resources like air and water is critical to reduce dependence on Earth supply chains, making biological systems an economical, self-sustaining alternative to conventional physicochemical treatments [1]. Microalgae represent an ideal candidate for Bioregenerative Life Support Systems (BLSS) due to their photoautotrophic metabolism, which allows them to act as efficient oxygen producers, consume carbon dioxide (CO_2), and simultaneously absorb dissolved pollutants from wastewater [2]. By coupling these photobioreactors with hydroponic greenhouses, a circular design can be achieved to enable water recycling, bioremediation, air revitalization, waste management, and fresh food production. To overcome space-specific challenges such as microgravity, cosmic radiation, and contamination risks [3], a closed, modular "Multistep" photobioreactor was designed. Sterilization of culture medium and wastewater was needed to ensure aseptic growth of the culture. During the first laboratory testing, a closed single-step tubular photobioreactor was assembled, with light intensity and liquid flow calibration to maximize biomass growth. Two main operational challenges were highlighted: mitigating pressure increases, caused by CO_2 insufflation, and counteracting the toxic effects oxygen accumulation in the culture medium, which inhibit carbon dioxide uptake. Experimental trials were conducted through three separate fed-batch cultivation cycles in the same plant using *Chlorella vulgaris*, a robust strain selected for its high resilience to space environments and its performance in bioremediation [4]. These trials evaluated biomass growth performances and pH stability by varying the CO_2 insufflation patterns, tracking the volume of gas injected, and optimizing the gaseous retention time. The operational parameters directly influenced the culture environment, showing that an optimized dosing frequency maintained the pH within a stable, physiological range, preventing carbon limitation without causing medium acidification. Characterization of the harvested biomass highlighted stable properties, with an increase in protein and carotenoid concentration during fed batch cultivation. Future perspectives will analyze the Multistep modular photobioreactor to address enhanced concentration and greater resilience to potential leakages or culture poisoning compared to traditional layouts. This configuration allows for homogeneous carbon availability along the photobioreactor, through the concurrent introduction of wastewater and exhaust air. The treated water and the exhaust biomass, then, can be easily recovered from this system, allowing the microalgae reutilization as a high value biofertilizer for the hydroponic greenhouses. Lastly, future works will focus on introducing a wastewater pretreatment (as anaerobic digestion) to enhance nutrient bioavailability and determining precise CO_2 solubility dynamics in wastewater.

Keywords
Space, Microalgae treatment, Carbon dioxide uptake

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The role of catechin and of catechin-rich foods in the Maillard reaction: a chemical insight

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The Maillard reaction, is one of the most important and complex chemical processes involved in the non-enzymatic browning of foods, that occur between reducing sugars and amino groups in proteins, peptides and amino acids during heat treatment. This reaction leads to the formation, among others, of dark-colored polymeric compounds, known as melanoidins. Although in recent years melanoidins have been attributed beneficial properties for human health (e.g., antioxidant and antimicrobial)1, it is certain that the Maillard reaction is responsible for the loss of nutritional value in foods, inducing changes in protein components and therefore reducing their assimilability, and leading to the formation of mutagenic and carcinogenic compounds. Among the various strategies for controlling this reaction the addition of functional ingredients such as phenolic compounds, capable of trapping reactive intermediates produced during the reaction, has been considered2.

Based on these premises, herein we report the results of a systematic investigation of the effect of catechin and related compounds on the course of the Maillard reaction3. The investigation was further extended to complex food matrices.

In a first series of experiments catechin was reacted for 30 min at 120 °C with 1 molar equivalent of lysine and glucose under low moisture conditions, in order to simulate the cooking environment. The formation of a series of products was observed, which were purified and identified as catechin-glucose adducts based on LC-MS and NMR analyses. Notably, in the presence of catechin the formation of furosine, a typical marker of the Maillard reaction, was completely inhibited. In agreement with this observation, in the presence of catechin, the reaction mixture looked lighter in color. Similar results were observed when the reaction was run with other reducing sugars and amino acids.

As expected, the presence of catechin conferred significant antioxidant properties to the reaction mixtures in the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay and notably, these properties were related not only to the presence of residual catechin but also to the catechin-related products formed during the reaction.

In a second series of experiments, the evaluation of catechin effect on the Maillard reaction was further extended to food matrices such as egg white, milk and white flour. The different mixtures were incubated at 180 °C for 30 min, and the colorimetric analysis showed that catechin reduced non-enzymatic browning whereas the ferric reducing/antioxidant power (FRAP) assay results showed higher reducing properties in all catechin-containing samples. In another series of experiments the same experimental protocol was adapted to apple samples rich in catechin/epicatechin in order to evaluate whether the inhibitory effects observed in model systems could be retained under more realistic conditions. Under the same reaction conditions (120 °C, 30 min), apple addition significantly reduced furosine formation and non-enzymatic browning, while enhancing the antioxidant properties of the reaction mixtures. The formation of epicatechin–glucose adducts further supported the active involvement of apple polyphenols in modulating the Maillard reaction. Finally, the anti-browning effect of apple phenolics was also confirmed in a proof-of-concept crème brûlée preparation under realistic cooking conditions.These results open new perspectives toward the exploitation of phenol-rich food and possibly agri-food by-products, in a circular economy perspective, for modulating food color and antioxidant properties.

Keywords: Maillard reaction, catechin, antioxidant activity, food color, catechin rich-food

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Understanding Metal–Support Effects in CO_2 Hydrogenation to Methanol through Data-Driven Analysis

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Fossil fuel dependence has driven atmospheric CO_2 increases, contributing to climate change and ocean acidification. To support carbon neutrality goals and a circular carbon economy, CO_2 conversion into valuable products has emerged as a promising strategy. In particular, CO_2 hydrogenation to methanol, a versatile energy carrier and chemical feedstock, has gained increasing attention through data-driven and machine-learning (ML) approaches. However, much of the existing literature on CO_2 conversion to methanol has been emphasizing the use of ML in optimizing reaction conditions and performance prediction rather than chemical interpretability of heterogeneous catalysts and data-driven catalyst design insights for conversion process. Thus, the present study aims to provide a comprehensive ML-assisted analysis of heterogeneous catalysts for CO_2 hydrogenation to methanol. The analysis is based on a documented dataset comprising nearly 3500 entries, integrating literature-reported experimental data with ML-driven reconstruction of missing values. Upon training the ML model for chemical interpretable analysis of heterogenous catalyst in CO_2 conversion to methanol, analysis of significance of various descriptors such as such as active phase, support, and metal content and the operating conditions (like temperature, pressure, and space velocity) were made.

This work reveals that the characteristics of catalyst supports are consistently identified as the most critical factors across all algorithms used to train the ML model, often surpassing the role of the metallic active component in terms of CO_2 conversion and methanol selectivity. Although Cu-based catalysts dominate the existing literature on CO_2 conversion to methanol, our findings indicate that numerous less-studied metals (such as Ce, La, Pr) exhibit higher average CO_2 conversion rates, especially in multi-metallic combinations (such as Cu–Zn, Cu–Zr, Cu–In). When paired with specific supports (including C, MnOx, In_2O_3, ZrO_2), this typical multi-metallic combination shows improved selectivity for methanol synthesis. Besides uncovering the novel catalyst formulation for CO_2 hydrogenation to methanol, this work points out the systematic bias present in existing experimental studies and uncovers an essential trade-off between activity and selectivity. Finally, this study highlights the potential of merging data science with chemically interpretable analysis, which offers valuable practical insight and viewpoints for the rational, synergy-driven design of next-generation CO_2-to-methanol catalysts.

Green biosynthesized iron-based microparticles: Performance and ecotoxicological evaluation for Cr(VI) remediation

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The development of environmentally friendly materials for water remediation using sustainable and green synthesis approaches has become increasingly important for addressing emerging environmental challenges. In this work, biogenic iron-based microparticles supported on montmorillonite (BioFe-MMT) were synthesized through a one-pot green biosynthetic route employing an anaerobically stabilized bacterial consortium isolated from the Paraná Delta wetland (Argentina). The resulting material combines the reductive capacity of biogenic iron phases with the adsorption properties of montmorillonite, providing a multifunctional platform for contaminant removal. Hexavalent chromium [Cr(VI)] was selected as a model pollutant due to its high toxicity, persistence, mobility, and potential for bioaccumulation in aquatic ecosystems. The performance of BioFe-MMT for Cr(VI) remediation was evaluated, achieving up to 99% removal of Cr(VI) and 97% removal of total chromium from aqueous solutions at pH 4.0. The remediation process involved both the reduction of Cr(VI) to the less toxic Cr(III) form and its subsequent adsorption onto the biogenic particles and clay support. The environmental safety of the synthesized material and the treatment products was assessed through standardized bioassays using Rhinella arenarum larvae. BioFe-MMT and the treated supernatant exhibited negligible toxicity, whereas exposure to Cr(VI) solutions caused mortality and sublethal effects, including reduced body size, tail malformations, and behavioral alterations. MicroPIXE analysis confirmed chromium accumulation in the digestive tract and gills of exposed larvae, with a bioconcentration factor reaching 12.26 L kg^{-1} after 96 h of exposure. These results demonstrate that BioFe-MMT is an effective and environmentally compatible material for chromium remediation, combining green synthesis, high removal efficiency, and low ecotoxicological impact. The developed material represents a promising sustainable strategy for mitigating chromium pollution in aquatic environments.

