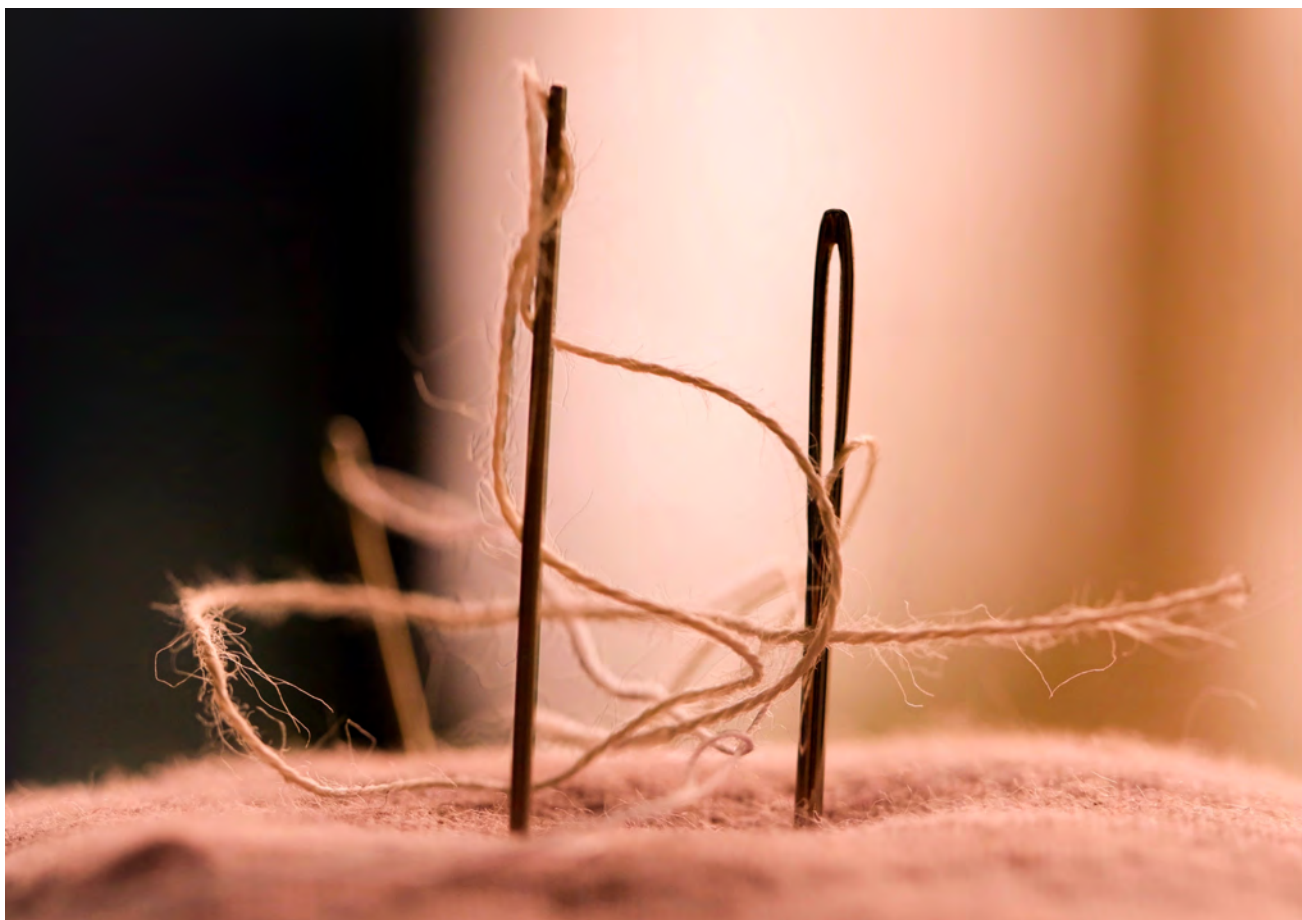


July 2024
Environmental Chemistry Group
Bulletin



Meeting report: Killer Threads! The environmental impact of fast fashion was the topic for the 2024 ECG DGL and symposium. **Kiri Rogers** summarises this event (pp 5-6), and there are more detailed reports by two of the speakers, **Dr Thomas Stanton** (p 10) and the Distinguished Guest Lecturer **Dr Raquel Prado** (pp 11-13). **Sir James Bevan**, formerly Chief Executive of the UK Environment Agency recounts the highlights of his career to Cranfield University's **Niall Marsay** (pp 15-17).
Environmental Briefs: (pp 18-23) **Bence Solymosi** discusses catalytic systems for removing persistent organic micropollutants.

