RSC INTEREST GROUP
ENVIRONMENTAL CHEMISTRY

January 2025
Environmental Chemistry Group
Bulletin

Meetings. This issue reports five scientific meetings covering Carbon Capture and Storage, living in a doughnut economy, global policymaking, outreach at IF Oxford, and communicating sustainability.

CCS. Carbon Capture and Storage also features in two articles by **Michael Stephenson** and **Jon Gluyas**, respectively.

Environmental Briefs. **Cameron Ellis-Frew** examines the chemistry of e-cigarettes and vapes.

Interviews. **Adam Peters** recounts his consultancy career at WCA Environment. **Yassir El Hadri** shares his T-level studentship project at the RSC Sustainable Laboratories.

Also in this issue. The Chair's report highlights the evolution of the ECG *Bulletin* over the past 20 years. **Kiri Rodger's** reviews *Greenhouse Gas Removal Technologies*. Upcoming meetings include our biannual conference on 'Chemistry of the Whole Environment' in June and as an online event in February, 'Analysis of Complex Environmental Matrices'.

Contents

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ECG *Bulletin*

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Report

Chair's report

Caroline Gauchotte-Lindsay (University of Glasgow, caroline.gauchotte-lindsay@glasgow.ac.uk)

This issue of the ECG *Bulletin* marks not only my first as Chair, but it also celebrates an incredible **30 years of publication**. In honour of our milestone, I've undertaken a special project exploring the evolution of the ECG *Bulletin*. With the help of large language models, I conducted an in-depth analysis of 20 years of ECG *Bulletins*, uncovering trends, themes, and insights that showcase how our group has adapted to meet the challenges of environmental chemistry and broader global issues. This retrospective not only pays tribute to the dedicated contributors who have shaped the ECG *Bulletin*, but also provides a lens through which we can chart our future path. As we look ahead to 2025, I am excited to build on this rich legacy, fostering new opportunities for advocacy for a fairer, greener future.

This year saw transitions in officer roles — I took over from **Rowena Fletcher-Wood** as Chair, **Helena Rapp-Wright** became Treasurer, succeeding **Valerio Ferracci**, and whilst **Laura Alcock** remains our Secretary, she has moved halfway across the world. To ensure a smooth transition, Rowena is now our Vice-Chair, and we plan to appoint a new Vice-Chair in 2025. We welcome three new elected committee members: **Adam Peters** (see p. 6), **Amy-Louise Johnston**, (see p. 23) and **Emma Braysher**. Additionally, we co-opted **Gary Fones**, who will be chairing **#EnvChem2025** at the University of Portsmouth. **Table 1** summarises the Officers roles since 2015, an update since the 20th anniversary issue.[1]

In 2024, the ECG organised seven diverse and impactful events. The breadth and impact of our activities reflected a cohesive approach to addressing current environmental challenges, engaging both experts and the public, and fostering interdisciplinary collaboration to drive meaningful change. Our flagship **Distinguished Guest Lecture and Symposium**, *"Killer Threads: Fast Fashion's Impact on the Environment"*, focused on the environmental consequences of modern textile manufacturing, mass consumption, and waste disposal. The medal was awarded to **Dr Raquel Prado**, Head of Research and Sustainability at **Ananas Anam**, a textile company who developed **Piñatex** — an innovative, eco-friendly leather alternative made from pineapple leaf fibres. By using agricultural waste, **Ananas Anam** promotes circular economy principles and reduces environmental impact compared to synthetic or animal-based leathers.[2] The **Communicating Sustainability Workshop** (pp. 11-13) was facilitated by **Dr Mario Moustras** (RSC Management Interest Group). This workshop, aimed at doctoral students and early career researchers (ECRs), provided practical strategies for effectively conveying complex ideas to non-technical audiences. The event was supported by **Imperial College London**. The committee is now exploring how to extend this training to other ECRs across the UK. We introduced

Table 1. *Honorary RSC ECG Officers, 2015-2025.*

Year	Chair	Vice-Chair	Secretary	Treasurer
2015-2016	Martin King	William Bloss	Zoe Fleming	Dr Jo Barnes
2016-2017	Martin King	William Bloss	Zoe Fleming	Cecilia Fenech
2017-2019	Zoe Fleming	Martin King	Tom Sizmur	Ian Forber
2019-2020	Tom Sizmur	Zoe Fleming	Glynn Skerratt	Valerio Ferracci
2020-2021	Tom Sizmur	Rowena Fletcher-Wood	Glynn Skerratt	Valerio Ferracci
2021-2022	Rowena Fletcher-Wood	Tom Sizmur	Steve Leharne	Valerio Ferracci
2022-2023	Rowena Fletcher-Wood	Caroline Gauchotte-Lindsay	Laura Alcock	Valerio Ferracci
2023-2024	Rowena Fletcher-Wood	Caroline Gauchotte-Lindsay	Laura Alcock	Valerio Ferracci
2024-2025	Caroline Gauchotte-Lindsay	Rowena Fletcher-Wood	Laura Alcock	Helena Rapp-Wright

Table 2. *ECG Bulletin editors 2015-2025.*

Year	Editors
2015	Julia Fahrenkamp-Uppenbrink, Tom Sizmur, Glynn Skerratt
2016-2017	Julia Fahrenkamp-Uppenbrink, Rowena Fletcher-Wood, Tom Sizmur, Rupert Purchase, Glynn Skerratt
2018	Rowena Fletcher-Wood, Tom Sizmur, Clare Topping, Steve Leharne
2019-2020	Rowena Fletcher-Wood, Tom Sizmur, Laura Newsome, Clare Topping, Steve Leharne
2021	Rowena Fletcher-Wood, Tom Sizmur, Laura Alcock, Steve Leharne
2022-2024	Rowena Fletcher-Wood, Laura Alcock, John Collins, Caroline Gauchotte-Lindsay

a new type of workshop with the **Place of Chemistry in a Doughnut Economy** (pp. 20-22). Through interactive activities, participants developed systems-thinking frameworks to tackle sustainability issues. We hope this meeting will inspire a series of future events and communications centred on sustainable economic models. **Air Quality in the 21st Century**, organised in collaboration with DEFRA's Air Quality Expert Group, addressed emerging issues in air quality measurement and regulation. **Circular Chemistry: Carbon Capture and Storage** explored cutting-edge CCS techniques and storage solutions. Our outreach efforts included the **IF Oxford 2024 Festival** (p. 23), where we engaged the public with interactive activities on water pollution, plastic waste, and ocean acidification. Committee member Adam Peters attended the **Burlington Consensus 3** meeting (pp. 18-19) that highlighted the crucial role of scientists in shaping global policymaking on chemicals and pollution.

Figure 1. *AI generated image of me preparing the retrospective.*

Our website remains well visited, with over 42 visits per day on average, primarily through Google. Interestingly, we are also beginning to receive visits via queries on AI search engines such as perplexity.ai. ECG *Bulletin* articles continue to be popular! By the time you read this, we will have transitioned to our new website: https://www.rsc-ecg.com/, where you will find all your favourite content in a more accessible, user friendly, and RSC-aligned format.

Our vision in 2025 is to map our activities around the theme of a **Just Transition**. This will focus on the research, cultural changes, systems thinking, and training required for chemists to contribute to a resilient future. We will keep you updated on these developments. I am also excited that, in 2025, we will host our third in-person **#EnvChem Chemistry of the Whole Environment** event at the **University of Portsmouth**. Abstract submission is now open (see p. 36)!

Artificial intelligence (AI) continues to play an increasingly significant role in our personal and professional lives. Having used ChatGPT, a large language model (LLM), for nearly two years and recently upgraded to the Pro version, I decided to harness its capabilities to present a retrospective of ECG *Bulletin* contents over the last 20 years. I uploaded the ECG *Bulletin* PDFs and then engaged ChatGPT by asking a series of questions and prompts to compile key themes, insights, and highlights. I only tackled the last 20 years as PDFs produced earlier were not accessible to ChatGPT. This retrospective not only celebrates the rich legacy of the ECG *Bulletin*, but also highlights the potential of AI-driven tools. I was particularly struck by how the ECG *Bulletin* has consistently been at the forefront of our field's topics, including a contribution from Professor Richard Thompson based on his groundbreaking 2004 *Science* paper on microplastics[3], before they were even named! Additionally, the ECG *Bulletin* appears to serve as a comprehensive repository of all things arsenic.

In tribute to past ECG *Bulletin* contributors, **Table 2** updates that presented in our 2015 anniversary issue[1] with the last 10 years of editorial teams. More here: https://shorturl.at/ucyla And, if you are a ChatGPT Pro user, you can try the GPT I created (https://shorturl.at/MA9iF) to explore more.

ECG Bulletins: a 20 years retrospective

Co-authored with ChatGPT.

Plastics and microplastics

The issue of plastics, particularly microplastics, emerged in ECG *Bulletins* in the early 2000s. The first explicit mention came in 2004, with **Richard Thompson**'s article on *Problems with Plastics*, co-authored with **Steve Rowland**. This article laid the foundation for subsequent microplastics research, marking the first step toward understanding environmental impact. Subsequent ECG *Bulletins* continued to address plastic pollution, and the growing concern over microplastics. In 2014, the ECG *Bulletin* featured Richard Thompson's **Distinguished Guest Lecture**, which underscored the emerging threat of microplastics to the environment. Throughout the years, focus shifted from large plastic debris to microplastics and their effects on marine life, human health, and ecosystems. From 2014 onwards, the ECG *Bulletins* covered innovative solutions and increased regulatory efforts to address the plastic crisis, including new recycling technologies and eco-friendly materials.

Pharmaceuticals in the environment

This topic began gaining attention in the ECG *Bulletins* in the early 2000s. In 2005, **Pharmaceuticals in the Environment: Fate, Effects, and Regulation** brought together experts to address the environmental persistence of pharmaceutical compounds. Key speakers included **Emma Pemberton**, **Alex Tait**, and **Alistair Boxall**, who highlighted concerns about pharmaceutical residues in wastewater, soil, and water systems, and their role in antimicrobial resistance (AMR). ECG *Bulletins* later covered advances in detection and growing concern about AMR. Innovative solutions like advanced oxidation processes (AOPs) for wastewater treatment arose, and issues highlighted the impact of microplastics in exacerbating pharmaceutical pollution.

Atmospheric chemistry and climate change

Atmospheric chemistry, particularly its role in climate change, has been a key theme in ECG *Bulletins*; starting with early discussions on the chemistry-climate interactions in the 2005 Faraday Discussion, which examined the stratospheric–tropospheric ozone exchange and the role of free radicals in atmospheric processes. In the following years, focus shifted to the role of atmospheric chemistry in global warming and air quality. Notable topics included ozone depletion, the role of hydroxyl radicals in the atmosphere, and aerosol interactions with atmospheric systems. By 2010, ECG *Bulletins* focused on urban air pollution and greenhouse gases, particularly their impact on climate change and atmospheric reactions. In the later years, especially 2014–2024, ECG *Bulletins* saw the integration of satellite technology to monitor air pollutants and the growing importance of climate modelling. Solutions, such as the development of greenhouse gas removal technologies and aerosol geoengineering, were also discussed.

Arsenic contamination in the environment

Arsenic contamination in groundwater is a recurring ECG *Bulletin* theme, focusing on its environmental, health, and remediation implications.

2004–2007: Arsenic contamination in Bangladesh and other parts of Asia. Reports highlighted that millions were exposed to high levels of arsenic through drinking water, leading to chronic health conditions.

2007–2009: Health risks of arsenic in India, Bangladesh, and Vietnam. Phytoremediation was discussed as an innovative approach, with plants like *Pteris vittata* for arsenic cleanup.

2011–2019: Global arsenic contamination, including regions like Latin America and Europe. New arsenic removal technologies tested in Bangladesh and India, like community-based filters and larger-scale treatment plants, were presented.

Two decades of the ECG *Bulletin* reveals a dynamic evolution of environmental chemistry. Milestones underscore the interconnectedness of environmental systems and the need for holistic approaches to solve complex, multifaceted issues. Environmental problems do not exist in isolation, but are part of broader ecological, societal, and economic networks. The future of environmental chemistry will depend on our ability to integrate technological innovation with ethical responsibility. Emerging challenges such as nanomaterials, geoengineering, and sustainable resource management offer opportunities to develop solutions that not only mitigate harm but also promote equity and resilience. The ECG *Bulletin* continues to be a vital platform for sharing insights, fostering interdisciplinary collaboration, and inspiring action. Let us chart a course towards a healthier, more resilient, and more just world for all.

References

1. R. Purchase, ECG *Bulletin*, January 2015, pp. 4-6.
2. K. Rodgers, ECG *Bulletin*, July 2024, pp. 5-6.
3. R. C. Thompson et al. *Science*, 2004, **304**, 838; https://doi.org/10.1126/science.1094559

Interview

The ECG Interview: Adam Peters

Adam Peters (WCA Environment, adam.peters@wca-consulting.com)

Adam Peters is a Principal Consultant at WCA Environment and an environmental chemist with over 20 years of experience in consultancy, regulation, and academia. He has been closely involved with the development and implementation of bioavailability based Environmental Quality Standards for metals in both Europe and Australia. Adam's main areas of expertise are in environmental fate and behaviour, and the bioavailability and effects of trace metals in relation to the use of biotic ligand models; environmental risk assessment of industrial chemicals; and the assessment of persistent, bioaccumulative and toxic (PBT) substances.

What inspired you to become a scientist?

I have always wanted to know why things are the way they are, and had some really enthusiastic and engaging teachers for biology and chemistry when I was in school who really encouraged questioning things.

How did you come to specialise in chemicals management?

Sometime after completing my PhD in metal speciation, I took a job with the Environment Agency, and was very surprised by just how important the regulation of metals in the environment was. I was fortunate to have a background in the chemical side of metal bioavailability just as it was starting to become recognised as important for regulation.

Could you describe your current job?

I am an Environmental Consultant, but much of my work involves finding simple ways to present complex information and deliver practical solutions.

What advice would you give to anyone considering a career in environmental chemistry?

Approach everything with an open mind and draw your conclusions based on the evidence, you might be surprised by what you find.

What are some of the challenges facing the environmental chemistry community?

A lot of aspects of environmental work are driven by regulations, so ensuring that outputs are both scientifically robust, but practical and simple enough to be useful for regulatory applications is extremely important.

What is the most rewarding aspect of your career so far?

Seeing the first presentation on the Biotic Ligand Model at a SETAC Europe meeting in ~1998, and taking something purely academic to form the basis for the implementation of Environmental Quality Standards for several metals in surface waters, not just in Europe but also other parts of the world, that can be applied by ordinary practitioners.

If you weren't a scientist what would you do?

Probably not very much worth noting.

And what do you do when you are not working?