Keywords:
Biogenic iron-based materials; Chromium remediation; Ecotoxicological assessment

Chlorella vulgaris as a Sustainable Strategy for Polyethylene Microplastic Biodegradation

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Microplastics (MPs), particularly polyethylene, polypropylene, and polystyrene, have emerged as major pollutants in aquatic ecosystems [1], posing a serious threat to marine organisms and human health [2]. Traditional wastewater treatment plants are often ineffective at removing smaller MPs and rely on expensive or environmentally unsustainable technologies [3]. This research aims to develop a sustainable, cost-effective, and circular strategy for MPs removal through the use of the microalga *Chlorella vulgaris*. Unlike previous studies that focused on MPs-microalgae aggregation, this work employs *Chlorella vulgaris* as a biodegradation agent, enabling a reduction in PE microplastic concentration while simultaneously producing biomass. Three 250 mL batch reactors were compared: one containing *C. vulgaris*, one containing the microalga with 67 mg/L of PE MPs (MAPE), and one containing only PE MPs at the same concentration [4]. Microalgal concentration was monitored through spectrophotometry, demonstrating that *C. vulgaris* can grow in the presence of MPs up to approximately 1.25 g_{DB}/L. After cultivation, the cultures were analyzed using optical microscopy, FTIR, and TGA, comparing the standard algal culture, MAPE, and PE alone. Microscopy images showed a visible change in PE transparency over time (**Figure 1**) and TGA curves revealed an unusual thermal behavior for PE MPs (**Figure 2**), indicating a potential degradation process. FTIR spectra after 14 days of cultivation showed similar patterns between *C. vulgaris* alone and MAPE, highlighting the analytical limitations of this technique for detecting PE at low concentrations (**Figure 3**). Several issues were encountered in the microplastic quantification method. Therefore, analyses on macro-plastics will be performed to better assess the biodegradation potential of *C. vulgaris*. Meanwhile, literature review and experimental work will be carried out to identify a reliable and effective quantification method.

Tables and Figures

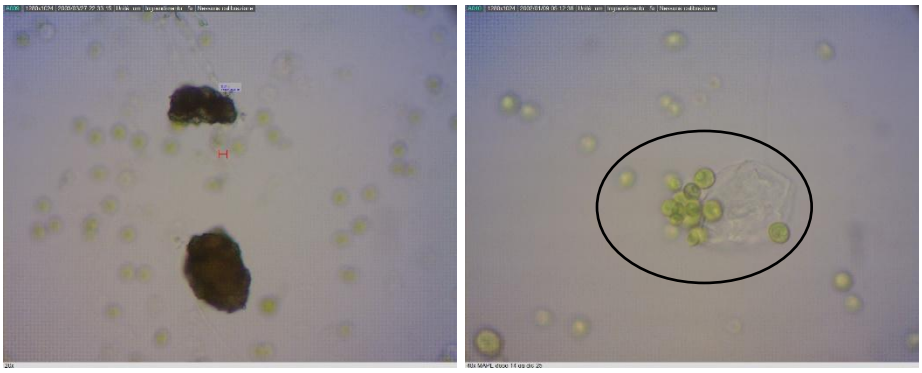


Figure 1. Optical microscopy images (20×) of the MAPE culture at day 1 (left) and day 14 (right). A visible change in the transparency of PE can be observed over time.

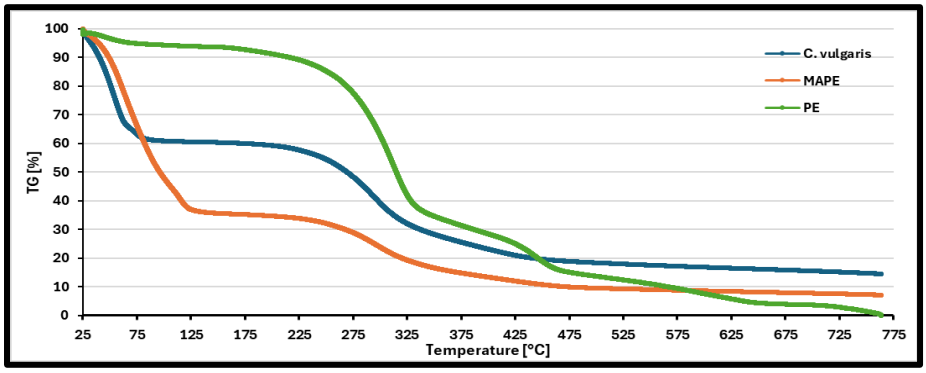


Figure 2. TGA curves of *C. vulgaris*, PE, and MAPE after 14 days. The PE curve differs from the standard reference profile, suggesting degradation.

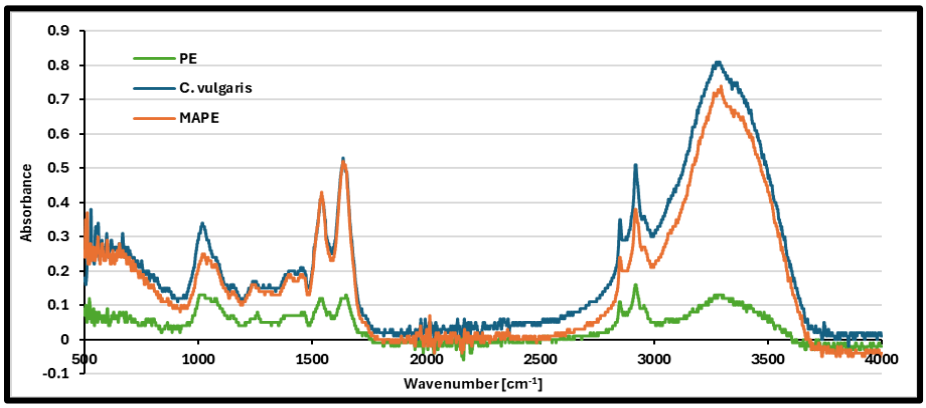


Figure 3. FTIR spectra of *C. vulgaris*, PE, and MAPE after 14 days.

Keywords
Microplastics biodegradation; *Chlorella vulgaris*; Microalgae-based wastewater treatment.

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Heterogeneous Pd Catalysis in Confined Spaces: The Role of Soy-Protein Cryogels

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The demand for more sustainable catalytic platforms has led to the development of bio-based materials as catalyst supports [1]. In the context of our research on biomass-derived materials [2-4], soy protein-derived cryogels were developed to provide a confined microenvironment able to promote the dispersion and stabilisation of transition metal atoms. In this study, palladium was successfully immobilised within the cryogel network. A library of substituted biphenyls was synthesised via Suzuki–Miyaura coupling reactions after optimization of the reaction conditions. The cryogel demonstrated excellent recyclability retaining its catalytic activity for up to 10 cycles. The use of mild conditions and high yields suggests that soy-protein cryogels are promising supports for heterogeneous palladium catalysis in cross-coupling chemistry, in line with the principles of green chemistry and the circular economy.

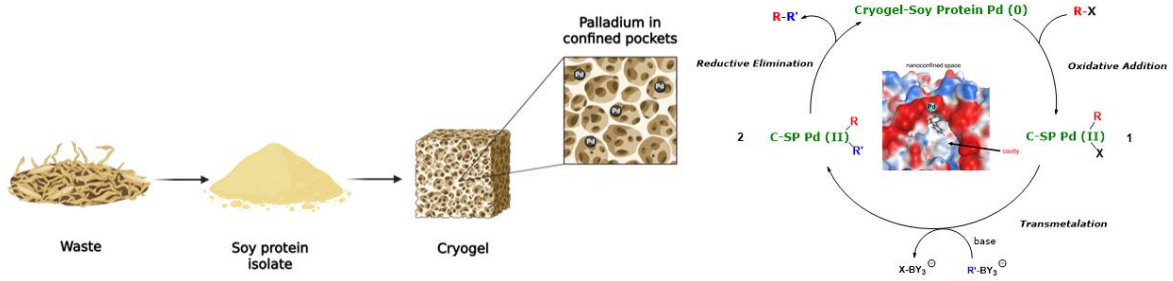


Figure 1. Graphical abstract of the research work.