William James assesses Li ion battery fire risks, and **Gemma Miller** details the sources and pathways of textile pollution.

Also in this issue: **Stephanie Powley** speaks about her role as an analytical chemist with British American Tobacco.

There is a book review from **Valerio Ferracci**.

Rowena Fletcher-Wood gives an outreach update.

Pablo Campo Moreno speaks for World Environment Day.

Laura Alcock has some horticultural insights, and we announce three upcoming meetings.

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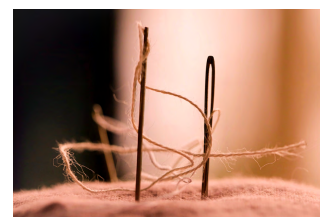
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Front Cover — Close up of two needles and thread (Shutterstock)



Interview

The ECG Interview: Dr Stephanie Powley

(British American Tobacco, stephanie_powley2@bat.com)

Steph studied for her first degree (in environmental chemistry) at Bangor University and then completed a MSc at Southampton University. Employment with British American Tobacco (BAT) was interspersed with research for a PhD on the analysis (LC-MS) of oligonucleotides, again at Southampton University, before Steph returned to BAT where she investigates the impacts of vaping.

What inspired you to become a scientist?

Despite coming from a very artistic family, I have always had an interest in why and how things work, which sparked my interest in the sciences. Also, growing up on the Isle of Wight, being surrounded by water, and having a surfing background, I was always aware of potential pollution problems and how it affected me and others.

How did you come to specialise in analytical chemistry?

During my undergraduate degree, and then more so during my masters, I found that my favourite part of chemistry was analysis. Being able to measure and quantify components within a product I found fascinating. It was so much more than looking at the theoretical side or synthesising products like an organic chemist, I got to work on what I love.... Instruments. Before my PhD, I took a job at the Oceanography Centre, which was applying basic principles to address marine chemistry, but I missed the complexity and certainty that spectroscopy techniques offer. Now I am back at BAT, I just love being able to diversify analytically, and when we get questions from our stakeholders internally, e.g. how much of this compound is in there, or what compounds are newly formed when you vape this device? Being able to answer those questions is so fulfilling. It's great!!

Could you describe your current job?

My current job is understanding the fundamental chemistry of our products and researching ways to help support our tobacco harm reduction programme.

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

I think be open to whatever comes along; I never expected that I would be working in an industrial lab. I had hoped that I'd be working in marine chemistry, collecting seawater samples and analysing them. I had no idea, until I tried it that this wasn't for me! As I've had so many breaks by just going for all opportunities that came across my path. Initially I tried this job out for six months, thinking it was a transition job, but I ended up staying because I loved it!!

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

One of the main challenges is the culture, particularly in this country, of "we don't need experts". There have been some fantastic, more grassroots, campaigns of getting environmental awareness across social media and the news. It's a shame that we need people who are non-scientists pushing this agenda, but if we as scientists can work alongside, and in support then, hopefully, we can get back to a stage where people actually will trust scientists and experts.

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

Being in the same place for so long (11 years), I've seen the development of a lot of products that can reduce the risks of smoking by reducing the toxicants associated with combustible products through vaping technologies, and the analysis I've done has gone a long way to supporting continued developments. Being able to help our product developers understand what they need to do with their products to make them potentially less harmful for consumers is very fulfilling!

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

I think I would like to work with animals in some way, maybe as a zookeeper!

And what do you do when you are not working?