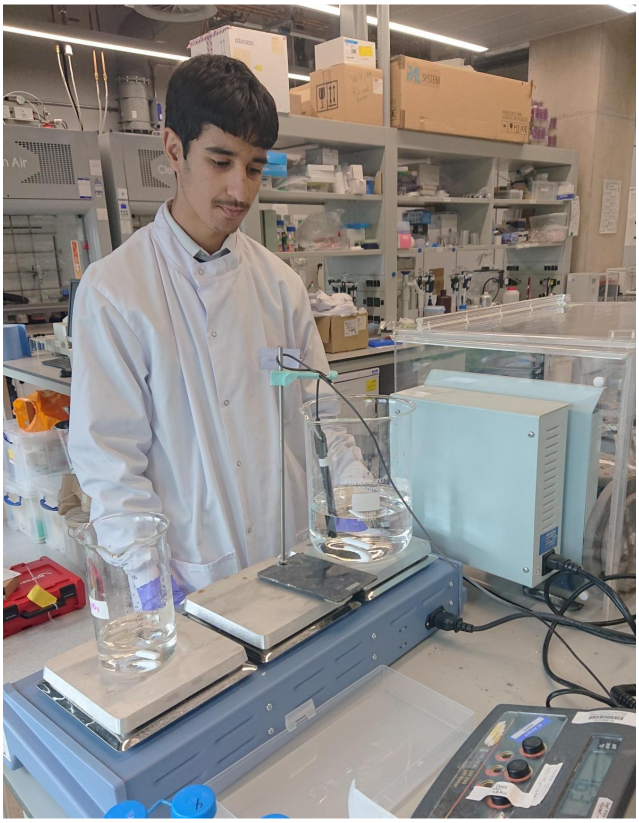
Usually riding my bike or woodturning.

Interview

Project Interview: Yassir El Hadri

Helena Rapp-Wright (Imperial College London, h.rapp-wright@imperial.ac.uk)

Yassir completed his T-level studentship programme at Imperial College London in the Environmental Research Group (ERG) in 2024. T-level studentships describe two-year technical qualifications, which importantly combine work experience and practical work with academic study. As part of the RSC Sustainable Laboratories Grant awarded to Dr Helena Rapp-Wright and Amber Vaughan (L23-8109900824), he completed a project investigating the feasibility of reusing "single-use" plastics in the laboratory. In this project, he learned the importance of sustainability as well as the fundamentals of analytical chemistry, including liquid chromatography and mass spectrometry (LC-MS) for trace analysis. The results of the project are currently being compiled, and the team will hope to publish these soon.



What inspired you to take a T-level in science?

T-level science opens pathways to various scientific careers, which has allowed me to explore and learn many ways a scientist can have a positive impact in the world. The combination of classroom learning, and hands-on industry placement appealed to me because I prefer practical, real-world experience over purely theoretical study.

> **"The skills and knowledge you will gain [through T-Level Science] will be incredibly rewarding…"**

How are you enjoying T-level science?

I am enjoying the course; it has really opened my eyes to new opportunities and pathways. I feel that the course has significantly contributed to my personal and academic growth. Working alongside dedicated professionals has inspired me to look forward to the future. I also really enjoyed learning key skills but learning to work independently was the most challenging. This is because, for the first time in my life, my actions have been decisive for my future. "Time is what we want most, but what we use worst": this quote from Willian Penn made me understand the importance of using your time wisely.

Could you describe your placement project within the ERG?

The project that I was part of involved finding the most environmentally sustainable method for reusing plastics in the laboratory (pipette tips, Tritan bottles etc.). There were many steps to the project, including selecting solvents that are environmentally friendly, thus making the project greener. After selecting the solvents, we spent a lot of time in the laboratory doing a lot of pipetting. Although this was not the most enjoyable part of the process, it definitely taught me that patience is necessary to be able to get results. I also had the chance to use a microscope to see the difference between the clean pipette and a used one.

I enjoyed learning about LC-MS and its functions; the technique gave us large data sets, which had to be processed so we could select the best solvents. After analysing all our data, I prepared a poster about the project, explaining what it is about, what we found and how this would be helpful for other laboratories.

What are some of the challenges you faced during your project?

Data analysis: this was very stressful because I had to stay focused with very large data sets. This was challenging because it was the first time that I was fully working with data, and it was very time-consuming, although it really enhanced my understanding of the Laboratory Information Management System (LIMS), for which I will forever be grateful. Another challenge was presenting the project; this was challenging because it was the first time that I had to present my findings to other professionals. I was very nervous but, thanks to my mentors helping me rehearse it, I was ready and very happy to let others know what the project was about.

What is the most rewarding aspect of your course and placement project so far?

During my placement at Imperial College London, I most enjoyed being part of the sustainability project, because it expanded my knowledge in many ways. It has also helped me gain new skills such as working in a team, analysing and presenting my findings, safe handling of equipment; and it had a massive impact on my communication skills. The most rewarding aspect of my course was definitely having a chance to get a taste of real-world experience. I also enjoyed doing practical work at the University, because it enhanced my understanding and knowledge of science.

What advice would you give to anyone considering T-Level Science?

My advice would be to fully embrace both the academic and practical components of the course. Engage actively in your industry placement, as it provides invaluable hands-on experience. Stay curious and open-minded, ask lots of questions, and take advantage of the opportunity to network with professionals in the field. Balancing the workload can be challenging, but the skills and knowledge you gain will be incredibly rewarding and beneficial for your future career.

What kind of career are you hoping to have in the future, and how would you like to achieve this?

I would like to work in the biomedical sector; biomedical science's capacity to comprehend the intricate human body and the diseases afflicting it has driven my pursuit of understanding its complexity. This ardour propels my ambition to contribute to advancements in medical research and healthcare. Upon achievement of this, I aspire to augment my knowledge by pursuing a career in microbiology, thereby broadening my career prospects.

And what do you do when you are not working?

In my free time, my extracurricular involvement in the University football team for two competitive seasons provided me with invaluable teamwork and leadership skills. Additionally, my engagement in weight training as a hobby instilled discipline and adherence to routine, whilst contributing to maintaining my physical health and fitness.

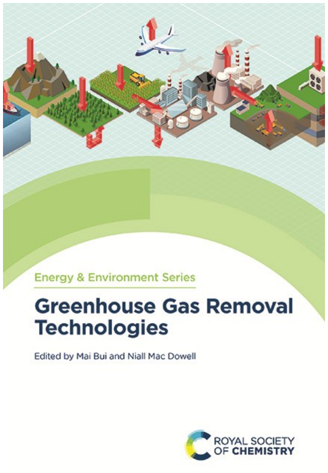
Book review

Greenhouse Gas Removal Technologies

Kiri Rodgers (University of the West of Scotland, kiri.rodgers@uws.ac.uk)

This book provides the most up to date information on Greenhouse Gas Removal (GGR), with a focus on the removal of atmospheric CO_2. It explores approaches needed to meet climate change mitigation strategies across multiple disciplines.

This comprehensive volume addresses a critical aspect of climate change mitigation - greenhouse gas removal (GGR) technologies. The book brings together expert perspectives on various technological approaches to removing carbon dioxide and other greenhouse gases from the atmosphere. GGR technologies will be essential in limiting global warning to temperatures below 1.5°C (targets by the IPCC and COP21) and will be required to achieve deep reductions in atmospheric CO_2 concentration. In the context of recent legally binding legislation requiring the transition to a net zero emissions economy by 2050, GGR technologies are broadly recognised as being indispensable.



The book emphasises the urgent need to meet climate change targets. It highlights that conventional mitigation methods, such as fuel switching, renewable energy, nuclear power, and CO_2 capture and storage, must be rapidly developed to achieve the necessary gigatonne-scale CO_2 removal.

The book is structured into several chapters, each focusing on different aspects of GGR. It covers a wide range of technologies, where each chapter is authored by experts in the field, ensuring that the content is both authoritative and up to date. Content includes:

- **Afforestation and Reforestation**: Planting new forests and restoring degraded ones to absorb CO_2.
- **Bioenergy with Carbon Capture and Storage (BECCS)**: Growing biomass, producing energy, and capturing and storing the CO_2 .
- **Direct Air Capture (DAC)**: Using chemical processes to capture CO_2 directly from the air and storing it underground.
- **Soil Carbon Sequestration**: Enhancing the ability of soil to capture and store CO_2 through agricultural practices.
- **Enhanced Weathering**: Accelerating natural processes that remove CO_2 from the atmosphere through mineral reactions.
- **Ocean-based Methods**: E.g. ocean fertilisation to increase the absorbance of CO_2.

The book provides scientifically rigorous analyses of each technology's potential, limitations, and current development stage. Despite the technical depth the writing remains accessible, making complex scientific concepts comprehensible to readers with a basic scientific background. In addition, a standout feature of this book is its holistic approach. It not only discusses the technical aspects of each GGR technology but also addresses the political, economic, and social challenges associated with their deployment. This makes it an invaluable resource for policymakers, researchers, and industry professionals who are working towards achieving net-zero emissions.

A potentially new concept is explored across Chapters 3 (Negative emissions: the role and response of the climate system. *Author: Chris D Jones*), 4 (Accounting negative emissions. How difficult could it be? *Author: Andrea Ramirez Ramirez*), and 7 (Geochemical negative emission technologies. *Author: Olivia Hawrot, James Campbell, Frances Buckingham, and Phil Renforth*). This is “negative emission” technologies, the process of removing more CO_2 emissions than are being created.

Overall, the 502 pages of this book provide a thorough and balanced examination of the various GGR technologies, their potential to mitigate climate change, and the challenges that need to be addressed to achieve widespread deployment. It is an essential resource for anyone interested in the science and policy of climate change mitigation.

Reference

Greenhouse Gas Removal Technologies, ed. M. Bui and N. Mac Dowell, Royal Society of Chemistry, Cambridge, 2022. ISBN 978-1-83916-199-5

Book review

Emerging Nanotechnologies for Water Treatment

Pablo Campo-Moreno (Cranfield University, p.campo-moreno@cranfield.ac.uk)

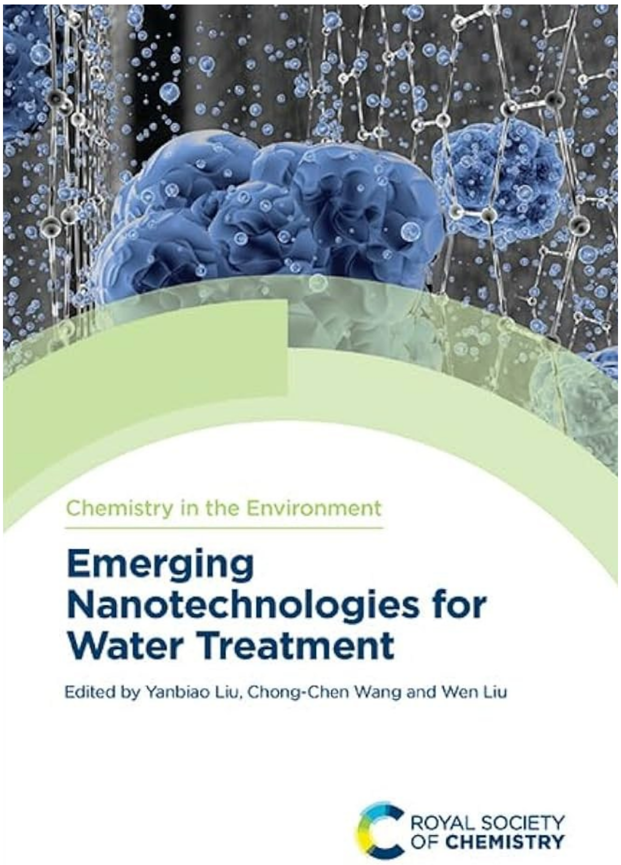
The physical and chemical properties of nanomaterials may be tailored to environmental application in water quality monitoring and water treatment.

Technology plays a vital role in water purification. It may be deployed to remove harmful substances and pathogens to ensure water wholeness, or preventing oxygen depletion in receiving waters because of organic matter and nutrients in sewage. Innovation is critical to keep up with growing water demands and to protect the environment. To address these issues, the water sector must not only upgrade current treatments, but also seek new decentralised, highly efficient and multifunctional processes. The editors of this book discuss promising technologies bridging the nanoworld and full-scale water treatments.

Written as stand-alone literature reviews, the 17 chapters and over 500 pages summarise information on the synthesis and characterisation of nanomaterials deployed in filtration, adsorption, catalysis, and disinfection. The editors have curated contributions from experts, ensuring the scientific accuracy and applicability of the content. To help the reader's navigation through this collection, however, a table of contents grouping the chapters into topics is needed. For example: 'monitoring', 'adsorption', 'advanced oxidation processes,' and 'other processes'.

Readers will gain insights into (1) synthesis and properties of nanomaterials tailored to improve water purification efficiency, and (2) cutting-edge applications such as photocatalysis, nanosensors for quality monitoring, and hybrid nanotechnology-based systems. Discussion on regulatory frameworks and nanomaterial risks in water systems could have added value.

Application to full-scale water treatments is discussed in two key chapters, which thus deserve special mention. Chapter 4 describes how silver, which possesses anti-microbial properties, avoids biofouling. Hydrophilic nanomaterials can improve permeability by increasing the hydrophilic nature of the membrane surface. This may prevent bacterial growth on membrane surfaces, so ensuring membranes used in desalinisation and water reuse may be themselves reused. This reduces costs. Chapter 16 explains the concept of nanobubbles, providing a thorough theoretical description of how nanobubbles behave and interesting case studies (e.g. enhancement of aeration mass transfer).



'*Emerging Nanotechnologies for Water Treatment*' is a good read for professionals and academics interested in environmental nanotechnology at early technology readiness levels.

Reference

Emerging Nanotechnologies for Water Treatment (Chemistry in the Environment Series No. 4), ed. Y. Liu, C. Wang, W. Liu, Royal Society of Chemistry, Cambridge, 2022. ISBN 978-1-83916-302-9

Meeting report

Communicating sustainability: Enhancing research impact

Helena Rapp-Wright (Imperial College London, h.rapp-wright@imperial.ac.uk)

On the 6th of November 2024, a communication skills workshop for promoting sustainable solutions was held for doctoral students and early career researchers. The event provided an opportunity to tackle environmental challenges through interdisciplinary collaboration and teamwork, focusing on innovative ways to communicate solutions.

The workshop aimed to enhance participants' communication and research-pitching skills while fostering engagement, meaningful discussions, and networking opportunities within the environmental sustainability community.

The session began with **Dr Mario Moustras** from the RSC's Management Interest Group inviting participants to introduce themselves and share their expectations for the workshop.

Dr Moustras then shared practical tips on effectively communicating research to non-technical audiences. His guidance included:

- **Start with the big picture**: Explain why the research matters and its broader importance.
- **Use common analogies**: Break down complex concepts by connecting them to everyday experiences.
- **Focus on benefits**: Highlight practical outcomes and impacts.
- **Explain essential terms**: Avoid technical jargon to ensure accessibility.
- **Tell a story**: Sharing narratives that illustrate how the research solves real-world problems.
- **Show human impact**: Discuss tangible benefits like improved health, environmental gains, and quality of life enhancements.
- **Use visuals and scale comparisons**: Employing graphics or analogies to convey complex data in relatable terms.
- **Encourage personal connection**: Link the research to actions individuals can take.

Dr Moustras illustrated each tip with sustainability-related examples, ensuring relevance and clarity for participants.

Guest speakers

During the event, we had the privilege of hearing from two prominent researchers, **Dr Gbemi Oluleye** and **Dr Paul Ferguson,** who shared insights into their sustainability-focused careers and research.

Dr Oluleye, a lecturer at the Grantham Institute, leads groundbreaking research on Green Industrial Interventions, developing optimisation-based decision-support frameworks to evaluate and enhance the economic viability of sustainable solutions for decarbonising energy-intensive industries.

Dr Ferguson, a Principal Scientist at AstraZeneca, focuses on integrating sustainability into analytical methods for therapeutic drug development. His work includes identifying 'greenest' measurement techniques, alternative sample preparation methods, and environmentally friendly approaches to analytical processes.

Both speakers shared their career journeys, highlighting how they transitioned into sustainability roles. They discussed the importance of communication skills, reflecting on their personal experiences, and tied their stories to the tips shared earlier by Dr Moustras. They openly shared examples of their "epic fails" when communicating sustainability, including recent experiences, reassuring participants that even experienced professionals face challenges. This emphasised the value of workshops like this to build resilience and improve communication skills.