Keywords: Pd-coupling reactions, heterogeneous catalysis, soy-protein

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Practical Activities in Green and Sustainable Chemistry Education:

Filipino Teachers' Praxis, Challenges, and Opportunities

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Chemistry practical activities foster scientific inquiry by enabling the connection between observable phenomena and their microscopic and symbolic representations. However, there is a paucity of studies on how sustainability-oriented hands-on practical activities are embedded in classroom instruction. This study examined Filipino chemistry teachers' perspectives and experiences with practical activities and explored how green and sustainable chemistry (GSC) was integrated into teaching practice. Using a multi-method design, data were collected from 326 teachers through the IUPAC International Teacher Survey on GSC Practical Activities, supplemented by semi-structured interviews. Findings indicated that many teachers rely on simulation-based instruction due to limited laboratory resources, time constraints, and curricular demands. Despite these challenges, teachers exhibited adaptive practices through improvisation and inquiry-oriented tasks. Moreover, explicit integration of GSC remains limited, constrained by inadequate materials and teachers' expertise. These findings highlight systemic and pedagogical gaps in the implementation of GSC-oriented practical activities that necessitate targeted and sustained professional development programs for both pre-service and in-service teachers. In this light, this research proposed a framework that could guide the implementation of the GSC learning experience. Strengthening teacher capacity, improving access to resources, and developing context-responsive instructional materials are imperative to advancing sustainability through chemistry education.

Keywords: practical activities, laboratory experiments, green chemistry, sustainability education, chemistry teachers

Concentration of clarified red dragon fruit juice using hydrophobic P(VDF-HFP) flat-sheet membranes: a comparison of osmotic, direct contact, and vacuum membrane distillation

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Abstract

Poly(vinylidene fluoride-hexafluoropropylene) P(VDF-HFP) flat-sheet membranes were prepared via the non-solvent induced phase separation (NIPS) technique using polyethylene glycol (PEG) as pore former agent and Tamisolve® NxG as sustainable solvent [1]. The resulting membranes were used for the concentration of clarified red dragon fruit juice through osmotic distillation (OD), direct contact membrane distillation (DCMD) and vacuum membrane distillation (VMD).

Membrane characterization revealed a thickness of 110 ± 7 µm, top and bottom contact angle values of 88 ± 2 ° and 107 ± 7 °, respectively, an average pore size of 0.14 µm, and a porosity of 79 ± 3 %. In the DCMD process, conducted with a temperature difference (ΔT) of 20 °C, average evaporation fluxes of approximately 1 kg m^{-2} h^{-1} were obtained. In the OD process, performed at 25 ± 2 °C using a 60 wt % calcium chloride dihydrate solution as the stripping agent, average evaporation fluxes of about 1.4 kg m^{-2} h^{-1} were achieved. These values were slightly higher than those previously reported for the concentration of the same juice using commercial polypropylene hollow-fiber membranes [2]. The combined DCMD–OD process operated at a ΔT of 15 °C resulted in improved membrane performance, with average evaporation fluxes reaching approximately 1.7 kg m^{-2} h^{-1}. The highest productivity was obtained using a VMD setup, which achieved average evaporation fluxes of about 2.5 kg m^{-2} h^{-1} at 25 ± 2 °C.

Keywords

Membrane preparation; Membrane characterization; Osmotic Distillation; Direct Contact Membrane Distillation; Vacuum Membrane Distillation.

Acknowledgements

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Green extraction of lignin from tiger nuts by-products via process intensification technologies and bio-derived solvents

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The increasing resistance of the current pathogenic agents exposes the need to develop new functional compounds with enhanced biological action. Lignin, a bio-based framework present in lignocellulosic biomass, puts forwards as a strong candidate for chemical, pharmaceutical, and biomedical applications due to its chemical structure based on phenolic compounds. This work tackles a sustainable recovery of the lignin present in tiger nut (TN) (*Cyperus esculentus* L.) by-products and the assessment of its biological activity. Following **Green Chemistry principles**, a protocol that includes process intensification and bio-based solvents was implemented. Namely, high-pressure-based techniques such as Accelerated Solvent Extraction (**ASE**) were used in combination with natural deep eutectic solvents (**NaDES**) (Figure 1). The methodology enabled a noted 50% delignification through the system choline chloride-lactic acid (ChLA). While this performance was maintained at a major level of operation (41%). Antioxidant activity of the recovered lignin-rich extracts was measured through TEAC, DPPH and FRAP assays to preliminarily evaluate the potential biomedical applicability of these crudes. Cytotoxicity by MTT was assessed in CaCo-2 cell lines to determine their biological safety. In addition, antibacterial potential was confirmed in presence of *S. aureus* and *S. entecus*. Finally, a sustainability assessment by **green chemistry metrics** (eco-scale, PMP or E-factor) confirmed the low environmental footprint of the whole methodology.

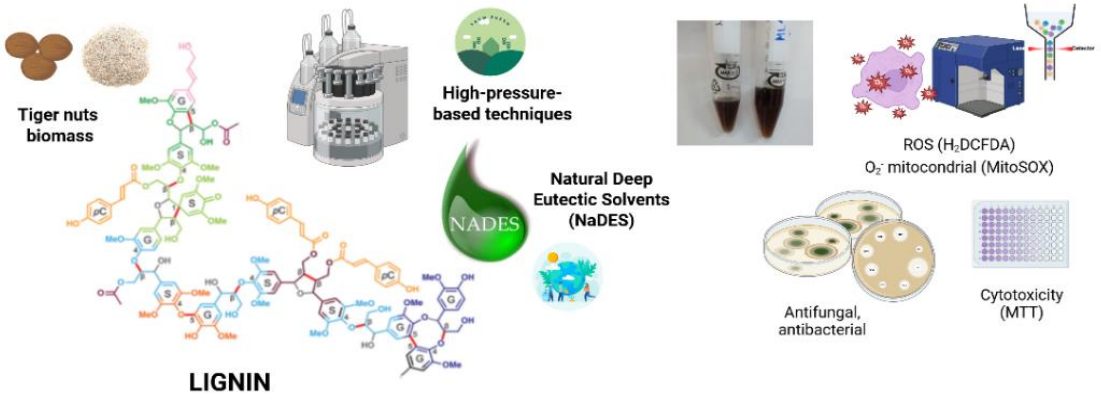


Figure 1. General overview of the work.

Keywords
Lignin; sustainable non-conventional protocols; deep eutectic solvents

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Integral valorization of olive leaves through ultrasound -assisted green-solvent extraction to obtain phenols and sugars

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Olive pruning leaves are one of the most abundant residues produced by the agro-food industry in the Mediterranean region. In Spain, where olive cultivation accounts for a major share of agricultural output, these leaves are an important source of lignocellulosic waste. In addition, their high phenolic content makes them especially interesting as feedstock for obtaining high-added-value compounds.
The aim of this work is to develop a full valorization route for this biomass based on an ultrasound-assisted solid-liquid extraction to recover bioactive phenolic compounds and enzymatic hydrolysis to obtain fermentable sugars. The study examines the process from three perspectives: sample preparation and storage; the use of green solvents and process intensification during the extraction of polyphenols; and the subsequent use of the extracted solid for enzymatic hydrolysis to produce fermentable sugars. To characterize the target compounds, high-performance liquid chromatography (HPLC) was used.
First, the impact of storage and drying conditions, particle size, and the amount of sample used on the extraction performance was evaluated. Afterward, several extraction conditions, including the use of bio-based solvents and natural eutectic solvents (NAES), different co-solvent ratios, and extraction times, were optimized. Finally, an assay was performed to determine whether the solid remaining after extraction could be converted via enzymatic hydrolysis into fermentable sugars more efficiently than the untreated biomass. This was tested using leaves, branches, and mixtures of pruning residues.
Overall, the results show that combining extraction with enzymatic hydrolysis is a practical strategy, especially with unsorted pruning biomass, by enabling the recovery of valuable antioxidant-rich extracts while still allowing the biomass to be used for fermentable sugar production.