I love being out in nature taking pictures of animals, landscapes, and plants. Oh, and I also love crochet.



Book review

Indoor air pollution

Valerio Ferracci ((National Physical Laboratory, valerio.ferracci@npl.co.uk)

People in developed countries spend approximately 90% of their time indoors, however, indoor air pollution is often overlooked relative to outdoor air quality. This book¹ provides a comprehensive exploration of this issue.

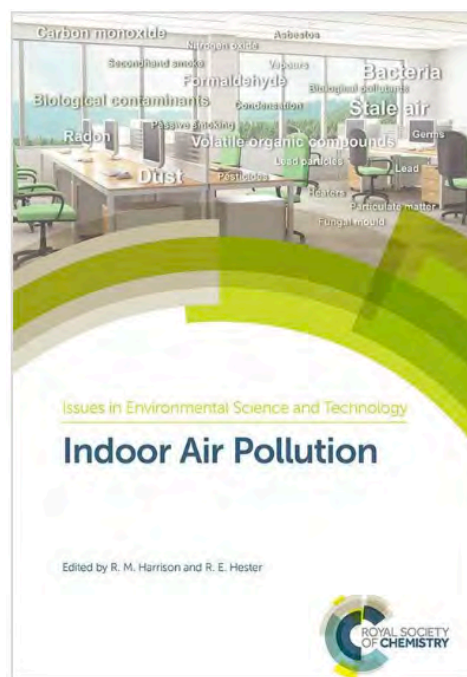
While most air quality management policies focus on outdoor pollution, there is a growing recognition of the importance of indoor air quality. The issue has become all the more relevant following the COVID-19 pandemic, which highlighted the role of indoor environments in virus transmission, and when addressing the energy efficiency of buildings, ensuring insulation and air tightness are accompanied by efficient ventilation.² As people spend most of their time indoors, indoor environments contribute disproportionately to personal exposure, which is why it is important to understand the processes affecting indoor air quality.

The book highlights the major challenges in studying indoor air: the heterogeneity of indoor environments, each accompanied by different sources of pollutants; and the difficulties (logistical and financial) of performing measurements using complex instrumentation in representative indoor environments.

The initial chapter focuses on indoor pollutants in homes, offices, and schools, as well as in other microenvironments such as restaurants, hair salons, and fitness centres. Each section offers insights into the diverse sources and impacts of indoor pollution. The following chapter focuses on outdoor air as a source of indoor pollution, and discusses how species such as nitrogen dioxide, ozone and particulate matter can infiltrate from the outdoors. The roles of ventilation, filtration and building air-tightness are also explored. Conversely, the opposite process can also occur, and a subsequent chapter explores indoor emissions as sources of outdoor pollution, considering in particular, halogenated compounds, typically used as flame retardants and stainproofing additives, and how they can bioaccumulate in outdoor environments.

A chapter authored by Nicola Carslaw (a speaker at the RSC/IOP Indoor Air event³) examines the gas- and mixed-phase chemistry occurring in indoor environments. Photolysis tends to be less important due to lower light levels, but interactions with surfaces become more

Indoor environments make a disproportionate contribution to personal exposure to pollution.



important. Chemical reactions between ozone (infiltrated from outdoors) and terpenes (from cleaning and personal care products) can lead to the formation of a variety of products, some of them harmful to health

An account of bioaerosols in indoor environments follows, made all the more relevant since the COVID-19 pandemic (note the book was published in 2019, prior to the first UK national lockdown). A thorough account on the methods used to monitor bioaerosols, and the challenges associated with them, is provided.

Lastly, the book delves into the impact of indoor air on pollution exposure and health. The negative health effects of indoor pollutants (e.g. asthma exacerbation, as well as decreased cognitive performance) are illustrated, along with recommendations on how to reduce exposure by limiting ingress of outdoor pollution and reducing indoor sources.

Overall, the volume offers a comprehensive insight into the scientific aspects and implications of indoor air pollution, serving as a valuable resource for researchers, students, consultants, and policymakers in understanding and addressing this important issue.