Case studies activity

Dr Moustras facilitated group discussions during the workshop, organising participants into groups of five to brainstorm solutions to real-world environmental challenges. Each group addressed one of several case studies, showcasing how chemistry can drive sustainable innovations.

Case studies

- **Improving inner-city air quality**: Airborne pollution from vehicle emissions poses significant health risks, particularly for individuals with respiratory issues. Efforts like the EU's Air Quality Directive and London's Ultra-Low Emission Zone aim to tackle this, requiring standardised monitoring systems to ensure effectiveness.
- **Protecting water resources**: Water pollution remains a critical concern for human health and the environment. The EU Water Framework Directive prioritises cleaner rivers, lakes, and groundwater, aiming to enforce legal limits on pollutants to improve water quality.
- **Mapping microplastic pollution**: A 2022 citizen science study in Montana's Gallatin River found microplastics in 57% of samples, highlighting the pervasive nature of this issue even in remote areas. This underscores the urgency for global action against plastic pollution.[1]
- **End-of-life textiles**: Approximately 5 million tonnes of clothing are discarded annually in the EU, with only 1% recycled into new garments. Innovations like Renewcell transform textile waste into biodegradable raw materials, offering a sustainable path forward.[2]
- **Fertiliser efficiency enhancers**: With the global population projected to reach 10.9 billion by 2100, sustainable food production is vital. Only 50% of nitrogen fertilisers are absorbed by crops, with the rest causing environmental harm. Nitrogen stabilisers, such as urease and nitrification inhibitors, can significantly reduce these losses.[3]
- **Lignin as a renewable resource**: Lignin, a by-product of the paper industry, is currently burned for energy. However, it holds potential as a renewable resource for producing bio-based products, offering a sustainable alternative to waste.[4]

Participants were then allowed to select an idea to work on, including new ideas unrelated to the provided case studies.

Once their idea or case study was chosen, each group engaged in a structured problem-solving activity:

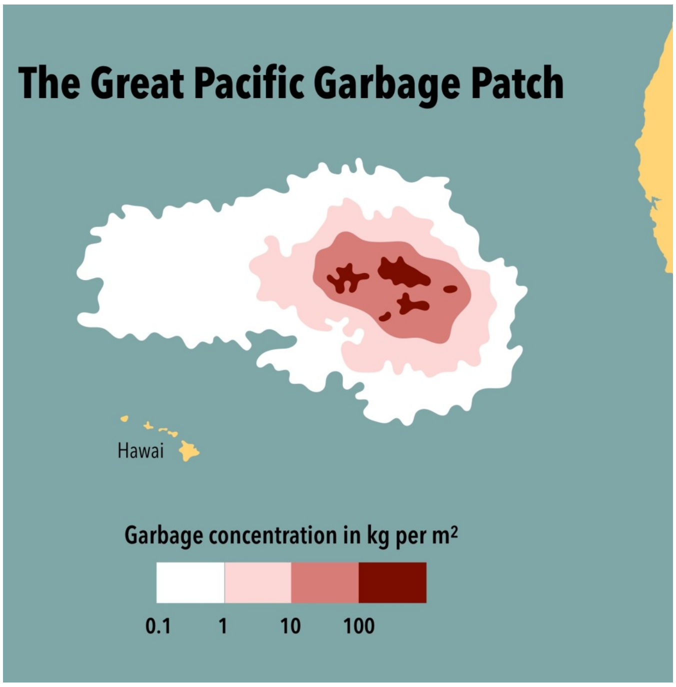
1. **Identify the target user**: Define the specific group of people or organisations the research, technology, or service would benefit. This involved understanding the shared characteristics, needs, and preferences of the target group.
2. **Define the problem**: Pinpoint the primary challenge or issue faced by the target user.
3. **Analyse existing solutions**: Explore current alternatives or approaches the target user is utilising, including competitor research and accessible technologies or services.
4. **Articulate the value proposition**: Highlight what makes their proposed research, technology, or service unique and how it offers an advantage over existing solutions.
5. **Describe the solution**: Detail the features, functions, and benefits of the proposed idea or innovation.
6. **Identify key metrics**: Establish the key indicators or measures of success for the proposed solution.

Figure 1. *Participants presenting their ideas for solutions to one of the sustainability challenges selected for the workshop.*

Through this collaborative process, groups analysed challenges, identified knowledge gaps, and developed potential solutions. Innovative ideas ranged from public awareness campaigns to advanced technological solutions, demonstrating the value of interdisciplinary teamwork.

The exercise not only fostered creativity but also emphasised the importance of collaboration in addressing environmental issues. By combining diverse expertise, participants gained a deeper understanding of the complexity of sustainability challenges and learned practical tools for interdisciplinary problem-solving. This activity also inspired ideas for future research and potential partnerships, reinforcing the role of chemistry as a central driver of impactful solutions.

"Many expressed their enthusiasm about integrating communication strategies, interdisciplinary approaches, and feedback into their work, highlighting the workshop's practical value in enhancing research impact and fostering collaboration.…"



Mapping plastic contamination in the Great Pacific Garbage Patch.

Pitch presentations

Finally, participants worked in teams to prepare a 5-minute pitch tailored to their target audience, with each team member presenting a portion of the project. The presentations were reviewed by Dr Moustras, Dr **Marcia Philbin,** Chair of the Management Interest Group, and the guest speakers, who provided constructive feedback (**Figure 1**). The feedback was well-received, with participants expressing enthusiasm for integrating the suggestions into their future communication efforts. This activity not only strengthened their pitching skills but also highlighted the value of clear and impactful communication in advancing sustainability-focused projects.

Conclusions

Overall, the workshop was highly engaging and well-received, sparking meaningful discussions among participants on how to apply the skills and insights gained to their own research. Many expressed their enthusiasm about integrating communication strategies, interdisciplinary approaches, and feedback into their work, highlighting the workshop's practical value in enhancing research impact and fostering collaboration.

Acknowledgements

This joint event was organised by the Royal Society of Chemistry's Environmental Chemistry Group and Management Interest Group, in collaboration with the Sustainability Working Group from the Researchers' Society at the MRC Centre for Environment and Health, the Environmental Exposure and Health HPRU, and the Chemical Radiation Threats and Hazards HPRU at Imperial College London.

References

1. National Geographic *Case Study: Mapping microplastic pollution in search of solutions*. https://media.nationalgeographic.org/assets/file/Case_Study-Mapping_Microplastic_RL_final.pdf
2. cefic, End-of-life textiles: From trash to treasure. https://cefic.org/a-solution-provider-for-sustainability/chemistrycan/driving-the-circular-economy/end-of-life-textiles-from-trash-to-treasure/
3. cefic, Fertilisers Efficiency Enhancers: Increasing yields whilst lowering emissions. https://cefic.org/a-solution-provider-for-sustainability/chemistrycan/going-climate-neutral/fertilisers-efficiency-enhancers-increasing-yields-whilst-lowering-emissions/
4. cefic, Lignin: a promising renewable resource for bio-based products. https://cefic.org/a-solution-provider-for-sustainability/chemistrycan/driving-the-circular-economy/lignin-a-promising-renewable-resource-for-bio-based-products/

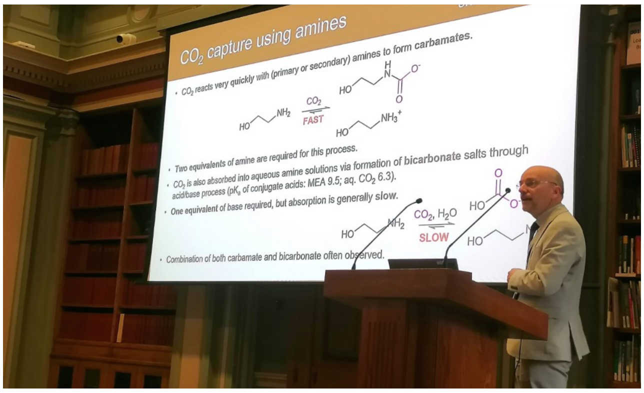
Meeting report

Carbon capture, storage and utilisation: Starting to put the climate change genie back in the bottle

Laura Alcock (Edwards Co. Ltd, laura.alcock@edwardsvacuum.com) and Rowena Fletcher-Wood (rowena.fletcherwood@gmail.com)

On 9th September, the ECG partnered with the Applied Materials Chemistry Group (AMCG) for a one-day event at Burlington House, London, focused on Carbon Capture and Storage (CCS). The event hosted 26 in-person delegates and 3 online, exploring how CCS can help achieve net zero and mitigate climate change.

Chaired by **Laura Alcock** (Edwards Ltd and Environmental Chemistry Group), Session 1 on Carbon Capture and Storage Process Chemistry featured keynote speaker **Professor Chris Rayner** (University of Leeds), who discussed "Post-Combustion Carbon Dioxide Capture – From Laboratory to Power Station and Beyond." Originally developed in the 1930s for natural gas processing, this technology is now applied to combustion streams.



Professor Rayner presents process requirements of CO_2 capture with amines.

Professor Rayner discussed the challenge of capturing trace CO_2 concentrations, noting that solvent-amines systems must process around 2,500 tonnes of air at current CO_2 levels (418 ppm). Monoethanolamine (MEA) systems have a parasitic load of 20-30% in coal-fired power stations, with costs affected by capture stability and water's heat capacity. Using a 70% dimethyl sulfoxide (DMSO) solution can raise the pKa of CO_2, potentially lowering energy demands for industrial processes. To reach net zero by 2050, a target of 2,000 CCS plants by 2040 has been set.

Dr David Bott from the Society of Chemical Industry, in his talk "Testing a Virgin Fossil Carbon-Free Supply Chain for Chemicals," emphasised reducing reliance on virgin fossil fuels and overcoming industry barriers. He introduced the Flue2Chem Project, which converts CO_2 emissions from sources such as biomass boilers into organic intermediates, e.g. dodecanol and ethylene oxide using thermocatalytic processes. These intermediates are then used in surfactants for cleaning products and coatings, integrating five key industries. Flue2Chem also addresses social risks and performs life cycle analyses.

Dr Bott discussing reasons for low action on Climate Change.

Introduced by **Andrew Dunster** (Applied Materials Chemistry Group), **Dr Jan Skocek** (Carbonation Technologies) presented online, 'ReConcrete: Launching fully circular cement and concrete'. The low energy mineralisation pathway faces challenges identifying suitable feedstocks and requires harsh conditions to rapidly carbonate salts like olivine. However, recycled Portland cement concrete may be a solution: offering a large as-yet-unused carbon sink. Carbonation of hydrated cement paste from old concrete can effectively store CO_2, and, in addition, the resulting carbonated cement paste reacts with calcium hydroxide (lime) in the presence of water to make new cementitious materials. Cement separated from concrete is mineralised with a raw flue gas, creating a carbonated reconcrete product (RCP) that acts as supplementary material in the cement manufacturing process. The process is rapid, low energy, reduces the CO_2 footprint of cement, and promotes circularity and recycling.[3] The first concrete recycling plant using this technology has been constructed in Poland.

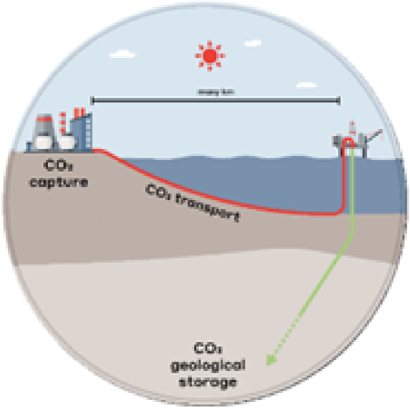


Figure 1. *Representation of distance from oil well to carbon capture site.*[1]

bonates absorbed by plants or washed into oceans. Models suggest that 0.5 to 2 Gt of CO_2 could be removed annually, but these predictions need validation in field studies, especially since emissions often occur far from absorbing crops. The minerals used could also be applied to shorelines and oceans, with initial trials showing no pH changes. Additional benefits include increased silicon content in plants, enhancing their resistance to herbivores and reducing downy mildew infections.

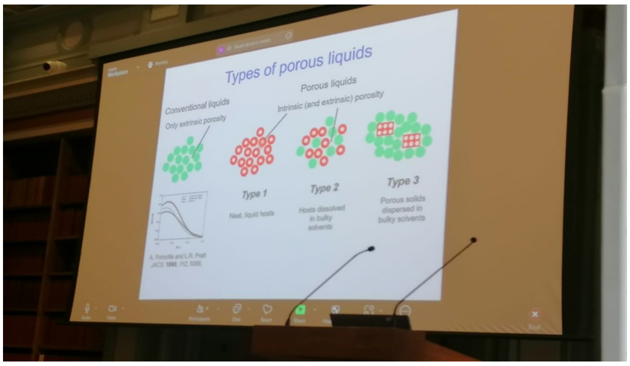
Dr Skocek remotely presenting newly developed alternative formula cements.

Rowena Fletcher-Wood (Environmental Chemistry Group) chaired Session 2, Carbon Capture and Storage – Methods and Efficiencies, featuring **Professor Rachael James** (University of Southampton) who presented on "Sequestration of Atmospheric Carbon Dioxide by Rocks, Soils, and Seawater." She focused on CO_2 removal from the atmosphere, addressing the challenge of 12 Gt of CO_2.

Professor Rachael James discussing pathways for CO_2 sequestration in agricultural soils.

Enhanced rock weathering improves natural carbon capture by adding specific rocks to agricultural soils, facilitating the formation of car-

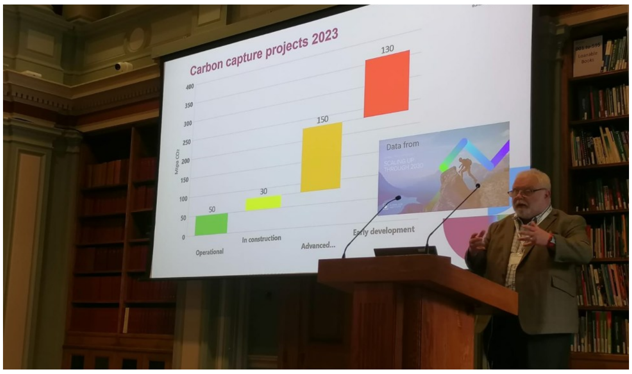
Professor Stuart James (Queen's University Belfast) presented online on "Porous Liquids for Energy-Efficient Carbon Capture and Mechanochemistry for Solvent-Free Chemical Manufacturing." He discussed how the scaled particle theory identifies cavity formation as the main energy penalty. Porous liquids (PLs) are created by combining standard zeolites or MOFs with large solvents that cannot be trapped in their pores, enhancing gas solubility and selectivity.



Professor Stuart James remotely introduces different types of porous liquids.

Challenges include volatility, corrosiveness, and high energy demand. Stability has been achieved with zeolite RHO/CHA combined with Genosorb® PL, enhancing CO_2/CH_4 selectivity, improving material economy, and doubling CO_2 capacity. Costs for heating, cooling, and pumping are low; models suggest greater efficiency through vacuum regeneration instead of thermal methods.

Joanne Rout (Applied Materials Chemistry Group) chaired Session 3, Carbon Capture and Storage Alternative Energies, featuring **Professor Jon Gluyas** (Durham University) who presented on "Carbon Capture and Geostorage: A Key Component of the Energy Transition – Opportunities and Risks."