Keywords: Olive biomass; Green solvents; Ultrasound-assisted extraction

A Sweet Flow: HMF Production and *in-situ* Valorization into Valuable Nitrile-containing Compounds via Telescopic Flow Chemistry

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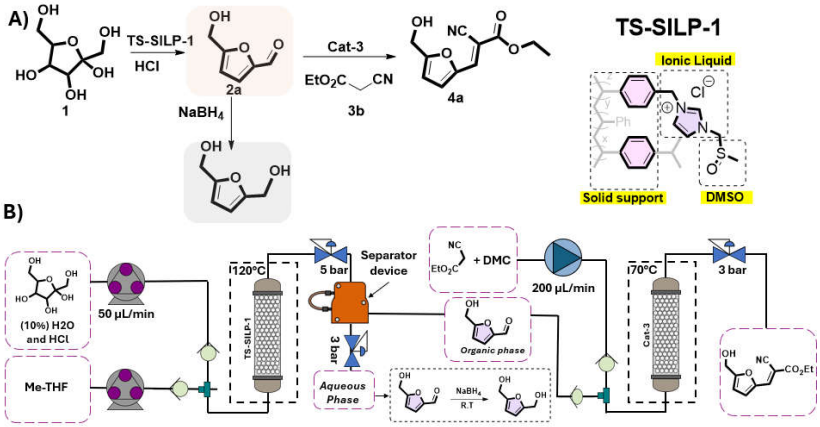
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Biomass have gained attention due to the possibility to replace fossil feedstocks for the production of biobased transportation fuels, heat, power, and biomaterials[1]. In this research, a biorefinery approach is reported for applying telescopic flow chemistry for the efficient synthesis of sugar-derived biomass compounds, specifically D-fructose, into valuable nitrile-containing compounds. This approach deals with the use of Task-Specific Solid Ionic Liquid Phases (TS-SILPs), designed at the molecular level to integrate both the stabilizing properties of ionic liquids and dimethyl sulfoxide within a solid phase solvent system. In this way, these polymeric materials facilitate the stabilization of the well-known 5-hydroxymethylfurfural and its key intermediates, thereby enhancing both its synthesis and downstream transformations. The solid-state nature of the TS-SILPs enables the development of a liquid–solid–liquid continuous flow configuration, which simplifies separation, allows for its continuous separation and reuse, and enables the synthesis and telescopic transformation of HMF into different derivative products. This methodology streamlines unit operations and aligns with principles of green chemistry, demonstrating the potential of designing multifunctional supported solvents as media to advance sustainable biomass valorization through integrated continuous processing.



Scheme 1. (A) General one process two steps synthesis of HMF derivatives by coupling multiphasic HMF synthesis with its telescopic valorization by Knoevenagel condensation and by reduction to BHMF of the organic and the aqueous phase, respectively. (B) Schematic representation of the biorefinery platform developed in this research.

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Garlic (*Allium sativum*) as a Sustainable Bio-adsorbent for Selective Hg^{2+} and Pb^{2+} Removal from Water

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This study investigates the selective adsorption of highly toxic Hg^{2+} and Pb^{2+} ions from complex aqueous media using garlic paste (*Allium sativum*) as a natural, thiol-rich bio-adsorbent, even in the presence of competing borderline metal ions such as Cu^{2+} and Zn^{2+}. This approach represents a promising nature-based solution for sustainable heavy metal remediation, transforming an abundant, low-cost agricultural product into an eco-friendly tool to combat water pollution. Heavy metal contamination in water bodies remains a severe global and regional environmental crisis, with Bangladesh facing acute challenges due to rapid industrialization and unregulated discharges from sectors like textiles, leather tanning, batteries, and electroplating and causes significant ecological and human health risks through bioaccumulation in aquatic food chains. The primary aim of this work is to evaluate garlic paste as a sustainable solution for selective Hg^{2+} and Pb^{2+} removal, capitalizing on its sulfur-containing functional groups to exploit the Hard-Soft Acid-Base (HSAB) principle for preferential binding over competing ions. The biosorbent was characterized via Fourier Transform Infrared (FTIR) spectroscopy, Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS) and elemental mapping to identify functional groups and binding mechanisms, while batch adsorption experiments optimized parameters including pH, contact time, and adsorbent dose, with isotherms and kinetic models applied to elucidate the process. FTIR revealed spectral shifts confirming chemisorption involving thiol, hydroxyl and carboxyl groups; SEM-EDS and mapping showed preferential Hg^{2+} and Pb^{2+} accumulation in sulfur-rich regions. Optimal conditions yielded high removal efficiencies of 98% for Hg^{2+} and 86% for Pb^{2+}, with the Langmuir model indicating favorable monolayer adsorption and pseudo-second-order kinetics suggesting chemisorption dominance. By valorizing locally abundant garlic through waste-to-resource principles, this natural adsorbent offers a scalable, low-energy, cost-effective alternative to conventional adsorbents, minimizing environmental impact while promoting circular economy practices.

Keywords: Selective adsorption; Heavy metal removal; Garlic biosorbent; Hg^{2+} and Pb^{2+} removal; Water treatment; Sustainable remediation

Non-thermal plasma for greener organic chemical synthesis

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Non thermal plasma (NTP) is a physical phenomenon where a gas becomes partially ionised and forming many reactive species with differing levels of energy- including electrons which possess enough energy to break chemical bonds. These reactive species are used to perform various chemical reactions, and the application of NTP to the synthesis of small molecules such as NH_3, NO_x, and O_3 has been well explored, but the use for more complex organic molecules is limited. Despite this, exciting and insightful examples have been published, showing how valuable NTP can be as a synthetic tool.

Recent literature examples have shown that NTP is able to promote the formation of peptide bonds in aqueous acidic conditions[1], sequester oxygen atoms from CO_2 to form epoxides[2], and form cyano compounds through the use of CH_4 and N_2[3,4], among others. More generally, NTP is a promising tool able to improve atom economy, reduce E-factor, and avoid the use of hazardous reagents, among others; it provides a new and different way of activating reagents, enabling reactions outside of those allowed by traditional methods.

Keywords: Non thermal plasma, alternative synthesis, organic chemistry, sustainability.

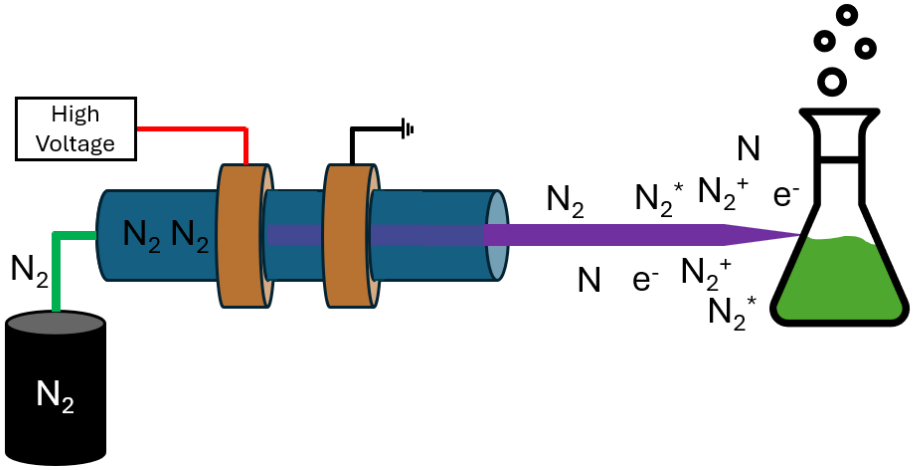


Figure 3: A schematic indicating the reactive species produced by non thermal plasma, and applying them to a chemical reaction.