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Meeting report

Killer threads! Fast-Fashion's impact on the environment.

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

The Environmental Chemistry Group's 2024 Distinguished Guest Lecture and symposium, held on 18th March at Burlington House, focused on environmental concerns surrounding fast fashion – from the pollution problems posed by the overproduction of clothing to ways of mitigating the environmental consequences of textile waste. **Dr Thomas Stanton**, **Professor Will Wise**, and our ECG Distinguished Guest Lecturer, **Dr Raquel Prado**, shared their invaluable insights on these environmental challenges.

The textile industry plays a significant role in global manufacturing, providing clothing and textiles for billions of people worldwide. However, the environmental impacts associated with textile production, particularly in the context of fast fashion, which refers to the rapid production and consumption of inexpensive clothing, have raised concerns regarding resource depletion, pollution, and waste generation.

To explore the current situation, this RSC meeting began with a talk by **Dr Thomas Stanton** about fibre pollution and microplastics. Dr Stanton (Loughborough University), a lecturer in Environmental Science and a freshwater scientist, discussed his research on the



Figure 1. Effect of the textile industry on the environment.

prevalence and impacts of plastic and microplastic fibres in the environment, particularly from synthetic fibres used in fast fashion. His findings reveal that textile fibres originating from washing machines and direct washing in water bodies are a significant source of environmental pollution. While natural fibres make up a large proportion of those found in rivers and the atmosphere, the addition of chemicals and dyes to garments can have ecotoxicological effects similar to those of typical pollutants. Dr Tom Stanton emphasised the importance of improved wastewater treatment and sustainable manufacturing practices to mitigate fibre pollution. Tom highlighted the environmental implications of chemicals used in textile production, including dyeing, and tanning processes. This provided a great transition to our next speaker, **Professor Will Wise**, who focused on the leather industry's sustainability efforts.

Will from Northampton Leather provided insights into the leather industry's efforts to reduce its environmental impact. These include examining the discharge of harmful chemicals into waterways, which contributes to water pollution and ecosystem degradation. Efforts to reduce chemical usage and adopt eco-friendly alternatives are essential for minimising the environmental footprint of the textile industry.

He also addressed that, despite leather's reputation as a durable and potentially "green" material, the tanning process involves numerous environmental challenges, including water consumption, effluent contamination, and worker safety concerns. Will highlighted ongoing research into alternative tanning



Dr Thomas Stanton from Loughborough University.

methods, such as the use of deep eutectic solvents (DESs) and polymer beads, to minimize water usage and reduce environmental impact.

After a networking lunch, the conference continued with a presentation from our distinguished guest lecturer, **Dr Raquel Prado** (Ananas Anam) discussing natural fibres and innovative solutions. She highlighted the potential of natural fibres as a more environmentally friendly alternative to synthetic fibres. Ananas Anam is a company producing sustainable textiles from pineapple leaf fibres. Dr Prado highlighted the environmental impacts this industry can have, from a water, waste and land use perspective (**Figure 1**). She also discussed the Ananas Anam's innovative process of transforming agricultural waste into a pioneering, low-impact textile called Piñatex®. This approach not only reduces waste but also provides employment opportunities in rural farming communities.

Rewarding discussions followed between guests and the experts summarising textile waste and recycling challenges. The experts emphasised the pressing issue of textile waste generation, which is projected to increase by 62% by 2030, exacerbating water pollution, landfill usage, and climate change. While recycling offers a solution, only 8% of textile waste is currently recycled. Manufacturers face challenges in separating and



Professor Will Wise from Northampton Leather.

recycling mixed materials, underscoring the need for improved infrastructure and collaboration between industry, researchers, and policymakers.

The insights shared by these experts highlight the complex environmental challenges posed by textile fibres and the need for innovative solutions. By embracing sustainable practices, promoting natural fibres, and developing effective recycling methods, the textile industry can contribute to a more circular economy and reduce its environmental footprint.



Dr Raquel Prado is presented with the 2024 DGL medal by ECG committee's outgoing Chair, Dr Rowena Fletcher-Wood.