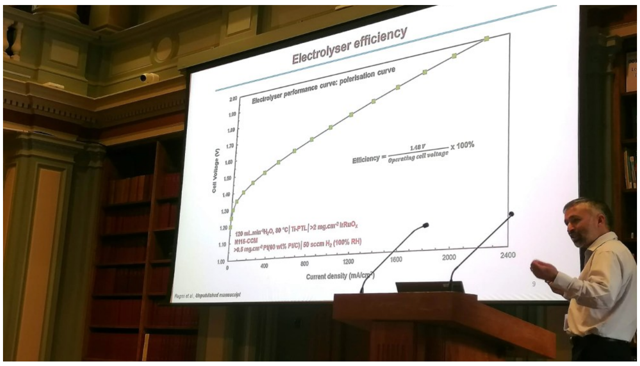


Professor Gluyas highlights number and proportion of carbon capture projects in various stages in 2023.

He discussed the correlation between quality of life and energy use, noting that fossil fuels' energy density is only surpassed by nuclear energy.

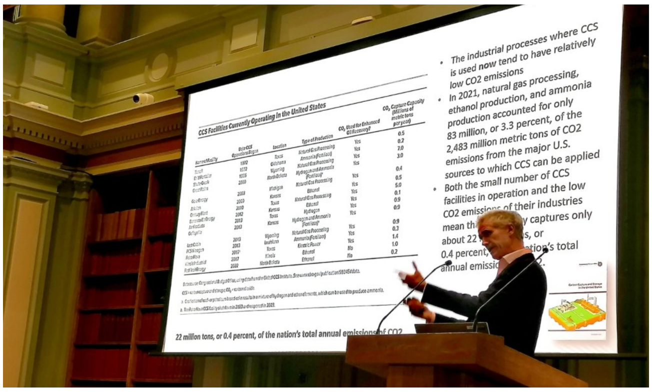
Professor Gluyas (see pp. 29-33) identified key ongoing CCS projects, including that of SaskPower where captured CO_2 has been used for enhanced oil recovery in Saskatchewan, Canada (**Figure 1**). In the UK, porous, permeable, geological rock, which can act as a sink for CO_2, has a potential storage capacity of >78Gt which greatly exceeds the *ca.* 360 Mt CO_2 UK annual generation. Public (mis)understanding was highlighted: the rock is not "just beneath our feet", but >800 m below, with 1.0-2.5 km more common (**Figure 2**). However, multiple natural mechanisms result in the relocation of CO_2. The first injection is planned for 2027, because of safety checks.

Next, **Dr Yagya Regmi** (Manchester Metropolitan University) asked, "Is hydrogen the key that unlocks decarbonisation?" He took on 'hard to decarbonise' industrial sectors such as ammonia synthesis and posed a green hydrogen solution. Burning 1 kg of hydrogen generates just 10 kg of CO_2, but green hydrogen costs 2-3 times more due to energy requirements. Dr Regmi set a cost target of $1/kg and analysed electrolyser efficiency by mapping voltage against current density.



Dr Regmi shares progress and improvement in efficiency of his carbon capture electrolyser.

Challenges include mitigating crossover (leakage between oxygen and hydrogen) and system engineering. Dr Regmi noted hidden costs, such as titanium machining, which is nearly as expensive as platinum, leading to stainless steel preference. In Session 4, Carbon Capture and Storage Applications and Attitudes, **Professor Michael Stephenson** (Stephenson Geoscience Consulting Ltd) discussed how diverse global attitudes toward CCS, influenced by energy demand growth, have resulted in varied implementation strategies. In the United States, CCS is mainly applied to ethanol, hydrogen, and ammonia production, where capture costs are lower, and the focus is financial benefits, not climate abatement. Consequently, major contributors like industrial power and electricity generation are not pursuing CCS. In Southeast Asia, environmental management is framed around economic growth, balancing decarbonisation with gas reserves exploitation. 1990-2019, rising energy demands were met via fossil fuel combustion and CO_2 sequestration.



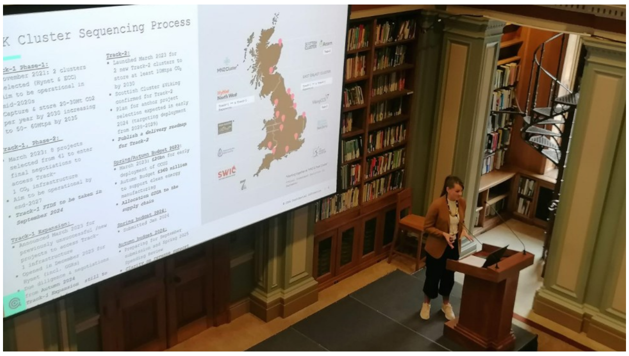
Professor Stephenson reviewing CCS sites, their capacity and the issues in the USA.

Europe showcases innovation, subsidisation, and diverse waste management, with varying levels of development across "hubs and clusters" featuring advanced legal and regulatory frameworks. In contrast, West Africa is in the early stages of CCS, with scepticism about its efficacy, as many believe the historical "culprits" of climate change originated elsewhere. Notably, some of the most populous nations contribute the least pollution per capita and expect compensation for addressing climate issues (**Figure 3**).

Martin Jones from Captimise presented on "The Need for Screening Studies in Carbon Capture Projects." He introduced Captimise and discussed CCS screening, emphasising the benefits and importance of starting these studies early in a project. Captimise has collaborated with 30 CO_2 emitters to assess the feasibility of carbon capture projects, exploring multiple technologies with EU funding and royal endorsements.

Martin Jones presenting on the need for feasibility studies in CCSU projects.

The final talk, given by **Georgina Katzaros** (Carbon Capture and Storage Association), spoke on "Building Momentum of CCUS in the UK: Making Carbon Capture Projects Happen." She outlined deployment projections, supply chain impacts, and market factors driving CCS adoption. Since 2021, approximately £21 billion has been invested in UK CCUS projects and £960 million in clean energy, yet funding is limited. While UK industry aims for 50% local content, the US has implemented a \$85/tonne CO_2 storage subsidy. However, insufficient government support threatens the UK's CCS efforts and risks driving critical industries abroad, highlighting the need for a solid industrial action plan and greater regulatory certainty.



Georgina Katzaros presents the existing Carbon Capture and Storage Association UK projects.

During the day, recurring issues included low CO_2 concentrations, sites in the CCUS production chain typically many kilometers apart, and the cost of materials and energy for these technologies.

References

1. S.E. Daniels, L. Hardiman, D. Hartgill, V. Hunn, R. Jones, N. Robertson, *Deep geological storage of CO_2 on the UK continental shelf*, National Archives, 2023. https://assets.publishing.service.gov.uk/media/63dd00c8e90e075da7464b4b/ukcs-co2-containment-certainty-report.pdf.
2. D. J. C. MacKay, *Sustainable Energy — without the hot air*, Bloomsbury Publishing, New York, 2008.
3. M. Zajac et al. *Energies* 15 (**10**) 2022. https://doi.org/10.3390/en15103597

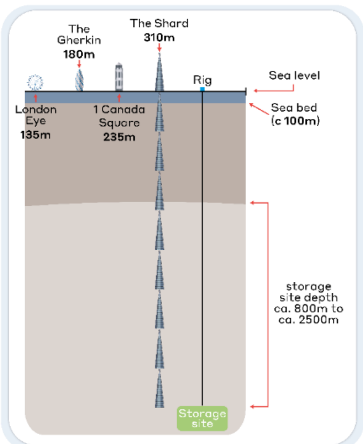


***Figure 2.** Representation of typical depth of carbon storage site relative to London landmark buildings[1].*

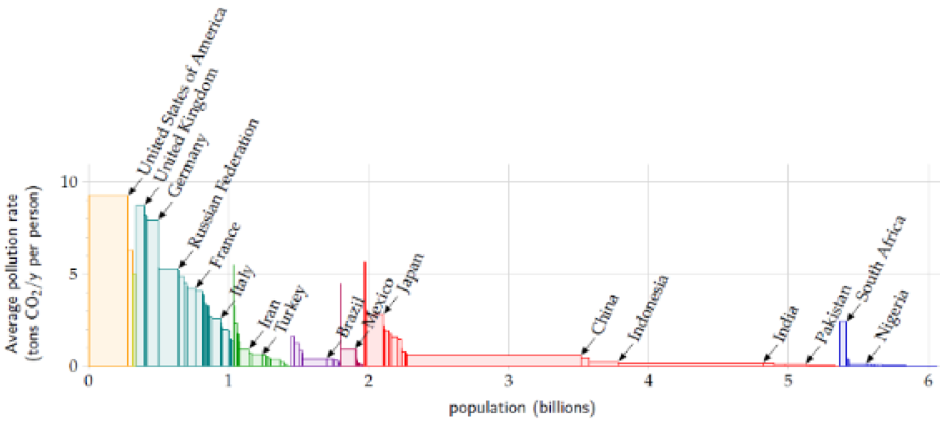


***Figure 3.** Area graph representing average pollution per person from 1800 – 2004 against population of major polluting nations[2].*

Meeting report

Burlington consensus 3: Scientists at the heart of global policymaking

Adam Peters (WCA Environment, adam.peters@wca-consulting.com)

The RSC held a **Burlington Consensus 3** meeting on the 27th of September 2024. This is an intergovernmental Science Policy Panel for Chemicals and Waste and with the purpose of preventing or reducing pollution, putting scientists at the heart of global policymaking.

Chemical pollution is estimated to cause approximately nine million premature deaths globally every year and represents an equivalent threat to those posed by climate change and habitat loss. The United Nations has, therefore established a Science Policy Panel to contribute to evidence-based policy development and strengthen the science policy interface to improve the management of chemicals and waste to prevent pollution.

The Parliamentary Under-Secretary of State at the Department for Environment, Food and Rural Affairs, **Emma Hardy MP**, provided a short introductory talk emphasising the importance of this issue for the UK government.

Chemical pollution poses an equivalent threat to those of climate change and habitat loss.

This was followed by a short explanation of what the Science Policy Panel (SPP) is and how it was formed by **Camilla Alexander-White** FRSC ERT CChem (Lead Policy Advisor — International Chemicals at the RSC) and **Tom Welton** OBE FRSC (President of the RSC 2020-2022; and RSC Ambassador for Sustainable Chemicals Policy).

The conference then moved on to three sessions on the role that the SPP plays in international chemicals policy:

- interdisciplinary skills
- expertise for the SPP
- the road ahead for the SPP

The Science Policy Panel and the International Chemical Policy Landscape in 2024-2040 – what role will it play?

This session provided a diverse range of perspectives on the role of the SPP from a selection of international organisations including the IPCC, UNEP, and the WHO, industry (represented by Astra Zeneca), and the third sector (represented by Greenpeace). Overall, this session focused on the importance of cooperation between all those involved and potential conflicts of interest within multistakeholder environments. Notably, many of the interventions from the environmental sector are about the prevention of ill health rather than its treatment. The need to protect health via environmental protection, and the importance of gathering evidence about the cost effectiveness of interventions were some of the key issues raised by the speakers.

Interdisciplinary skills and expertise for the SPP

The second session of the day introduced a selection of examples of how interdisciplinary skills and experiences, combined with cooperative working, are required for successful delivery. Some of the key points raised by this session were the importance of access to independent science to ensure a more balanced situation between the various contributing parties, and the representation of a diverse range of views and contributions.

Sustainability was highlighted, alongside the importance of moving towards a whole-systems approach to stewardship, for example, reducing the production of wastes rather than dealing with waste disposal. Long range transport is an important factor to consider with air pollution, although in practice relatively few substances are actually managed, and the issues are usually only treated very locally. This highlighted the fact that there is a need to understand the consequences of any actions taken.

The road ahead for the UN SPP

This session introduced the ways in which the SPP might contribute to the development of policies aimed at preventing pollution. The first presentation was from the **UNEP Chief Scientist Andrea Hinwood** and introduced a UNEP horizon scanning report on planetary health and human wellbeing.

Society is facing multiple potential crises, including uninhabitable parts of the globe, chemical pollution, and the environmental impacts of conflicts and resource extraction. Risks arise from exposure to harmful chemicals, and potential adverse effects of diverse and complex chemical mixtures, presenting implications for toxicity and future populations. It is important that, going forward, we aim to prevent environmental and human health impacts by preventing exposures to toxicants, rather than dealing with the problems that they cause.

Society is facing multiple potential crises, including uninhabitable parts of the globe.

This will require governments to work towards longer-term targets, although there may be many short-term targets along the way.

Capacity building – what should be expected of the SPP?

This session introduced a variety of projects aimed at building the capacity to deliver against the goals that were raised in earlier sessions.

The first presentation introduced the work of **Jamal Hassan** and **Professor Anthony Gachanja** of the Jomo Kenyatta University of Agriculture and Technology, who have been providing training courses in the use of Liquid Chromatography Mass Spectroscopy (LCMS) through the Pan-Africa Chemistry Network.

There are currently relatively few facilities in Africa that are routinely using LCMS, but this is a key analytical technique that can be used for a wide variety of different applications. Training researchers and chemists in the practical use of LCMS is enabling more research groups to apply the technique routinely. Chemical analysis is important for agriculture, mining, and environmental protections, and the increasing use and application of LCMS and GCMS. Without these training courses it would take much longer for scientists and researchers in Africa to develop the capacity to tackle both current and future chemical pollution problems.

Other presentations in this session introduced some of the lessons learnt from projects aimed at providing sustainable education facilities in developing areas. A key learning was the need to use technologies that can be used and maintained locally to ensure that the local communities can be certain that the technologies used can provide local benefits over the longer term. This requires training local communities in the operation and maintenance of technologies, and the ability to recycle or safely dispose of waste.

Another project involved building the capacity to address arsenic contamination of drinking water supplies in India and Pakistan. This work involved enabling local scientists to analyse arsenic in groundwaters using practical methods that could be applied locally to identify problematic drinking water sources and address the problems directly. This required training chemists both in the analyses required, but also the health and safety requirements of laboratory working to ensure that the workers are adequately protecting themselves.

Keynote speech Professor Sir Geoff Mulgan

The final part of the conference was a guest lecture by **Professor Sir Geoff Mulgan** (University College London) on observations from various science policy interfaces, and how science relates to political power. Whilst science can provide evidence-based recommendations about the best or most appropriate approaches to solve problems, it cannot resolve the value judgements that are inevitably required to make the political decisions that stem from them.

Perhaps the most important message from this was the importance of involving the wider society in identifying the important priorities for future research. This ensures that scientists are asked the right questions, and able to address concerns of society overall.

Meeting report

The place of chemistry in a doughnut economy

Helena Rapp-Wright (Imperial College London, h.rapp-wright@imperial.ac.uk)

On the 14th of October 2024, the ECG committee hosted a workshop exploring chemistry's role in advancing sustainability through the lens of a "doughnut economy". This innovative event brought together chemists passionate about applying systems thinking with individuals from diverse backgrounds eager to collaborate and drive positive change.

The circular economy concept challenges traditional economic models, emphasising sustainability and resource efficiency.[1] Chemistry is crucial in this transition, particularly in developing green technologies and processes.[2] The chemical industry is pivotal in creating innovative products from renewable feedstocks, designed for reuse and recycling.[3] This approach addresses global challenges such as climate change, wealth inequality, and resource depletion.[1] Chemists are central to guiding society towards a sustainable material future, reimagining mobility and plastics within a circular economy framework.[2] The integration of chemistry into the doughnut economy model (**Figure 1**) promises positive socio-economic and environmental outcomes, aligning economic activities with broader societal values and sustainability goals.[1,2]

The workshop

The workshop began with facilitator **Anna Cupani** guiding participants to form a circle for introductions. Participants then paired up for the "talking stick" exercise, where one person spoke for three uninterrupted minutes about their interest in attending the event, while their partner listened attentively. Afterwards, roles reversed, allowing the partner to share their perspective. Finally, both engaged in a three-minute dialogue, exploring their diverse motivations for joining the workshop. This exercise ensured equal opportunities for expression and fostered mutual understanding. All participants then collectively discussed these motivations, creating a safe space for dialogue and establishing a neutral knowledge base for all participants.