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Sustainable Development of Bismuth-Based Nanostructures to Enhance the Effects of Radiotherapy

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Keywords: green synthesis, bismuth-nanoparticles, radiotherapy

Half of cancer patients receives radiotherapy; however, its limited selectivity often results in damage to surrounding healthy tissues. Nanomedicine aims to overcome this limitation through the development of functional materials capable of locally enhancing radiation effects while minimizing injury to healthy cells [1,2]. In this study, a nano-hybrid (BiNar EP), composed of bismuth (III) and a purified natural extract (EP) obtained from simulated grapefruit peel waste from the Mexican citrus industry [3,4], was synthesized through a sunlight-assisted green route [5]. BiNar EP was characterized using complementary physicochemical techniques and subsequently evaluated in normal (HaCaT) and cancer (HeLa) cells to determine its toxicity and intracellular localization. The ability of BiNar EP to induce nuclear DNA damage in HeLa cells and in a plasmid DNA probe after ionizing radiation (IR) activation was also tested. The resulting nanoparticles exhibited semi-spherical morphology, an average size of ~35 nm, a zeta potential of -14.69 ± 0.11 mV and good colloidal stability (PDI = 0.2615) with antioxidant and fluorescent properties. Biological evaluation demonstrated that EP reduced cell viability by about 20% across 0.1-500 µg/mL. According to ISO 10993-5:2009, this is not cytotoxic. BiNar EP showed IC_{50} values of 397.1 µg/mL in HeLa cells and 401.2 µg/mL in HaCaT cells. These values suggest a broad safety margin at these concentrations. Ionizing radiation induces DNA double-strand breaks (DSBs), triggering repair pathways that can be detected by immunofluorescence microscopy. HeLa cells treated with 10 µg/mL of BiNar EP and irradiated with Cs-137 exhibited a greater number of DNA damage foci 24 h postirradiation compared with the control group. Additionally, molecular probe assays showed that BiNar EP increased nanometric DNA damage after Co-60 irradiation at a 1:100 BiNar EP ratio. These results support the valorization of agro-industrial by-products as sustainable sources of precursors for green nanoparticles synthesis and demonstrate the potential of BiNar EP as a promising nano-adjuvant for enhance the effects of radiotherapy.

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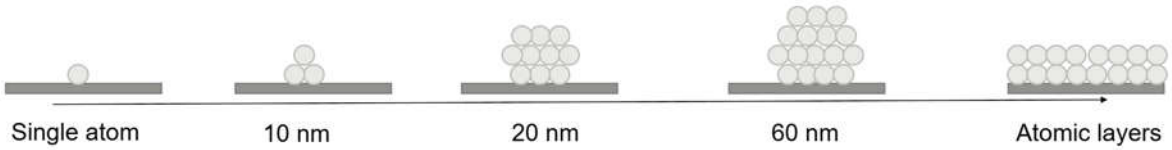
A Collaborative Investigation on the Effects of Flue Gas on Sn-based Catalysts for Continuous CO_2 Electro-reduction to Formate

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CO_2 levels in the atmosphere have been increasing since the industrial revolution and are the leading contributor to climate change. Aspart of the strategy to tackle climate change, CO_2 utilisation has the potential to be a transformative technology to aid in curbing greenhouse gas emissions and whilst contributing to circular chemical manufacturing. There is a whole raft of products that can be produced from CO_2 but their viability at industrial scale is not completely realised at present.[1] Large scale industrial CO_2 emissions from power generation, concrete and steel manufacturing, typically do not consist of only CO_2, but also contain several low concentration compounds, such as SO_2 and NO_X, especially using coal as the fuel source. The contaminants can have a detrimental effect on the efficiency of the catalysts employed in CO_2 electro-reduction.[2]

Our work is focused on exploring novel Sn electrocatalysts that convert CO_2 to formate and benchmarking them in industrially relevant and scalable conditions.[3]



Using magnetron sputtering to produce a range of Sn catalysts on carbon paper (single atom – nanoclusters – atomic layers), we then apply these in a continuous flow electrochemical reactor under a range of conditions using mixtures of SO_2 and CO_2. Our aim is to investigate the effect SO_2 concentration plays on the efficiency of the tin catalysts in both flow and batch conditions and determine the viability of scale up in real world industrial conditions. In addition to the performance metrics from the $CO_2 \rightarrow$ formate reaction, the electrocatalysts will be investigated using imaging and electrochemical measurements.

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Integrating Green and Sustainable Chemistry into Undergraduate Teaching in Guatemala: A Comparison of Three Methods for the Removal of Orange G from Water

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The implementation of green and sustainable chemistry in education should be a gradual and consistent process to achieve the benefits of safer and more responsible chemistry for future generations. At the Universidad de San Carlos de Guatemala, during the final year of the undergraduate chemistry program, a project was proposed in which the knowledge acquired in courses such as Natural Products Chemistry, Soil Chemistry, Analytical Methods Validation, and Environmental Chemistry was integrated. For this purpose, three methods were applied to remove Orange G dye from water.[1] The chemistry of dyes is particularly important in Guatemala, as many water sources are contaminated and the country faces significant legislative challenges. Culturally, most of the traditional clothing depends on artisanal dyeing, which is often poorly managed and contributes to water pollution. This approach allows students to put into practice the principles of green and sustainable chemistry in a real-world problem. In this way, filters based on clays, the use of waste orange peel (albedo) as an absorbent material, and NADES of camphor-menthol in different proportions were tested. A calibration curve of the Orange G dye was prepared at concentrations of 0.5, 1, 2, 4, 8, and 10 ppm in triplicate. The remaining dye in water was measured using UV-Vis spectroscopy at 464 nm. Turbid samples were filtered, and in cases where emulsions formed, they were broken using salt. The results showed that absorption with clay-based filters removed 60%, bio adsorption with orange peel removed 95%, and removal using NADES achieved 10%. These findings can lead to new proposals for water remediation and help students apply practical knowledge to real problems, bringing them closer to green chemistry with a more positive and responsible attitude. Students reported that this type of integrated project allows them to understand classroom concepts more deeply and provides ideas on how a chemist can have an impact in their community.

Keywords: Contaminant removal, Green Chemistry, Waste Valorization, NADES, Sustainability in Education

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Pineapple Peel-Derived Hard Carbon Microspheres for Sodium-Ion Batteries

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This study investigates pineapple peel, an abundant agricultural residue, as a sustainable carbon precursor for producing hard carbon anodes for sodium-ion batteries. The conversion of biomass waste into functional electrode materials provides a practical approach to addressing both waste management and the demand for low-cost energy-storage materials. In this work, pineapple peel-derived hard carbons were prepared through hydrothermal treatment followed by pyrolysis at different temperatures to evaluate the influence of thermal treatment on their structural, morphological, and electrochemical properties. The synthesized carbon materials were comprehensively characterized using scanning electron microscopy (SEM), X-ray diffraction (XRD), and Raman spectroscopy analysis. Their sodium-storage performance was then assessed through cyclic voltammetry (CV) and galvanostatic charge–discharge (GCD) measurements. Among the prepared samples, the carbon obtained at 800 °C, denoted as HTC-PP-800, showed the most favourable overall performance. This sample exhibited a suitable balance between structural ordering, electrochemical reversibility, capacity retention, and cycling stability. HTC-PP-800 delivered a reversible capacity of 298.5 mAh g^{-1} at a current density of 0.05 A g^{-1}, demonstrating its potential for efficient sodium-ion storage. The enhanced performance is associated with the formation of a stable hard carbon framework and improved structural features at higher pyrolysis temperature. Overall, this study highlights the feasibility of transforming pineapple peel waste into value-added hard carbon anodes. The findings suggest that agricultural residues can serve as environmentally friendly and economical precursors for sustainable sodium-ion battery technologies.

Keywords: Hard carbon, Biomass, Hydrothermal Carbonization

Carbon-based Lewis/Brønsted acid catalysts for 5-HMF one-pot production

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Lignocellulosic biomass represents a valuable renewable feedstock for the synthesis of numerous green chemicals. Among the possible products that can be obtained from its degradation, 5-hydroxymethylfurfural (5-HMF) is a high added-value platform molecule that can be recovered from its cellulosic component via a three-step reaction promoted by both Brønsted and Lewis acid sites (Figure 1) [1]. In this study, we present a straightforward approach to synthesize efficient bifunctional catalysts by grafting benzyl sulfonic moieties (Brønsted sites) onto a carbon support (SX+ from NORIT, fraction < 50µm) functionalized with aluminosilicate patches (Lewis sites) grown from the precursor di-secbutoxyaluminoxytriethoxysilane [2]. The resulting bifunctional catalysts (Figure 2) were extensively characterized and their catalytic performance investigated for the one-pot upgrading of cellobiose to 5-HMF. Bifunctional catalyst I4@BATEOS/SO3H, with an average pore size of 45.8 Å and a total acidity of 1.25 mmol g-1, was found to be the best performing material, yielding 37% of 5-HMF out of a 96% conversion of the initial cellobiose feed when tested over 23 h at 423 K in a designed solvent mixture. No significant side products were observed after 23 h, confirming the high selectivity of the catalyst.