Report

Outreach report 2024

Rowena Fletcher-Wood (freelance science communicator, rowena.fletcherwood@gmail.com)

In 2023, our events totalled ~170 meaningful outreach engagements from ~1400 festival attendees. So far in 2024, we have already exceeded this, with ~275 meaningful outreach engagements at just two festivals where these were measured – **ATOM Science Festival** in Abingdon, and **Dorchester Science Festival**.

But how do we measure these engagements?

A fantastic measure is giving out materials. Some event organisers hand out stickers to each of their guests and count how many stickers are missing at the end of the event. Others use pots or bags to give out slime or other crafts, and again, see how many are left at the end. I have used a clicker before – but that can be hard work. Our *Float or sink?* demo (see *ECG Bulletin*, July 2022¹ and *ECG Bulletin*, January 2024²) asks participants to vote on whether a plastic item will sink or float, then we test them, usually by asking younger members of the audience to throw items into a giant Kilner jar, selectively unlidded only when we are ready to test. It is still a rough measure of engagement: some adults will not vote alongside their children, some vote without thinking, and inevitably the pots incur different numbers of votes. If I bring my own children, they also insist on having a go at the “game”, although by now, I am certain they have memorised the answers.

Why are there more this year?

In all honesty, it could be down to the sunshine in Abingdon (outdoors) and rainfall at Dorchester (driving participants to the science tent), we cannot know for

sure. Running fewer activities suggests improved engagement as one activity channelled into one game allows us to make accurate measurements. With multiple activities at a stall can result in participants only choosing one demonstration to engage with.

But what do the votes tell us?

In the case of our *Float or sink?* demo, as we have gathered more and more votes in subsequent years and at different locations, we are slowly building up a dataset which tells us something (on a population level) about public knowledge of plastics.

Analysis of around 1000 votes has revealed that people vote ‘float’ slightly more frequently than sink (58%) – accurate to the fraction of items under scrutiny that do indeed float. However, discerning which specific object sinks or floats is harder, and voters tend to be wrong 35% of the time. The most misleading item was a silicone rubber flower, which sinks, although our voters are convinced otherwise. Meanwhile, a piece of nylon rope got a split vote (I will leave you to try that one at home!).

What next?

We will be doing more events like this in the future, and we always need volunteers, so please do get in touch if you are interested in helping us, or running outreach yourself – full descriptions of activities may be found in *How To* resources on our website (<https://www.envchemgroup.com/resources.html>).

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1. *Float or Sink pilot* – see *ECG Bulletin*, July 2022, p.7.
2. *Accessible Evaluation at the BIG Event*– see *ECG Bulletin*, January 2024, p.10.



Sink or float?

- Anonymous
- Diverse representation
- High participation
- Embedded in activity

Webinar report

Contaminated land: extent of the problem and management

Laura Alcock (Edwards Ltd, laura.alcock@edwardsvacuum.com)

Edwards Product Company based at Clevedon celebrates World Environment Day annually with a range of activities, including a webinar supported by the RSC's Environmental Chemistry Group. For 2024, the theme was "Generation Restoration". ECG committee member, **Dr Pablo Campo-Moreno**, from Cranfield University presented this webinar to ~75 Edwards' employees, across two sessions with around 100 others requesting access to a recording.

Soil and land contamination

Dr Campo-Moreno began by highlighting the importance of soil to the modern world and everyday life, then clarifying the definitions of pollutants, contaminants and contaminated land. This was particularly poignant, as he highlighted the fact that land contamination is not limited to the surface of the land. Following this, Dr Campo-Moreno identified some of the substances that can contribute to soil pollution and land contamination, including the sources – particularly human activities – of these materials. Unsurprisingly, landfill is a significant source of the widest range of contaminant materials associated with land contamination.

A scale of the number of potentially and definitely contaminated land sites in Europe was presented, with Belgium-Flanders referenced as the most significantly contaminated area, at nearly three times the number of potentially contaminated sites per 1,000 capita compared with UK (the second highest for potentially contaminated land sites), though only slightly more actually contaminated sites per 1,000 capita than the closest nation (Finland).