Provocations

During the morning session, the workshop featured three speakers, each delivering a thought-provoking presentation on their research topics. These provocations set the stage for discussions on environmental and social justice, offering diverse perspectives to enrich the day's conversations. Each talk lasted between 10 and 15 minutes, followed by interactive question and answer sessions that encouraged participants to engage with the speakers' insights and share their own experiences.

The first provocation was delivered by **Tanya Sheridan**, Head of Policy and Evidence at the Royal Society of Chemistry (RSC). She highlighted key issues for chemists to consider, such as the role of new technologies, critical thinking, and raising awareness to support a doughnut economy approach.

Figure 1. *A doughnut economy image showing social foundations. Wikipedia Commons.*

Ms Sheridan discussed how chemical strategies can address planetary boundary challenges, including air pollution, waste, and water management, emphasising the relevance of RSC's sustainability efforts in both UK policy and the global context of the United Nations Sustainable Development Goals (UN SDGs). She concluded by urging participants to collaborate with policymakers and integrate their perspectives into research articles to enhance their real-world impact, creating opportunities for greater collaboration between academia and policy.

Our second speaker, **Professor Philippe Cullet**, spoke on international and environmental law, exploring the critical intersection of environmental justice and fairness, and emphasising the importance of engaging with communities to address inequalities. He noted that while development is often necessary to tackle disparities, it can inadvertently lead to increased pollution, perpetuating a cycle of environmental harm. Professor Cullet explained that environmental law typically reacts to issues by focusing on prevention through regulations. He stressed the need for technological advancements to be assessed for their impacts on both the environment and human health. He also advocated for integrating human rights into the doughnut economy framework and fostering harmony between people and nature, rather than viewing them as opposing forces. His provocation called for improved communication and collaboration among scientists, policymakers, and legal experts to shape laws that drive meaningful environmental and social change.

How should we handle and communicate negative findings from collected data?

The next speaker was **Andrew Grieve**, Senior Air Quality Analyst at Imperial College London, who focused on the critical issue of air pollution – one of the most significant environmental challenges of our time. He noted that many people live in areas exceeding the air quality thresholds set by the World Health Organisation (WHO), underscoring the urgency of addressing this invisible threat.

Mr Grieve highlighted the role of technological miniaturisation in making air pollution monitoring more accessible and affordable, enabling widespread data collection. He shared his extensive experience in citizen science initiatives, emphasising how involving the public enhances collaboration between science, policy, and law. He also discussed the importance of working with social and behavioural scientists to better engage communities. Drawing from his work supporting London neighbourhoods in air quality monitoring, he highlighted the positive impacts of empowering communities. Mr Grieve concluded with a thought-provoking question: How should we handle and communicate negative findings from collected data?

Our final speaker was **Maria Pontes**, Director of Programmes and Partnerships at EarthWatch Europe. Ms Pontes shared her extensive experience working with communities to foster meaningful connections with nature, emphasising the need for an emotional, not just rational, bond with the environment. She highlighted the importance of empowering communities through citizen science, enabling them to collect robust data while raising awareness of pressing environmental issues.

Figure 2. *Some participants during the group activity, Burlington House.*

Ms Pontes focused on water pollution, noting that access to clean freshwater remains a significant global challenge contributing to preventable deaths worldwide. She also stressed that this issue is not limited to developing nations but exists locally in the UK. By engaging citizens in data collection, policymakers and agencies gain vital resources to address these challenges effectively. Ms Pontes emphasised the need to mobilise communities to create pressure on regulators and agencies, amplifying the impact of their efforts. She asked, *What can individuals do to contribute?* And, *How can we engage underrepresented communities, moving beyond predominantly white and privileged participants?*

Group problem-solving workshop

Participants were divided into groups of approximately five to explore key themes:

1. *Goals, challenges, and learning*: Each group identified their desired outcomes, the obstacles they faced, and areas they wished to explore further.
2. *Problem selection*: By the end of the session, each group selected a specific problem to address in the next stage.

Participants were given Post-it notes and asked to write three keywords for each of five categories: needs, politics, technology, economics, and environment, based on their chosen goals and challenges. These notes were added to a shared whiteboard for collective review.

Next, a collaborative problem-solving session was held. Groups analysed their selected problem by mapping resources, identifying knowledge gaps, and considering potential hurdles. Using insights from the entire room, they developed strategies to overcome these challenges. The facilitator then organised the Post-its on the board by category, and participants voted on their top three priorities, which shaped the final ranking.

Participants discussed the potential benefits and challenges of their proposed solutions. Benefits included public awareness, community engagement, poverty eradication, international funding, and marketing campaigns. Challenges included ensuring unbiased and robust research, data availability, cultural value differences, funding concerns, and societal issues such as corruption, consumerism, controlled media, and lack of representation.

While the session did not produce a tangible "product" like in design-thinking workshops, participants left with:

- A clearer framework for tackling environmental justice issues.
- Insights into potential collaborations and synergies.
- A foundation for future work and partnerships.

References

1. J. S. Swarbrooke, In *Encyclopedia of Tourism Management and Marketing*, 2022, pp. 1002–1005.
2. M. Linder, *Green Chemistry Letters and Reviews*, 2017, **10**, 428–435 https://doi.org/10.1080/17518253.2017.1392618.
3. J. H. Clark, T. J. Farmer, L. Herrero-Davila and J. Sherwood, *Green Chemistry*, 2016, **18**, 3914–3934 https://doi.org/10.1039/C6GC00501B

Meeting report

Outreach report: IF Oxford 2024 – engaging everyone!

Amy-Louise Johnston (University of Nottingham, amy-louise.johnston1@nottingham.ac.uk)

In October 2024, I had the opportunity to volunteer with the Environmental Chemistry Group participating in one of over 100 events at the Oxford science and ideas festival (IF Oxford). The event was part of the Tech Works session, a relatively small event, with three other stall holders, targeted at all ages.

The ECG stand included three activities to engage with the public around water pollution, plastics in the environment, and ocean acidification. The audience was incredibly engaged. Many children were happy discussing what they knew about plastics in the environment and where they may have seen it in local rivers.

This was my first experience of volunteering with the ECG and it was a great experience!

Participants were first prompted to partake in the *'Float or Sink?'* activity in which they had to decide what will happen to five different plastic objects in water. Overall, 70–83% of participants correctly identified whether a bottle top, plastic bag, crayon and polystyrene packing cube will sink or float. A rubber plant proved to be the trickiest object to predict. Along with a simple demo showing how the same objects float or sink depending on the density of the solution (saline 'sea' water compared to deionised 'fresh' water), this led to many discussions around how solving the plastic pollution problem requires many different approaches.

Figure 1. *Ocean acidification demo in progress*

The visually impressive ocean acidification demo – with the inclusion of dry ice, production of water vapour and a colour change – brought many participants (adults and children alike) over to the stand (**Figure 1**). This also allowed for discussion of topics including acids/bases, pH scale, ocean acidification and greenhouse gases. Each topic was tailored to the knowledge of the participants. Very young children were able to get involved by matching the colour of the water at the start of to the pH scale and compare to the colour at the end. Hands-on science at its best!

The Tech Works event was ticketed (free entry, operating a Pay What You Decide model), with participant numbers managed by the event organisers to avoid overcrowding. *'The Float or Sink?'* activity indicated that over the course of the afternoon the ECG stand engaged with ~80 people (only an estimate as some families/groups cast one vote between them). Being part of a slightly smaller event, with less distractions in the room, allowed for more one-on-one discussions with participants, with lots of options to extend and tailor the demonstrations. The style of the event also allowed people to come back later in their visit with additional questions which occurred to them during their visit. I had a chance to discuss all different types of water pollution with participants, including my own research interests.

This was my first experience of volunteering with the ECG and it was a great experience! I was encouraged with how many people were stimulated to think a bit differently about chemistry – and if I recall correctly, one pertinent quote from the event was along the lines of *'Chemistry created plastics, so I guess chemistry does need to be involved in its solution'*. I hope demonstrating how complicated environmental problems are will get minds thinking and discussing environmental chemistry, and if that includes water pollution all the better.

Reference

R. Fletcher-Wood, 'Accessible Evaluation at the BIG Event', ECG *Bulletin*, January 2024, p.10.

Meeting report

Air quality in the 21st century

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On 9th December 2024, 102 delegates from academia, government, and the private sector attended a one-day conference at Burlington House, providing a broad and up-to-date survey of the measurement, regulatory and scientific issues affecting air quality.

The event built on the successful Monitoring Ambient Air conference series (last held in 2019) and was organised and hosted by Valerio Ferracci (National Physical Laboratory) and Gary Fuller (Imperial College London, Clean Air Champion), with the support of the RSC Environmental Chemistry Group (ECG), the UK Clean Air Programme, and DEFRA's Air Quality Expert Group (AQEG). The event received sponsorship from ACOEM, AQMesh, Cambustion and Enviro Technology.

The conference was divided into three sessions, each with a keynote lecture and two poster sessions. The day opened with an address from ECG Treasurer **Dr Helena Rapp-Wright** (Imperial College London), who provided a brief overview on recent ECG activities. The first session focused on the work of DEFRA's AQEG, a committee of specialist independent advisors on air quality. Each of the five presentations focused on a recently published (or soon-to-be-published) AQEG report.[1-4]

Dr James Allan (University of Manchester) gave an account of new opportunities in monitoring particulate matter (PM).[1] New technologies need to respond to a number of challenges in PM monitoring, including better coverage, improved sensitivity and source apportionment.

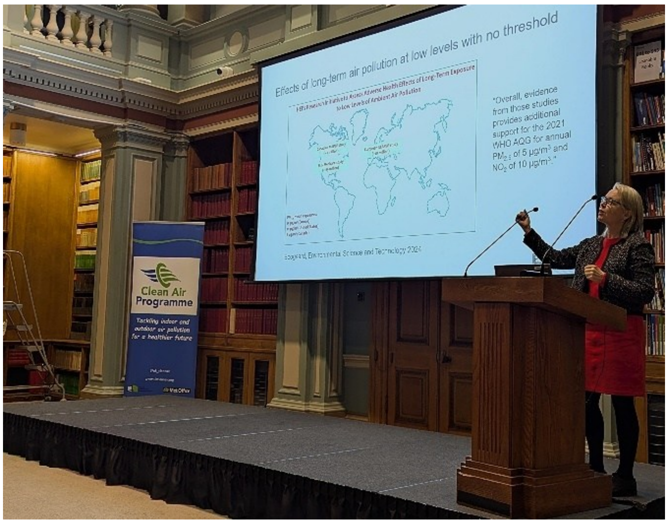
Professor Alastair Lewis (University of York) delved into the use of hydrogen for combustion application and its impact on air quality.[2] Depending on its combustion regime, hydrogen could act as a source of nitrogen oxides (NO_x). Modelling work showed that, if all other NO_x sources were removed, hydrogen-fuelled domestic heating alone would maintain many UK urban areas above the current WHO limit value for nitrogen dioxide (NO_2), part of the NO_x chemical family.

Professor David Topping (University of Manchester) focused on the adoption and integration of artificial intelligence (AI) in air quality management.[3] As the amount of environmental data gathered increases, AI-based deep-learning approaches have the potential to offer deeper insight into the relationship between pollutant emissions and their impacts.

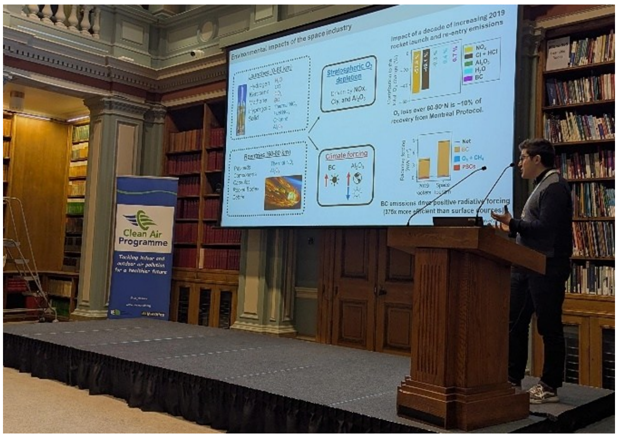
Professor Jo Barnes (University of the West of England), former ECG committee member and treasurer, discussed differentials in UK air pollution emissions and concentrations, with a focus on environmental justice. Mapping pollutant levels in the UK showed that the air pollution disproportionately impacts people in more deprived areas, while the least deprived households contribute more pollutant emissions.

Air pollution disproportionately impacts people in more deprived areas

Dr Sarah Moller (University of York) discussed the outcomes of a horizon scanning exercise aimed at identifying perturbations that may impact air quality.[4] These included underperformance of technology and regulations, increases in ammonia emissions, more frequent droughts, bioparticles and antimicrobial resistance, and loss of public confidence in science.



Professor Anna Hansell delivers her keynote talk on the health effects of air pollution.



Dr Connor Barker illustrates the environmental impacts of the space industry.

The first session was followed by lightening talks. Artist-in-residence **Dr Hazel Hunter** also delivered a short presentation of her work “Air not chocolate”, displayed at the venue. She aimed to transform the invisible air we breathe into visible works of art.

The second session focused on NO_x pollution and control strategies.

Lucy Webster (University of York) presented work on evaluating the variability of NO_x emissions between sectors, highlighting inconstancies in regulations.

Professor David Carslaw (University of York) reported on the mixed effectiveness of the strategy to retrofit older buses to abate NO_x emissions.

This was followed by a keynote lecture by **Professor Anna Hansell** (University of Leicester), who provided a historical perspective on the evolution of our understanding of the impact of air pollution on human health, including lessons learnt from long-term effects of conflict and the Covid-19 pandemic.

The third and final session focused on emerging pollution sources and health consequences. **Dr Steven Turnock** (Met Office) presented his modelling work on surface ozone, identifying anthropogenic NO_x and increasing methane emissions over the industrial era as the main drivers of tropospheric ozone increases.

Dr Karn Vohra (University of Birmingham) focused on the health effects from ammonia emissions, a precursor to PM. He showed that ~40,000-120,000 deaths globally may be attributable to ammonia each year, with China and India accounting for 30-60 % of this burden.

Dr Connor Barker (University College London) discussed the air pollution and environmental impacts of megaconstellation satellite missions. Emissions from launch and re-entry of these satellites are predicted to lead to large increases in black carbon in the upper atmosphere with complex implications for planetary radiative forcing, cooling at the tropopause and warming at the top of the atmosphere.

The oral presentations were complemented by 24 posters. A full list of these, including their abstracts, can be found online at the conference web page.[5] Given positive feedback, the organisers are planning to run a follow-up event in December 2025.