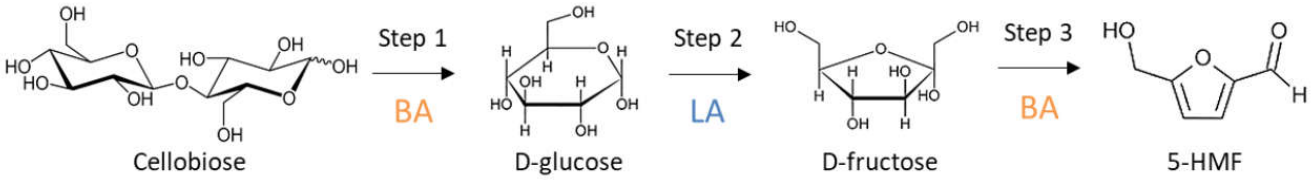


Figure 1. One-pot synthesis of 5-hydroxymethylfurfural from cellobiose.

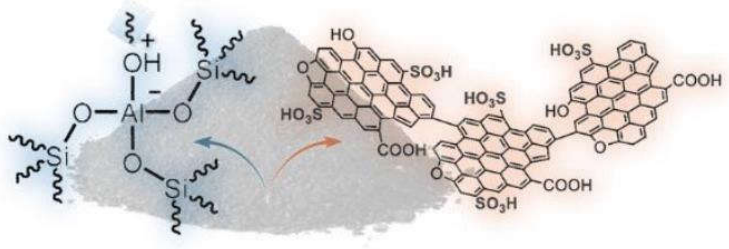


Figure 2. Schematic overview of the bifunctional carbon-based catalyst.

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Keywords: 5-Hydroxymethylfurfural • Bifunctional catalysts • Heterogenous acid catalysts

Extraction and Characterisation of Keratin Associated Proteins

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Sources of keratin such as feathers, wool and hair are a huge waste biomass, attributing to more than 40 million tonnes per year.[1] Currently most of this waste is disposed of in landfill or is incinerated creating a huge environmental impact.[2] Effective valorisation of this waste is therefore essential. With the major protein, keratin, having potential applications in cosmetics, pharmaceuticals and the food industry.[1] Human hair, an example of this keratin waste, is comprised of a polymer of keratin surrounded by a matrix which is where we find keratin associated proteins, which are small hydrophobic proteins.[3] The aim of the project is to fully extract, analyse and characterise the keratin associated proteins (KAPs) found within the hair matrix, using ionic liquids and deep eutectic solvents (DES) as potential green, designer solvents.[4]

Initial work has seen hair be successfully dissolved in varied Urea: polyol deep eutectic solvents (DES). Separation of individual proteins has been completed by gel electrophoresis and has been analysed using a variety of techniques including mass spectrometry. Although dissolution yielded no identifiable proteins, extraction of a specific KAP has been possible by using a vortex mixer with a Urea: polyol DES and a reducing agent. Currently this has seen distinct bands that are visible on a 1D SDS-PAGE with both keratins and KAPs identified by LC-MS/MS.

Moving forward it is essential to optimise these conditions to extract a variety of different types of KAPs as well as characterise these KAPs using FTIR, TGA, DSC and circular dichroism (CD). Native extraction can typically only yield small concentrations of this protein therefore, to achieve further analysis of this KAP on a larger scale, expression of the proteins in E. coli is being attempted. If this is successful it would yield high concentrations of protein for further analysis.

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Understanding Metal–Support Effects in CO_2 Hydrogenation to Methanol through Data-Driven Analysis

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Fossil fuel dependence has driven atmospheric CO_2 increases, contributing to climate change and ocean acidification. To support carbon neutrality goals and a circular carbon economy, CO_2 conversion into valuable products has emerged as a promising strategy. In particular, CO_2 hydrogenation to methanol, a versatile energy carrier and chemical feedstock, has gained increasing attention through data-driven and machine-learning (ML) approaches. However, much of the existing literature on CO_2 conversion to methanol has been emphasizing the use of ML in optimizing reaction conditions and performance prediction rather than chemical interpretability of heterogeneous catalysts and data-driven catalyst design insights for conversion process. Thus, the present study aims to provide a comprehensive ML-assisted analysis of heterogeneous catalysts for CO_2 hydrogenation to methanol. The analysis is based on a documented dataset comprising nearly 3500 entries, integrating literature-reported experimental data with ML-driven reconstruction of missing values. Upon training the ML model for chemical interpretable analysis of heterogenous catalyst in CO_2 conversion to methanol, analysis of significance of various descriptors such as such as active phase, support, and metal content and the operating conditions (like temperature, pressure, and space velocity) were made.

This work reveals that the characteristics of catalyst supports are consistently identified as the most critical factors across all algorithms used to train the ML model, often surpassing the role of the metallic active component in terms of CO_2 conversion and methanol selectivity. Although Cu-based catalysts dominate the existing literature on CO_2 conversion to methanol, our findings indicate that numerous less-studied metals (such as Ce, La, Pr) exhibit higher average CO_2 conversion rates, especially in multi-metallic combinations (such as Cu–Zn, Cu–Zr, Cu–In). When paired with specific supports (including C, MnOx, In_2O_3, ZrO_2), this typical multi-metallic combination shows improved selectivity for methanol synthesis. Besides uncovering the novel catalyst formulation for CO_2 hydrogenation to methanol, this work points out the systematic bias present in existing experimental studies and uncovers an essential trade-off between activity and selectivity. Finally, this study highlights the potential of merging data science with chemically interpretable analysis, which offers valuable practical insight and viewpoints for the rational, synergy-driven design of next-generation CO_2-to-methanol catalysts.

Role of CNF Origin in Tailoring Floating CNF–Silane Hybrid Aerogels

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Nanocellulose-based hybrid aerogels are an emerging class of bioinspired nanocomposites distinguished by their hierarchical porous architecture, low density, and high structural stability. These features enable the efficient immobilization and homogeneous dispersion of photocatalytic nanoparticles, minimizing aggregation while preserving active surface area. Additionally, their intrinsic floatability facilitates prolonged sun exposure at the air–water interface, thereby enhancing photocatalytic efficiency under natural sunlight conditions. Owing to these combined physicochemical properties, such sustainable materials are particularly well suited for the rational design of advanced photocatalytic systems targeting the degradation of organic pollutants in wastewater. Therefore, this study systematically investigates the influence of the initial cellulose source on the production of cellulose nanofibrils (CNFs) and on the subsequent fabrication of CNF–silane hybrid aerogels. Four cellulose feedstocks with distinct degrees of polymerization (DP) – microcrystalline cellulose (MCC, DP ≈ 140), eucalyptus cellulose (EYPT, DP ≈ 2742), α-cellulose (α-CEL, DP ≈ 950), and cotton linters (CL, DP ≈ 465) – were subjected to combined physicochemical pretreatments, including alkaline–acid hydrolysis and ultrasonication, to facilitate fibrillation. Subsequently, the pretreated cellulose was oxidized via TEMPO-mediated reactions, a selective process that converts primary hydroxyl groups into carboxylate functionalities, thereby enhancing fibril individualization and surface reactivity. The structural, chemical, and morphological changes induced by oxidation were comprehensively characterized using Fourier-transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD), and electron microscopy techniques (SEM and TEM). These analyses provided insight into the evolution of crystallinity, surface functionalization, and the nanoscale organization of CNFs, as well as the morphology of films obtained after solvent evaporation. The CNF-derived aerogels exhibited pronounced variations in macroscopic appearance and microstructure, strongly dependent on the originating cellulose type. In contrast to the relatively dense and compact morphology of CNF films, the aerogels displayed highly porous, three-dimensional architectures with tunable pore size distributions, bulk densities, and degrees of pore interconnectivity. These structural differences highlight the critical role of precursor characteristics in directing the assembly and performance of CNF-based porous materials [1].

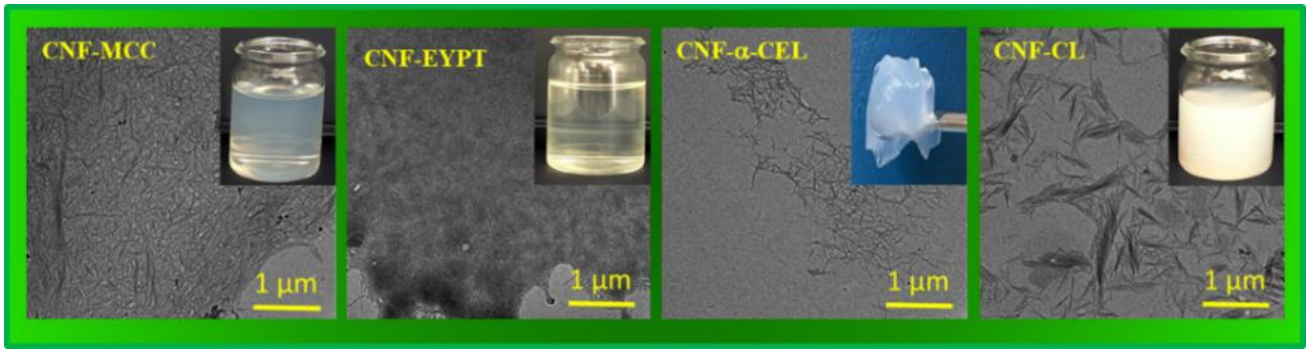


Figure 4. SEM microphotographs of CNF samples.