References

1. Air Quality Expert Group, *New Opportunities for Particulate Measurements*, 2024. https://uk-air.defra.gov.uk/library/reports?report_id=1162
2. Air Quality Expert Group, *Air pollution arising from hydrogen*, 2024. https://uk-air.defra.gov.uk/library/reports?report_id=1163
3. Air Quality Expert Group, *Statement on integration and adoption of AI in air quality*, 2024. https://uk-air.defra.gov.uk/library/reports?report_id=1160
4. Air Quality Expert Group, *Air pollution horizon-scanning: Seven potential risks of relevance to the UK*, 2024. https://uk-air.defra.gov.uk/library/reports?report_id=1161
5. Air Quality in the 21st Century, https://www.rsc.org/events/detail/80080/air-quality-in-the-21st-century

Article

Carbon Capture and Storage in four continents: How different attitudes will drive different implementation

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Despite the central place of Carbon Capture and Storage (CCS) in large-scale policy ambitions, the technology itself is seen very differently in different parts of the world: the views of many African scientists, professionals and policy makers are sceptical; in the USA the approach is resolutely capitalist; in Europe ideological; and in South East Asia pragmatic. This article looks at why these different views have evolved and the implications for future CCS implementation.

The IPCC 'illustrative model pathways', the Sustainable Development Scenario of the IEA, and the Energy Transitions Commission all foresee CCS technologies in emissions reductions for power, but increasingly also for hard-to-abate industries such as iron and steel, ammonia and refineries. CCS involves the capture, transport and then storage or disposal in geological formations of CO_2 at an industrial scale. Amongst the main factors influencing how CCS evolves are the costs of different aspects of the process, the availability and capacity of geological formations, opportunities for commercialisation, public views of the technology, and favourable policy, tax and regulatory environments.

Tax is particularly favourable in the USA which does not have a cap and trade mechanism like the Emissions Trading System (ETS) in the EU. Under Section 45Q of the Internal Revenue Code, tax credits apply to taxpayers that capture and store, or use carbon dioxide. Where prices for the capture costs are low, tax credits can be set very effectively against the capital and operational costs of carbon capture machinery. This is particularly the case for ethanol production for biofuels, ammonia production and natural gas processing, for which capture is relatively cheap in the US (**Figure 1**). An additional benefit is the commercial opportunity bestowed by the value of CO_2 for enhanced oil recovery in the US, aimed primarily at increasing oil and gas yields. The combination of relatively cheap capture, tax breaks and a ready market for CO_2 has produced a vibrant commercially-led environment for part of the CCS chain. However, this vibrancy does not

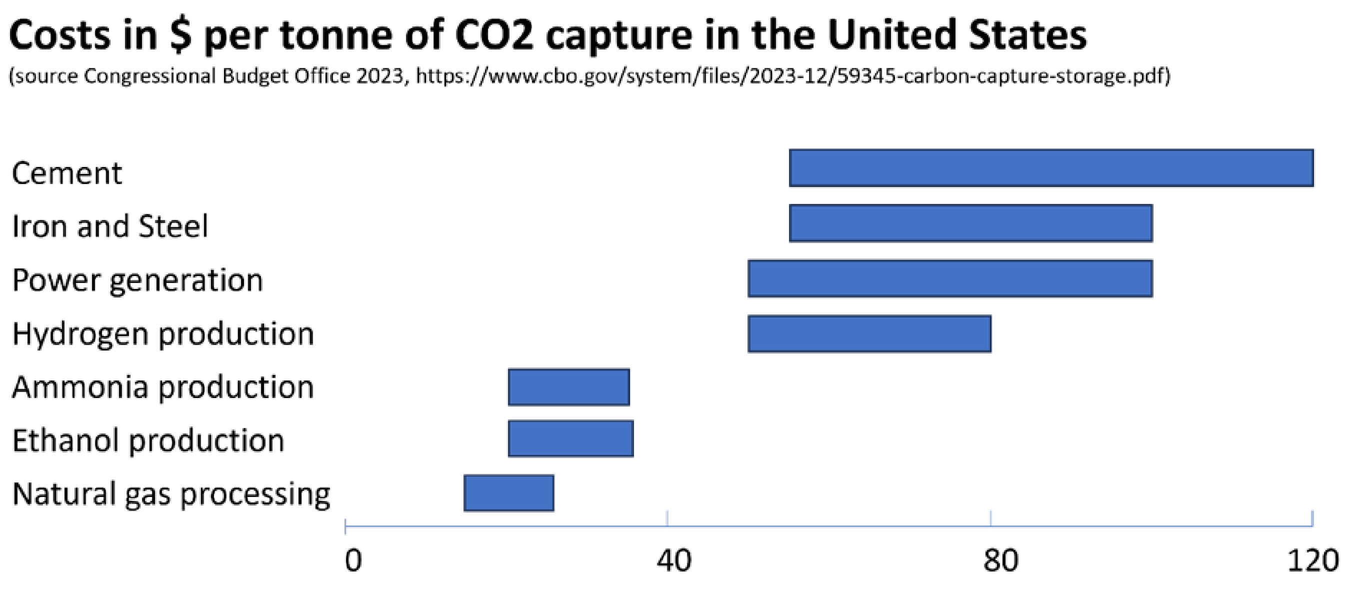

Figure 1. *Costs per tonne of CO_2 capture in the US: source US Congressional Budget Office 2023.*

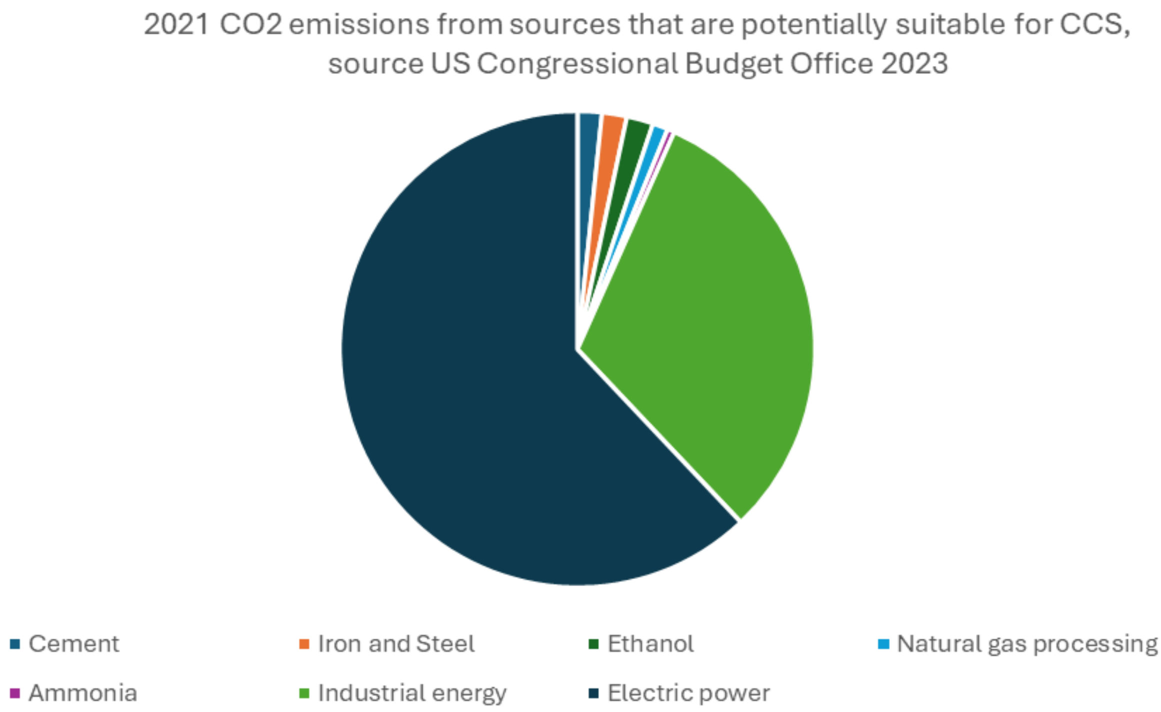

Figure 2. *US CCS is focussed on rather small emitters: ethanol, natural gas processing and ammonia. Source US Congressional Budget Office 2023.*

extend to the lower concentration point sources of CO_2 in the power and large-scale industry sector where capture costs per tonne are higher (**Figure 1**).

The result is that US CCS is focussed on rather small emitters. In 2021, natural gas processing, ethanol, and ammonia production accounted for only 83 million, or 3.3 percent, of the 2,483 million tonnes of CO_2 emissions from the major US sources to which CCS can be applied. Both the small number of CCS facilities in operation and the low CO_2 emissions of their industries mean that CCS today captures only about 22 million tons, or 0.4 percent, of the US's total annual emissions of CO_2 (**Figure 2**).

In SE Asia the situation is different. The International Energy Agency forecasts vigorous growth in the area including power demand increases from natural gas, oil and coal between now and 2030. The area has abundant fossil fuel resources and a fleet of thermal power plants that are mainly under 10 years old and thus likely to be in service for many years. Given this profile, it is surprising that the most active CCS projects in SE Asia are related to natural gas processing, rather than power generation.
This is because there are significant natural gas resources in SE Asia, albeit from high CO_2 gas fields. Wood Mackensie estimate that there are over 15 billion barrels of oil equivalent (BOE) of gas resources in Malaysia alone, including about nine billion BOE of gas which is undeveloped because of high CO_2 content. Many SE Asian countries recognise the importance of natural gas to drive economic development but are understandably resistant to large-scale venting to the atmosphere of CO_2 following CO_2 separation from the natural gas stream. The CEO of PTTEP, the Thailand national oil company, describes his approach as: 'The company will go on expanding its investment in natural gas production, but at the same time it will also incorporate the greenhouse gas emission issue in the decision-making process of

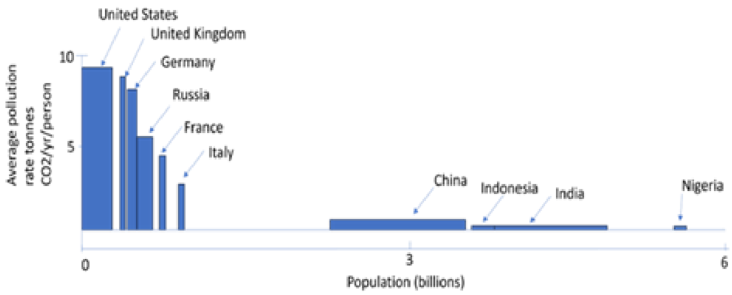

Figure 3. *Selected average cumulative pollution rate for selected countries (modified from D. J. C. MacKay,* Sustainable Energy — without the hot air, *Bloomsbury Publishing, New York, 2008)*

new gas projects'. Thailand's first CCS facility is at the Arthit gas field in the Gulf of Thailand. Malaysia's first large CCS project is also related to natural gas processing: the Kasawari gas field is being developed by Petronas and is forecast to be operational by 2025.

Europe is different again. It has the most developed regulatory and policy environment for CCS, including the ETS and innovative funding mechanisms such as 'contracts for difference'. The ETS aim is to lower greenhouse gas emissions and allow companies to trade emissions rights within the EU. The scheme covers around 45% of the EU's greenhouse gas emissions. A 2023 study on the effects of the EU ETS identified a reduction in carbon emissions in the order of -10% between 2005 and 2012 with no impacts on profits or employment for regulated firms, though large scale storage operations have yet to be developed. Looking ahead it is likely that Europe will develop a more full chain CCS in a wider range of forms than is currently true elsewhere in the world, with cement factories, refineries and thermal power stations developing CCS in a series of well-developed hubs and clusters. A very innovative model, known as Northern Lights, has also evolved in Norway, albeit subsidised heavily by the Norwegian Government. This is an open-source CO_2 disposal model whereby shipborne CO_2 from countries that border the North Sea area can simply be disposed of geologically for a fee.

In Africa conversations about CCS can be very different again. Although some progress has been made in African CCS at a policy level. Recent experience in Namibia and Nigeria talking to academics and professionals and running training courses suggests that many academics and professionals are doubtful about CCS. This is not because they don't want to do anything about climate change, or that they can't see new technical and science opportunities in CCS. The problem rather is that CCS is seen as an extra expense for struggling economies where energy (and other living) costs are already high to the point of causing civil instability (for example in Nigeria). There is also a growing realisation that the responsibility for high atmospheric CO_2 lies with the developed world (the Global North). This responsibility was nicely summarised by MacKay showing the cumulative size of historical CO_2 emissions, starkly contrasting the Global North and Global South (**Figure 3**). The reaction of many Africans to this is that the rich North should not get in the way of Africa's right to responsibly develop its fossil fuels, and that if CCS and other abatement methods are necessary to develop these fuels, then the Global North should pay for them.

What do these differing models and attitudes reveal about the state of CCS? First it might be fair to say that there is a lack of clarity as to what CCS is for. The economic policy instruments developed in the US have encouraged only a small CCS industry that effectively ignores the large emitters and enhances fossil fuel production through enhanced oil recovery. A similar result might be expected in SE Asia where CCS – as part of a national oil and gas company's environmental, social, and governance (ESG) program – might lead to less emissions through venting, but still enables natural gas as a fuel. Many detractors see CCS as an enabler of fossils fuels, and in the case of the US, this could be said to be true. Elsewhere in Europe, with perhaps the most sophisticated policy and regulatory system fostering a more complete CCS system, largescale CCS has been slow to start, and there are still no large projects operating. In Africa CCS is likely to be slow because of its costs, and because it may stand in the way of rapid development of fossils fuels seen by many as vital for Africa's growth.

CCS is a useful technology. It is safe and technically achievable. It is also currently the only way that large-scale industry can be decarbonized, and could be useful in the abatement of fossil fuel usage in the Global South which has large energy demands. However its commercialisation, through whatever route, sometimes leads to its aims being muddled. We have to face up to the fact that CCS costs money, and our leaders have to be honest about who should pay for it and what we are doing it for.

Further reading

1. V. Masson-Delmotte et al. (eds.) IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C.* An IPCC Special Report, *Cambridge University Press*, Cambridge, UK and New York, NY, USA, *pp. 3-24*. https://doi.org/10.1017/9781009157940.001.
2. https://www.iea.org/events/introducing-the-sustainable-development-scenario
3. https://www.energy-transitions.org/publications/better-energy-greater-prosperity/
4. https://www.cbo.gov/publication/59345

Article

Carbon capture and geostorage: a key component of the energy transition

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This paper reviews carbon capture, compression, transportation and storage, plotting the course of the UK over nearly 50 years from when CO_2 was first injected to December 2024 when, by virtue of issuing the first Carbon Capture and Storage (CCS) licence, the UK government initiated a new industry, possibly the first in the UK, which was not business as usual but which accommodates some (environmental) externalities to day-to-day operations.

Introduction

The versatility of coal and its high combustion temperature underpinned the industrial revolution. Exploitation of coal changed the relationship between humans and their environment forever. Humans now began to 'spend' what nature had stored for millions of years. A rudimentary calculation indicates that human consumption of fossil fuels is >100,000 years' worth of accumulated organic carbon annually. This has enabled a profound improvement in human quality of life. Energy derived from fossil fuels has helped lift 80% of the global population out of abject poverty, nearly doubled life expectancy, and massively reduced child mortality.[1] However, it irreparably affected the atmosphere and oceans. Fossil fuel combustion liberates several greenhouse and toxic gases including carbon dioxide (CO_2), water vapour, sulfur and nitrogen oxides, and methane (CH_4) through venting during fuel mining. CO_2 is the most significant greenhouse gas (**Table 1**) because of its volumes and atmospheric longevity.