Keywords
(nano)cellulose, aerogels, wastewaters, pollutant photodegradation, green chemistry
Acknowledgements
This work was supported by a grant of the Ministry of Education and Research, CNCS – UEFISCDI, project number **PN-IV-P1-PCE-2023-1020** (6PCE⁄08.01.2025), within **PNCDI IV**.
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β-TaON Photocatalysts for Enhanced Photoelectrochemical Water Splitting via Phase Control and Vanadium Doping

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Tantalum oxynitride (TaON) is a promising photocatalyst for solar water splitting, but its performance is often hindered by the difficulty of achieving phase-pure, thermodynamically stable β-TaON, insufficient crystallinity, stoichiometric deviation, and inefficient charge-carrier transport. In this study, two complementary strategies were applied to improve the photoelectrochemical performance of β-TaON. First, the oxygen partial pressure was adjusted by varying the O_2 flow rate from 0 to 0.35 L h^{-1} during Ta_2O_5 ammonolysis, thereby regulating the phase evolution pathway from Ta_2O_5 through β-TaON to Ta_3N_5. A narrow synthesis window for phase-pure β-TaON formation was identified at an oxygen flow rate of 0.25 L h^{-1}. Second, vanadium doping over the range of 0-25 at.% under optimized synthesis conditions with an O_2 flow rate of 0.25 L h^{-1} was employed to tune optoelectronic properties. X-ray photoelectron spectroscopy verified the successful substitution of V^{5+} at Ta^{5+} sites in the β-TaON lattice. X-ray diffraction analysis indicated that V doping up to 10 at.% enabled the retention of phase-pure β-TaON, whereas higher V contents induced formation of secondary phases. UV-vis diffuse reflectance spectra and Tauc analysis revealed that increasing vanadium content shifted the absorption edge toward longer wavelengths and narrowed the bandgap of the dominant β-TaON phase from 2.72 eV to 2.38 eV. Density functional theory calculations showed that V incorporation modulated the electronic structure of β-TaON, leading to bandgap narrowing, reduced electron effective mass, enhanced n-type conductivity, and favorable band-edge shifts. Photoelectrochemical measurements confirmed that moderate V incorporation enhances the photocurrent response and charge-transfer efficiency, while excessive V doping reduced performance due to secondary-phase formation and increased recombination. This work highlights a dual strategy for controlling phase composition and tuning the electronic structure of β-TaON, providing valuable insights into the development of efficient photocatalytic materials for solar fuel production.

Keywords: photoelectrochemical performance, vanadium doping, β-TaON

Two Novel Ionic Polyimides for Gas Separation Membranes: Synthesis, Characterization, and Gas Transport Properties

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Accelerated industrialization has significantly increased global energy consumption and carbon emissions, driving the demand for more energy-efficient separation technologies [1]. Industrial gas separations are essential in applications such as oxygen production, fuel processing, and chemical purification; however, conventional technologies, including cryogenic distillation and amine absorption, remain highly energy intensive [2]. Polymeric membranes have emerged as a promising alternative due to their lower energy requirements and operational simplicity [3].
In this work, two novel ionic poly(imides) were synthesized through a Menshutkin between diimidazolimide monomers and α,α-dibromo-p-xylene. The polymers differ in the presence of a methyl substituent in the backbone, introduced to investigate the effect of structural modifications on membrane properties and gas transport behavior.
The synthesized polymers were characterized by ^{1}H NMR, FT-IR spectroscopy, and X-ray diffraction (XRD), while their thermal properties were evaluated by thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Both materials exhibited excellent thermal stability, good solubility in common organic solvents, and outstanding membrane-forming ability, enabling the preparation of dense self-standing films by solvent casting.
Structural characterization revealed that the incorporation of methyl groups increased chain rigidity while decreasing polymer density and enlarging interchain spacing, indicating an increase in fractional free volume. As a result, the methylated polyimide exhibited higher gas permeability than its non-methylated counterpart. Gas permeation measurements also showed that CO_2 was the most permeable gas after H_2 in both membranes, highlighting the favorable interactions between CO_2 molecules and the ionic functionalities of the polymer matrix. These findings demonstrate that the introduction of methyl substituents effectively modulates the structural and transport properties of ionic polyimides, further supporting their potential as promising membrane materials for CO_2 separation applications.

Keywords: *membrane, gas separation, ionic polyimides*

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Production and Recovery of Cellulose Acetate Particles By Membrane-Based Processes: A Green Scalable Strategy

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Functional particulate systems at nano and submicron scale are widely used in several fields, including biomedical applications, agriculture, and advanced functional materials. Their performance strongly depends on particle size, distribution, morphology, and surface properties, which are critically governed by the synthetic route. Actually, there is a growing need to develop an efficient and scalable production strategies which could be sustainable, minimizing environmental impact and waste generation, and enabling efficient recovery of solvents and materials in agreement with circular economy principles. Membrane-based processes offer significant advantages in this context, in line with the principles of Green Chemistry. Among the manufacturing processes, nanoprecipitation (MN) is recognized as a mild, simple and energy-efficient strategy to fabricate particles [1]. MN approach governs solvent/non-solvent interdiffusion, leading to controlled supersaturation and homogeneous nucleation. In the present work, the MN of cellulose acetate (CA), a biopolymer derived from renewable cellulose, was studied since the classical dropwise nanoprecipitation led to macroaggregates and not uniform particles distribution. Two different membrane-based setups were investigated: Batch Membrane Nanoprecipitation (BMN) and Continuous Membrane Nanoprecipitation (CMN). CMN significantly improved particle formation, reducing aggregation, narrowing particle size distributions and increasing reproducibility. By promoting precise control over the contact between the phases along the membrane pores and diffusion-driven phenomena rather than bulk turbulent mixing, this membrane system enhanced process efficiency, and reduced material waste. From a sustainability perspective, materials were carefully selected to minimize environmental impact while ensuring process efficiency. Water was used as the non-solvent, whereas acetone and DMSO were chosen as solvents due to their favorable balance between solubility performance and safety profiles. Downstream processing was performed via tangential flow filtration (TFF) [2] to purify CA particles from DMSO-containing suspensions, thereby overcoming the limitations of conventional techniques in removing high-boiling organic solvents. This membrane-based route enabled efficient solvent exchange while preserving particle integrity, further contributing to process intensification. Overall, the integration of renewable polymer feedstocks, greener solvent systems, and membrane-based processes provides a coherent and scalable platform for sustainable particulate manufacturing.

Keywords: membrane nanoprecipitation, tangential flow filtration, biopolymers, cellulose acetate

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Circular Bio-Based Aerogels via Dynamic Imine Networks for Water Remediation and Heterogeneous Catalysis

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One of the major relevant environmental challenges of the 21st century is the heavy metal contamination of water, with industrial effluents that can release toxic Cu^{2+}, Pb^{2+} and Zn^{2+} ions at concentrations exceeding WHO safety limits [1]. Conventional remediation technologies, such as membrane filtration and activated-carbon adsorption, are often limited by high costs, limited regenerability and poor alignment with circular-economy principles. Bio-based materials derived from abundant biopolymers offer a promising alternative by combining sustainability, biocompatibility and tunable chemical functionality [2]. In this work, monolithic aerogels based on chitosan (CS) and aldehyde-functionalised lignin (LGN-CHO) were developed as reusable adsorbents for heavy metal removal and heterogeneous catalysis. Lignin was functionalised via the Reimer–Tiemann reaction to introduce aldehyde groups, which reacted with the primary amines of chitosan to form a dynamic covalent imine network [3]. The reversibility of these crosslinks under mild acidic conditions enabled a circular design in which all components can be recovered and reused. The resulting aerogels showed good solvent resistance and stability in the pH 7–9 range, and demonstrated efficient simultaneous adsorption of Cu^{2+}, Pb^{2+} and Zn^{2+} with maximum capacities of 32.8, 30.2 and 27.7 mg/g respectively [4]. DFT calculations revealed a tridentate ONO coordination mechanism, with Cu^{2+} exhibiting the highest interaction energy. When loaded with Cu^{2+}, the aerogels functioned as heterogeneous catalysts for the Chan–Lam cross-coupling reaction, achieving initial yields of up to 92% and retaining their activity over multiple cycles. Taken together, this work demonstrates a circular bio-based platform that integrates water remediation, material recyclability and catalytic valorisation within a single dynamic network.

Keywords: biomass,reversible aerogel, supported catalysts, sustainable chemistry, water remediation

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Development of Green Electrocatalytic System for Selective Phenol-to-Cyclohexanone Conversion

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The hydrogenation of phenol to cyclohexanone is an industrially important reaction with broad applications in fine chemicals [1], daily-use chemicals and biomass valorization [2]. Compared with conventional thermocatalytic processes, electrochemical hydrogenation (ECH) provides a greener alternative by enabling selective conversion under mild conditions through electrochemical potential control. However, current ECH systems still face several challenges. At the process level, they often rely on large amounts of liquid acidic or alkaline electrolytes [3], suffer from difficult product separation, require complex catalyst preparation [4], and depend on costly membrane materials with cumbersome pretreatment procedures [5]. At the reaction level, incomplete understanding of reaction mechanisms, excessive H* coverage causing over-hydrogenation to cyclohexanol [6], and the direct participation of electrolyte ions all limit reaction selectivity and efficiency [7]. Therefore, developing sustainable ECH systems with simplified reaction environments and reduced costs remains highly desirable.

In this work, a simple electrocatalytic suspension strategy is proposed. By combining a dispersed heterogeneous metal catalyst with a PTFE membrane configuration, the system aims to reduce dependence on conventional liquid electrolytes. Water serves as the hydrogen source, while a recyclable solid polymer electrolyte acts as the proton-conducting medium. This design is expected to enable closed-loop utilization of reaction media and supporting materials, improving sustainability and resource efficiency.

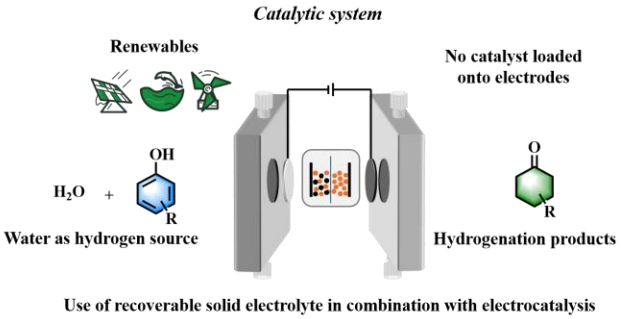


Fig. 1. Solid polymer electrolyte-assisted suspension electrocatalysis for phenol hydrogenation

Keywords: Electrochemical hydrogenation; Phenol; Cyclohexanone; Solid polymer electrolyte; Heterogeneous electrocatalysis; Green chemistry

Acknowledgements

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POSTER WINNERS AWARDS

The scientific quality of the posters presented at the XVIII International Postgraduate Summer School on Green Chemistry has significantly improved compared to previous editions. This enhancement reflects the increasing availability of high-level scientific instrumentation in underdeveloped regions and the growing focus on green chemistry research.

A total of 67 posters were presented, with 14 from online students and 53 from in-person attendees. Students showcased their research during the poster sessions held on Tuesday, July 7th, and Thursday, July 9th. Additionally, the posters from online students were made available for ongoing consultation on the website https://www.greenchemistry.school/poster-sessions/.

The Poster Sessions is a highlight of the Summer School, notable for the originality and diverse scientific contributions. The sessions featured a significant number of young researchers sharing their work, generating considerable interest among participants. During the poster awarding ceremony, seven participants were recognized for their outstanding posters and were given the opportunity to present their work orally during the Closing Ceremony.

There were 6 Awards: 2 for online poster presentations, and 4 in presence poster presentations.

The 2 winners of the GSSD Foundation Online Poster Award of the XVII International Postgraduate Summer School on Green Chemistry were:

Rayen Ben Aoun – *Université de Tunis El Manar, Tunisia*
Poster title: **"From Waste to Sustainable Solutions: Green Extraction of Chitosan with Deep Eutectic Solvents for Food Coating and Plant Stress Tolerance"**

Sara El Moujahed – *Sidi Mohamed Ben Abdellah University, Morocco*
Poster title: **"Bioinspired Collagen Films Reinforced with Waste-Derived Polyphenols for Sustainable Bioactive Packaging"**

The 4 in-person winners of the PhosAgro Poster Award in *"Memory of Professor Pietro Tundo"* of the XVII International Postgraduate Summer School on Green Chemistry were:

Gustavo Felix Bitencourt – *Universidade Federal do ABC – UFABC, Brazil*
Poster title: **"Metal-Free Aldehyde-Rich Covalent Organic Frameworks for Hydrogen Peroxide Production from Sunlight, Water and Air"**

Mayu Kamisono – *Kyushu University, Japan*
Poster title: **"Deep Eutectic Solvent-Based Selective Recovery of Platinum Group Metals from Spent Automotive Catalysts"**

Matteo Mora – University of Genova, Italy
Poster title: **"Carbon Dioxide Feeding Optimization in a Closed Microalgae Photobioreactor for Space Applications"**

Schubert Fernandes & Theodore Lunny– University of Nottingham and Nottingham Trent University, United Kingdom
Poster title: **"Transient Solvent Ramp Experiments for the Determination of Kinetic Parameters in Flow"**

The in-presence students Awards consisted in a cash prices (respectively 4 amount of 250€) sponsored by PhosAgro, "Poster Prize in Memory of Professor Pietro Tundo". The Awards were handed over to the students during the closing ceremony.

The Online Students Award consists of two scholarships offered by the GSSD Foundation for in-person attendance at the next edition of the Summer School 2027 from 5th of July to 9th of July in Venice, Italy. The winning students presented their research work with a PowerPoint presentation during the Closing Ceremony on the last day.





GSSD Foundation Online Poster Award:

Rayen Ben Aoun (*left) and* Sara El Moujahed (right)











The in-person winners of the PhosAgro Poster Awards:

Gustavo Felix Bitencourt (*top left*), Mayu Kamisono (*top right*), Matteo Mora (*bottom left*), and Schubert Fernandes & Theodore Lunny (*bottom right*)

CLOSING CEREMONY

The Closing Ceremony of the XVIII International Postgraduate Summer School on Green Chemistry marked the conclusion of an inspiring and enriching week of scientific exchange, networking, and professional development. During the ceremony, the President of the Green Sciences for Sustainable Development Foundation, Prof. Francesco Trotta, presented the Poster Awards to participants whose research contributions had been recognized for their excellence.

The ceremony also featured presentations and concluding remarks from members of the Organizing Committee. Dr. Aurelia Visa presented an overview of the data collected during the 18th edition of the Summer School, highlighting the growing number of in-person participants and the long-lasting impact of the programme. In addition to illustrating the results achieved in the 2026 edition, she retraced the history of the Green Chemistry Summer Schools, emphasizing their significant contribution to educating and inspiring generations of young researchers. Many former participants have since established successful careers as scientists, researchers, and university professors, demonstrating the enduring value of this educational initiative.

Following Dr. Visa's presentation, Prof. Mirabbos Hojamberdiev, Miss Graziana Gigliuto, and Prof. Fabio Aricò addressed the participants, underlining the importance of the Summer School as a unique platform for scientific collaboration, knowledge exchange, and professional growth. They concluded by encouraging the students to continue pursuing excellence in their future careers in green chemistry and sustainable development.

The ceremony concluded with the Closing Remarks delivered by Prof. Francesco Trotta, who reflected on the main achievements of the XVIII edition, expressed his appreciation to the Sponsors, participants, lecturers, and organizers, and reaffirmed the Foundation's commitment to promoting education and international cooperation in the field of green chemistry.

For further information about the Summer School and the activities of the Green Sciences for Sustainable Development Foundation, please visit **www.gssd-foundation.org**.



Signature of the Chairman of the Green Chemistry Summer School

10/07/2026, Venice, Italy

Group Photos of the XVIII International Postgraduate Summer School on Green Chemistry 2026





Teachers and Students of the Summer School

PHOTOS



Prof. Francesco Trotta, Chair of Summer School



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