Prior to the industrial revolution, atmospheric CO_2 was ~280 ppm. In 2024, it is nearly double that: 425 ppm, and increasing by ~40 Gt (billion

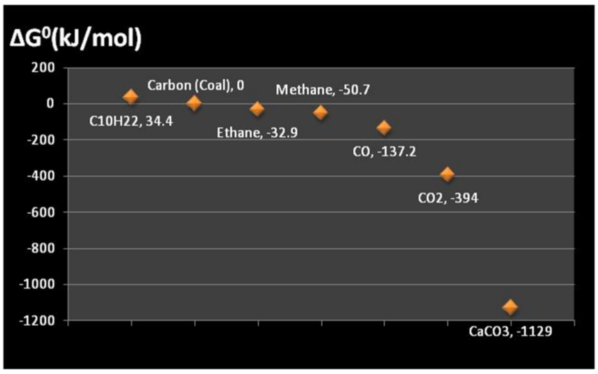

Figure 1. *Comparison of Gibbs free energy values for coal.*

tonnes) a (recent) year. Ocean water takes up (dissolves) much of that CO_2, becoming more acidic. Emissions of CO_2 to the atmosphere by humans have led to global warming and climate change. In 2024, mean global temperature rose marginally exceeded the 1.5°C 'limit' above pre-industrial levels, seen by many as the tipping point to run-away climate change.[2] Humankind needs urgently to reduce CO_2 to net zero. The enormity of this task cannot be understated. Global energy demand means that ceasing to use fossil fuels immediately is not feasible, and so we must ensure greenhouse gas emissions are massively reduced.

Carbon Capture and Storage (CCS)

CO_2 capture and permanent storage of the liberated gas has been proven for decades, but developed in only a handful of countries. In 2023, ~50 Mt (million tonnes) of CO_2 were captured and stored, but 40 Gt were produced by humans. CCS remains the only industrial-scale process capable of significantly reducing emissions in the medium term, and is key to all workable energy transition scenarios. Even in a future free from fossil fuel combustion, CCS will still be needed to remove

Table 1. *Greenhouse gases.(GHG) *GWP = global warming potential referenced to carbon dioxide.*[1]

Gas	Sources	Potency (GWP*)	Residence time (years)
Carbon dioxide (CO_2)	Natural processes (volcanic eruptions, plant and animal respiration), combustion of fossil fuels	1	10,000+
Methane (CH_4)	Decomposition of organic material, release of gases from fossil fuels, natural gas venting, coal mining and oil	27-30	100s
Nitrous oxide (N_2O)	Produced using commercial and organic fertilisers, fossil-fuel combustion, nitric-acid production, and biomass burning	273	>100
Sulfur dioxide (SO_2)	Fossil-fuel combustion and biomass burning	Not a GHG	-
Water vapour (H_2O)	Produced by natural processes and human activity	0.0005 to 0.001	100

CO_2 from ‘tough-to-decarbonize’ industries. Currently, CO_2 is used in fertiliser production (130 Mt of CO_2 per annum) and in enhanced oil recovery (70 Mt per annum). A further 30 Mt is used in other industries including in food. An annual total of 230 Mt[3] represents only around 0.5 % of global annual emissions. Moreover, for each of these uses, it is unclear how much CO_2 is really taken out of the system.

CO_2 may be injected into oilfields to enhance recovery of oil (EOR). The CO_2 dissolves in the oil, causing it to expand, and can reach parts of a petroleum reservoir that other agents cannot. CO_2-charged oil is later degassed and CO_2 reused. The process was first developed in Hungary in the 1950s, and further developed by Shell in response to the 1973 oil crisis. Alas, the CO_2 used by Shell came from natural subsurface pools, which could have remained undisturbed for millions of years! Under long term (> 10 years) injection, 0.15-0.20 tonnes of CO_2 help deliver 1 additional barrel of oil[4] although this may be up to 5 tonnes at early-stage[4]. Combustion of the oil so produced results in 0.8-2.1 tonnes of CO_2. So, at best, early-stage CO_2-EOR is carbon negative, but most projects using CO_2-EOR will still be net carbon positive

The problem with CO_2 is not versatility – it can be used in many processes, but stability (**Figure 1**). Nearly all processes involving CO_2 require energy input; this must come from a zero-carbon source if using CO_2 is to be carbon zero or negative.

Tough to decarbonise

Much of the energy transition can be achieved by displacing fossil fuel combustion with other primary energy sources. In the UK, the carbon intensity of power (electricity) generation has dropped from >500 g CO_2^{eq}/kWh 2006-2008 to 234 g CO_2^{eq}/kWh in November 2024.[5] The UK closed its last coal-fired power station on 30th September 2024, ending 142 years of electricity generation from coal combustion. Coal displacement was achieved by growth in wind and solar photovoltaic power sources.[6] Similarly, decarbonisation of ground-based transport systems is underway (slowly) by mandating growth in electricity -powered road vehicles together with hydrogen-fueled large road vehicles and railways.[7] Together, geothermal energy combined with use of waste heat and heat storage can be used to decarbonise heating (and cooling) in the built environment on nationwide scales.[8-10] There are some industries which are particularly difficult to decarbonise because their processes are intrinsically carbon intensive (**Table 2).**[11]

Industry	Emissions (Mt CO_2)	Year measured
Steel	2600	2023
Cement	1700	2021
Glass	95	2022

Table 2. *CO_2 emissions from tough-to-decarbonise industries.*[11]

Storage is but the final stage of CO_2 disposal: first it must be captured, compressed, transported and ultimately injected into the sub-surface. Each stage must be measured, monitored and validated to confirm how much CO_2 is stored. Monitoring must continue after cessation of injection and as each store is closed. The length of time for which monitoring must continue is defined differently in different authorities around the world. Lifecycle analysis must also be undertaken to ensure that greenhouse gas emissions are reduced.

CCS development

There are four broad options for CO_2 disposal in the subsurface[5,12-14] (**Table 3**). Storing CO_2 in abandoned coal mines or injecting it into deep, unmineable coal seams (where it may be adsorbed onto coal macerals) have been mooted, but, unlike the options listed, these have not been tried in practice and are considerably more challenging.

Carbon capture

Carbon capture is typically applied to large volume, point sources of CO_2. Most capture is associated with emissions from fossil-fuel based electricity generation. CO_2 is scrubbed from flue gas, a low pressure mix of fossil fuel combustion products comprising CO_2, sulfur oxides, unburned gas-phase hydrocarbons, particulate matters and air. The flue gases are cleaned of pollutants in a sequential process, with CO_2 scrubbingat the final phase. Several CO_2 adsorbents can be used, with ammonia most common. Ammonia adsorbs CO_2 when cold and releases it when heated, enabling recycling. The energy penalty is ~10-16% for 90% CO_2 removal.[15] Capture from pre-combustion or oxy-fuel power plants is likely to be more efficient since it occurs at higher pressure with fewer contaminants, but few such power plants are operational.[16] Similarly, capture from industrial site processes like limestone calcining for cement manufacture should be efficient, though presently remains at development stage.[17]

Carbon transportation

Once captured, CO_2 can be transported via tanker

Process	Advantages	Disadvantages
Inject CO_2 into depleted oilfield[5]	CO_2 injected into the oil leg and displaces oil to production wells.	Only at its least efficient, this process is carbon zero.
Inject CO_2 into depleted gas field[12]	CO_2 injected below gas water contact displaces gas to production wells without mixing. Once fully primed the CO_2 can be used for power generation via a CO_2 plume geothermal system (CPG)	Managing the transition from CO_2 gas injection to dense phase is at present untested in the real world.
Inject CO_2 into deep saline aquifer[13]	Typically, CO_2 injected deep in the aquifer. The buoyancy process then moves it up to beneath the caprock.	Even large saline aquifers, if bounded by geological discontinuities may have very limited capacity in terms of injected volumes.
Inject CO_2 into mafic rocks[14]	The CO_2 becomes mineralised and permanently locked into the mineral structure of the rock	CO_2 generating processes need to be co-located with suitable rock for mineralisation

Table 3. *CO_2 geostorage options.*

(road, rail or ship) or pipeline (in the gas/vapour phase or a dense super critical phase, depending upon whether the pipeline has been repurposed from the petroleum industry, where the line would likely not have the pressure integrity required for denser phase fluid over hilly terrains).[18] A substantial pipeline-based distribution system has been operating successfully for decades to deliver CO_2 from natural deposits and used for enhanced oil recovery projects in the USA.[19] The system has an excellent safety record.[20]

Carbon storage

Geostorage of CO_2 as a gas or dense phase fluid involves gas injection into porous and permeable reservoir rocks overlain by impermeable mudrock or salt. The reservoir interval could be a depleted oil/gas field or a saline aquifer. There are both challenges and opportunities with such storage. Sites must be at least 1 km below surface. At such a depth and under hydrostatic conditions, CO_2 exists as a dense phase low viscosity fluid. This enables easier CO_2 injection compared with a liquid and greater storage capacity than a gas.

Storage sites developed in depleted oil/gas fields are often well characterised because of the oil/gas production history and pre-production appraisal process. However, the integrity of old wells may be difficult to evaluate: if the depleted field is at low pressure, it may be better to initially inject gaseous CO_2 with later transition to the dense-phase. There are few data to calibrate this theoretical phase change. Storage sites in saline aquifers rarely have adequate characterisation because few wells are drilled into them.

Once injected, CO_2 migrates upwards because its density is lower than water. It may dissolve and, after an unknown period, react with alkali earth metals to precipitate carbonates. Monitoring is needed both during and after injection.

Carbon sequestration

Mineralisation may occur either in a conventional reservoir of by injecting CO_2 into a rock containing accessible alkali earth metals. This has been trialled successfully in Iceland by the Carbfix project,[14,21] where minor quantities of CO_2 were dissolved in water ahead of injection into basaltic rocks, where bicarbonate ions reacted with accessible Mg and/or Ca to become sequestered as a carbonate mineral. The process is rapid.[21]

Geostorage and geosequestration

UK – a case history

The first and, to-date, only injection of CO_2 into the subsurface in the UK occurred at the Egmanton (Nottinghamshire, **Figure 2**) in 1979, when BP examined the possibilities for enhanced oil recovery from East Midlands oil fields.[22-24]

CO_2 was delivered and stored in a 25-tonne capacity tank at 300 psia and -17°C. BP undertook a pre-pilot trial using “huff and puff” (injection and production).. The full test comprised use of 260 tonnes of CO_2 injected at rates of up to 30 tonnes/day. The only significant problem was the generation of hydrates in tubing and surface lines. No corrosion was observed and downhole gauges worked well. PVT experiments showed that at >1245 psia the gas phase disappeared, and two liquid phases appeared. Work on the core from EG68 demonstrated that CO_2 flooding could reduce residual oil saturation from 20-27% to as low as 3-6%. Attempts at water alternating gas (WAG) using small (10-20%) pore volumes of CO_2 were less effective. Calculations indicated that 7,500 tonnes (143 mmscf) followed by one pore volume of pore water would produce an additional 4200 bbl oil. Calculations suggested that 12,000 tonnes of CO_2 would be required to reduce

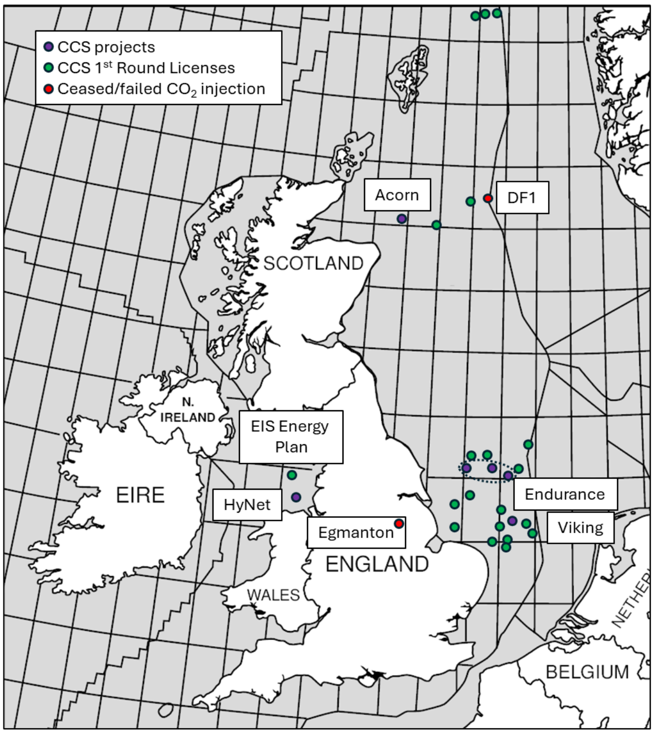

***Figure 2.** Locations of CO_2 injection and planned injection in the UK and on the UK continental shelf.*

water cut by 5-10% and, at the time, the cost was £1 million. Given the low injectivity of the formation (relative to water), the project was calculated to take 3 years, with no significant impact until ~6 years after injection. Given the extended time frame, the project was cancelled.

In the UK sector of the North Sea is the Miller Field. Like Sleipner, the petroleum in this field is mixed with CO_2. Discovered in 1982, it was depleted in the early years of this century, and operators BP proposed that it could become the first UK CO_2 storage site. The plan, DF1 project, was to develop a hydrogen fueled power plant at Peterhead north of Aberdeen, the same location as landfall for the oil export pipeline from Miller. Methane reformation with 90% of the waste CO_2 (1.8 Mt per year) could have produced hydrogen. This could enhance tail-end oil production from the field and the power plant would deliver 475 MW electricity at a carbon intensity of 43 g CO_2/kWh, tiny when compared with the mean UK performance at that time of 500 g CO_2/kWh or government target for 2030 of 100 g CO_2/kWh. Funding was not agreed and the project was dropped.

Simultaneously, the British Geological Survey undertook the first comprehensive assessment of CO_2 static storage capacity for the UK continental shelf, finding a total capacity >22 Gt across depleted petroleum fields and deep saline aquifers.[25] This was the basis the First UK CCS Competition. Consortia were invited to outline potential projects and bid for a share of a £1 billion development fund. The competition was cancelled in 2012.[26] However, a major step forward was made by National Grid Carbon when a CO_2 injection appraisal well was drilled into the Southern North Sea.[27] This included the first fully cored caprock section. A second CCS competition was launched and endorsed in the Conservative Party Manifesto ahead of the 2015 UK general election. Two consortia, one planning to inject CO_2 into the depleted Goldeneye Field offshore Moray in Scotland and the other to use Endurance offshore East Anglia were in negotiation with the government when the then Chancellor of the Exchequer cancelled support for CCS projects, citing high costs.[28] By now, three UK governments had failed to deliver CCS. "Carbon capture usage and storage: third time lucky?" is the astonishingly frank title of a publication from the UK House of Commons in 2019.[29] The publication has, however, proved to be prophetic. On 10th December 2024, the government announced the first CO_2 storage license, awarded to the East Coast Partnership to pipe CO_2 from industries in Teesside and (later) from power generation in Humberside to Endurance offshore East Anglia (**Figure 2**). Storage will begin in 2027.[30]

Risks to storage – real and perceived

CCS has often been portrayed as a risky business with respect to human and/or environmental disaster. But Holloway et al.[31] compared natural CO_2 systems with storage of anthropogenic CO_2. They concluded, "Major lake overturn events such as occurred at Lake Nyos in 1986 are considered highly unlikely to occur as a result of CO_2 storage..."[31] Another recent study investigated containment certainty for possible storage sites beneath the UK continental shelf (UKCS) where geology is particularly well known and has hosted 60 years of petroleum exploration, appraisal development and production.[32-34] They concluded that a pair of example storage sites subject to 25 years' worth of CO_2 injection and monitored for 100 years after cessation would maintain more than 99.9% of the injected CO_2 in the store.[33]

The major challenge and hence risk for CCS is not technical but commercial. Normal business-as-usual does not account for externalities such as the environmental impact of uncaptured CO_2. Thus, because there is an energy penalty for CCS, there is also a cost uplift relative to emitting it.

Moreover, externalities are much more easily included at a local/regional/national level: most of us are reasonably happy to pay for refuse collection so that the waste does not build up around our homes. However, as a colourless and odourless gas, CO_2 is easily neglected.

Conclusions

Each year, 40 Gt of CO_2 are emitted from human activity, driving climate change. Transition to low-carbon economies around the world is imperative. CCS cannot address the whole problem, but it can substantially reduce emissions.[34] It is demonstrably safe but, as of today, only 50 Mt per year are captured and stored.

References

1. UN, *IPCC Second Assessment Report*, undated, https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials.
2. D. Carrington, *The Guardian*, 2024 https://aliautonomie.it/wp-content/uploads/2024/05/Worlds-top-climate-scientists-expect-global-heating-to-blast-past-1.5C-target-The-Guardian.pdf,
3. IEA, *CO_2 capture and utilisation*, 2019, Carbon Capture, Utilisation and Storage - Energy System - IEA
4. V. Núñez-López, M. Moskal, *Frontiers in Climate*, 2019, **1** (5), Frontiers | Potential of CO2-EOR for Near-Term Decarbonization
5. A. Crossland, *Mygrid GB*, 2024, https://www.mygridgb.co.uk,
6. H. Ritchie, *OurWorldinData.org*, 2024, Share of electricity production from solar, 2023
7. A. Nqodi, T.C. Mosetlhe, A.A. Yusuff, *Energies*, 2023, **16** (18), 6715. https://doi.org/10.3390/en16186715.
8. J.G. Gluyas, et al. Keeping warm: a review of deep geothermal potential of the UK. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 2018, **232.1**, 115-126.
9. M.D.A. Albert, et al. *Renewable and Sustainable Energy Reviews*, 2022, **160**, 112230. https://doi.org/10.1016/j.rser.2022.112230.
10. J.G. Gluyas C.A. Adams, I.A.G Wilson, *Energy Reports*, 2020, **6**, 229-237, https://doi.org/10.1016/j.egyr.2020.12.006
11. T. Zhang, et al. *Clean Technologies and Environmental Policy*, 2024, **26**, 2077-2094. https://doi.org/10.1007/s10098-024-02810-5.
12. C.R. Jenkins, et al. *PNAS*, 2012, **109**, E35-E41. www.pnas.org/cgi/doi/10.1073/pnas.1107255108.
13. S. Bachu, S. Review of CO_2 storage efficiency in deep saline aquifers. *International Journal of Greenhouse Gas Control*, 40, 188-202.
14. A.S. Pétursdóttir, *Reykjavík University Masters Thesis*, 2019. https://hdl.handle.net/1946/39364.
15. K. Goto et al. A review of efficiency penalty in a coal-fired power plant with post-combustion CO_2 capture. *Applied Energy*, 2013, **111**, 710-720, https://doi.org/10.1016/j.apenergy.2013.05.020
16. M. Kheirinik, S. Ahmed, N. Rahmanian, *Sustainability*, 2021, **13**, 13567. https://doi.org/10.3390/su132413567.
17. M. Plaza, S. Martinez, F. Rubiera, *Energies*, 2020, **13** (21), 5692. https://doi.org/10.3390/en13215692.
18. E. Luna-Ortiz, *Offshore Technology Conference Asia*, 2022, Paper Number: OTC-31457-MS, https://doi.org/10.4043/31457-MS.
19. J.J. Dooley, R.T. Dahowski, C.L.Davidson, *Energy Procedia*, 2009, **1**, 1595-1602, https://doi.org/10.1016/j.egypro.2009.01.209
20. J. Gale, J. Davidson, *Energy*, 2004, **29**, 1319-1328, https://doi.org/10.1016/j.energy.2004.03.090
21. P.A.E. Pogge von Strandmann, et al. *Nature Communications*, 2019, **10**, 1983. https://doi.org/10.1038/s41467-019-10003-8.
22. D.J Gair, D.M. Grist, R.W. Mitchell, *European Offshore Petroleum Conference and Exhibition,* 1980, Paper 195.
23. D.M. Grist, F. Musgrave, R.W. Mitchell, *European Petroleum Conference*, 1982. Paper EOR 297.
24. D.S. Hughes, *DEVEX 2007 presentations, PESGB*, 2007.
25. S. Holloway, C.J. Vincent, K.L. Kirk, Industrial CO_2 emissions and CO_2 storage potential in the UK. British Geological Survey Commercial Report CR/06/185 (NC)
26. *National Audit Office,* 2012. https://www.nao.org.uk/wp-content/uploads/2012/03/10121829.pdf.
27. J.G. Gluyas, U. Bagudu, *Geological Society of London Memoir,* 2020, **52**, 163-171. https://doi.org/10.1144/M52-2019-47.
28. *National Audit Office*, 2017. https://www.nao.org.uk/reports/carbon-capture-and-storage-the-second-competition-for-government-support/#downloads.
29. *House of Commons*, 2019, **1094**. https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/1094/1094.pdf.
30. *Gov.uk*, 2024. https://www.gov.uk/government/news/contracts-signed-for-uks-first-carbon-capture-projects-in-teesside.
31. S. Holloway, et al. *Energy*, 2007, **32**, 1194-1201, https://doi.org/10.1016/j.energy.2006.09.001
32. G. Goffey, J.G. Gluyas, *Geological Society of London Memoir*, 2020, United Kingdom Oil and Gas Fields: 50th Anniversary Commemorative Volume.
33. J.G. Gluyas, H.M Hichens, *Geological Society of London Memoir* No. 20, 2004, United Kingdom Oil and Gas Fields, Commemorative Millennium Volume.
34. J. Daniels, *Global Status of CCS 2023 – Report & Executive Summary*, 2023. https://www.globalccsinstitute.com/resources/publications-reports-research/global-status-of-ccs-2023-executive-summary/

ECG Environmental Brief No. 43 ECGEB No. 43

The environmental impacts of e-cigarettes and vapes

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E-cigarettes and disposable vapes have become increasingly popular in the last decade, and they have also been a topic of controversy due to their impact on health and the environment. This ECG Environmental Brief focuses on trends in their consumption and on their environmental impacts.

Has there been an increase in users of disposable vapes?

A 2022 study found a significant increase in the use of disposable e-cigarettes in the UK between 2021 and 2022 [1]. **Figure 1** shows the percentage increase of disposable e-cigarette users in the years 2021-22 at different ages; the study found a significant increase in young users especially in the age ranges of 18-25, and less drastic increases in older age ranges (35-45). Other studies have shown a steady increase in UK users since 2012, as shown in **Figure 2**, based on data from Action on Smoking and Health for 2012-2023 and forecasts for 2024-2026 [2].

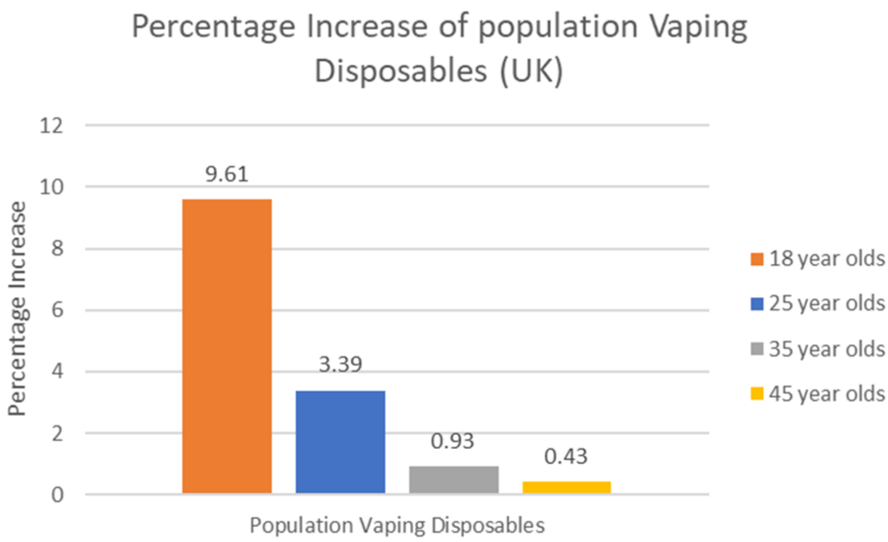

***Figure 1.** Percentage increase of vaping disposables.*[1]

What are the main environmental impacts of disposable e-cigarettes?

The main sources of pollutants and contaminants associated with disposable e-cigarettes are:

- *Lithium-ion batteries*
- *Plastic bodies/cartridges (microplastics)*
- *Nicotine and e-liquid*

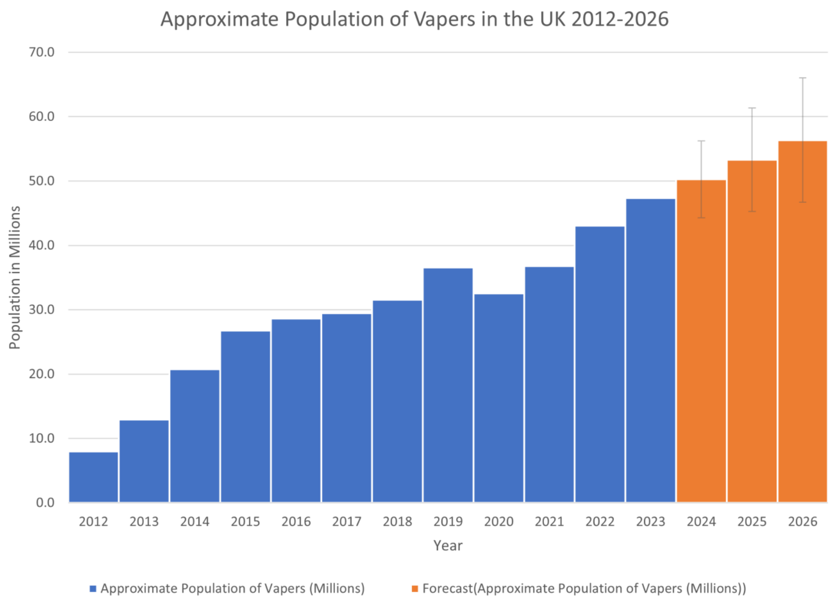

***Figure 2.** Approximate Population of Vapers in the UK from 2012-2026.*[2]

Lithium-Ion Batteries (LIBs)

The main environmental issues associated with LIBs arise from the effects of lithium, a toxic metal, on living organisms. The increased use of disposable e-cigarettes leads therefore to increasing concern around the production and disposal of LIBs [3,4]. LIBs, especially those associated with hand-held devices[5] such as disposable e-cigarettes, are generally disposed in landfill sites. This is due to weak regulations and lack of recycling infrastructure in many countries, both developed and developing. The impacts of LIBs on organisms and the environment are not limited to the presence of lithium,[6] as they may contain additional, potentially toxic elements — copper, nickel, and lead, as well as harmful inorganic compounds, for example $LiClO_4$, $LiBF_4$, and $LiPF_6$. When disposed in landfill, the toxic components of LIBs can become labile and bioavailable, as a result of processes such as weathering, ground disturbance, and biochemical activity. These processes may produce leachate, resulting in contamination of the area.

Plastics from disposable E-cigarettes

The use of plastics in the manufacture of disposable e-cigarettes is ubiquitous. Most e-cigarettes contain non-biodegradable plastic cartridges that are "poorly recyclable".[4] Plastic waste in landfills eventually breaks down into microplastics, which may then be transported into the environment through leachate and potentially contaminate groundwater and aquifers, surface waters, as well as the local flora and fauna if bioaccumulated [7]. Littering is an obvious source of pollution that is often overlooked: the very name of these e-cigarettes implies the notion of a throwaway product.[8] This has triggered remedial action against plastics, as with Canada attempting to achieve zero plastic waste by 2030[8] as well as Scotland proposing a ban on single-use e-cigarettes in 2023 along with a tax linked to recycling performance.[9]

Nicotine and e-liquid

The chemicals found in e-liquid include tobacco-specific compounds (e.g., nicotine), polycyclic aromatic hydrocarbons (PAHs), flavouring (e.g., *caryophyllene* oxide), toxic metals, phthalates, and flame retardants.[10] Many of these are identified as hazardous and potentially harmful by the US Environmental Protection Agency, and the US Food and Drug Administration. The effects of these toxic constituents can be detrimental to microorganisms, interrupting natural biogeochemical cycles and associated ecosystem services,[11] emphasising their safe disposal.

Conclusion

Increasing usage of disposable e-cigarettes is a cause for concern when considering the harmful environmental impacts they have during disposal, as well as the lack of infrastructure for recycling their components. The continuation of a 'throwaway' culture will lead to detrimental effects on the environment in years to come, as the demand for these products continues to increase. While legislature and government bodies have taken action to limit their usage, little improvements have been made to the way the materials used are repurposed rather than disposed in landfills.

References

1. H. Tattan-Birch et al. (2023). *Addiction, 118 (2), 382–386.*
2. Action on Smoking Health, (2023). Fact sheet: Use of E-Cigarettes (Vapes) among adults in Great Britain.
3. Lerner, C.A. et al. (2015). 'Environmental health hazards of e-cigarettes and their components: Oxidants and copper in e-cigarette aerosols', *Environmental Pollution*, 198, 100–107.
4. Pourchez, J. et al. (2022). 'From smoking to vaping: a new environmental threat?', *The Lancet Respiratory Medicine*, 10(7), e63–e64.
5. Mrozik, W. et al. (2021). 'Environmental impacts, pollution sources and pathways of spent lithium-ion batteries', *Energy & Environmental Science*, 14(12), 6099–6121.
6. Kang, D.H.P. et al. (2013). 'Potential Environmental and Human Health Impacts of Rechargeable Lithium Batteries in Electronic Waste', *Environmental Science & Technology*, 47(10), 5495–5503.
7. Chamanee, G. et al. (2023). 'Global perspective on microplastics in landfill leachate; Occurrence, abundance, characteristics, and environmental impact', *Waste Management*, 171, 10–25.
8. CBC News, (2023). Why disposable vapes are becoming an environmental liability, 'What on Earth?' [Why disposable vapes are becoming an environmental liability | CBC News] .
9. Hogg. D, (2023),.Summary Report: Scoping policy options for Scotland focussing on understanding and managing the environmental impact of single-use e-cigarettes, Zero Waste Scotland and Equanimator Ltd. https://cdn.zerowastescotland.org.uk/managed-downloads/mf-thteewjk-1688050310d.
10. P.D. Venugopal et al. (2024). Environmental persistence, bioaccumulation, and hazards of chemicals in e-cigarette e-liquids: short-listing chemicals for risk assessments. *Tobacco Control*, 33(6), 781-789.
11. Beutel, M.W. et al. (2021). A Review of Environmental Pollution from the Use and Disposal of Cigarettes and Electronic Cigarettes: Contaminants, Sources, and Impacts, *Sustainability*, 13(23), 12994.

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The highly successful #EnvChem series continues with #EnvChem2025, to be held at the University of Portsmouth June 12^{th} and 13^{th} 2025.

#EnvChem2025 provides a forum for early career and established researchers working across environmental chemistry to share their latest research findings.

Organised by the RSC Environmental Chemistry Group, the meeting will comprise presentations and posters on the following themes:

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- Emerging contaminants and novel techniques
- Atmospheric chemistry
- Ecotoxicology

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Event's page: https://www.rsc.org/events/detail/80727/envchem2025-chemistry-of-the-whole-environment

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