Contaminated land management

There was an explanation of the evolution of contaminated land management techniques and thought processes from discarding wastes in 1960, through application of intensive treatments in around 1990, to

the present approach of applying the most sustainable methods available and researching and development of newer and better sustainable methods in recent years. A brief nod was also given to the primary drivers of contaminated land management policy and the gap that currently exists.

Dr Campo-Moreno clarified the distinction between hazards and the risks that they present. This is key to understanding the selection of approach used for management of contaminated land, which involves identifying the hazards present and the risks associated with addressing them or not. From this, he moved on to the further analysis and decisions that may be carried out based on the assessment and the approaches that can be used.

A case study was presented around a leaking underground fuel tank causing contamination of the land where it is buried. This discussed the impacts of the contamination that need to be considered beyond the soil itself (e.g. plant uptake, vapourisation to air).

Sustainability and innovation

Dr Campo-Moreno's talk led to how to ensure that contaminated land management is as sustainable as possible, the SuRF-UK framework¹ and its principles for achieving this sustainable practice. He highlighted, as well, that sustainability applies to social and economic impacts, as well as the environmental aspects of any practices adopted and the indicators of these different areas. Critical to sustainable management of contaminated land is ensuring that the treatment minimises the risk of spreading or evolving the contamination. This is achieved through analysis of as much data as is available regarding the land to be managed and the certainty or uncertainty of the conditions of the contamination. An appropriate standard method and monitoring can then be applied to the management of the land in question. Innovation of new methods for soil remediation and contaminated land management were touched upon, as follows:

- Costs – capital and maintenance.
- Time associated with remediation.
- Permanent destruction of the contaminants.

Critical to sustainable management of contaminated land is ensuring that the treatment minimises the risk of spreading or evolving the contamination.

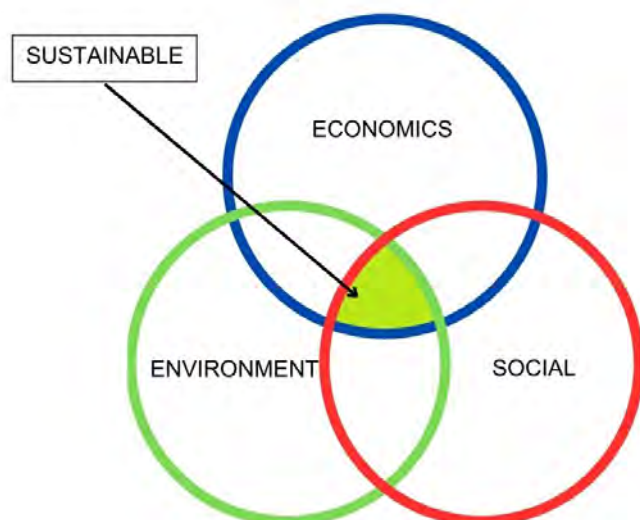


Figure 1. The triple bottom line of sustainable development.

- Neighbourhood concerns
- Logistical considerations

Sustainable practices consider all of these impacts and fall within the definition of sustainable development presented by the Report of the World Commission on Environment and Development 1987, the Brundtland report “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”. This was reinforced by the Venn diagram shown in **Figure 1**. Therefore, sustainable remediation needs to apply these principles the decisions being made.

Dr Campo-Moreno highlighted that this is not so simple as it may seem, as soil and water remediation also use resources, and there is the potential to do more harm

than good. Therefore, the benefits need to be weighed against the downsides of available methods and, perhaps the process of remediation itself. This is addressed through the SuRF-UK Framework, which Dr Campo-Moreno outlined as stating that sustainable remediation should “Optimise risk-management based on consideration of social, environmental and economic factors, but always ensure:

1. Protection of human health and the wider environment.
2. Safe working practices.
3. Consistent, clear and reproducible evidence-based decision-making.
4. Record keeping and transparent reporting.
5. Good governance and stakeholder involvement.
6. Sound science.

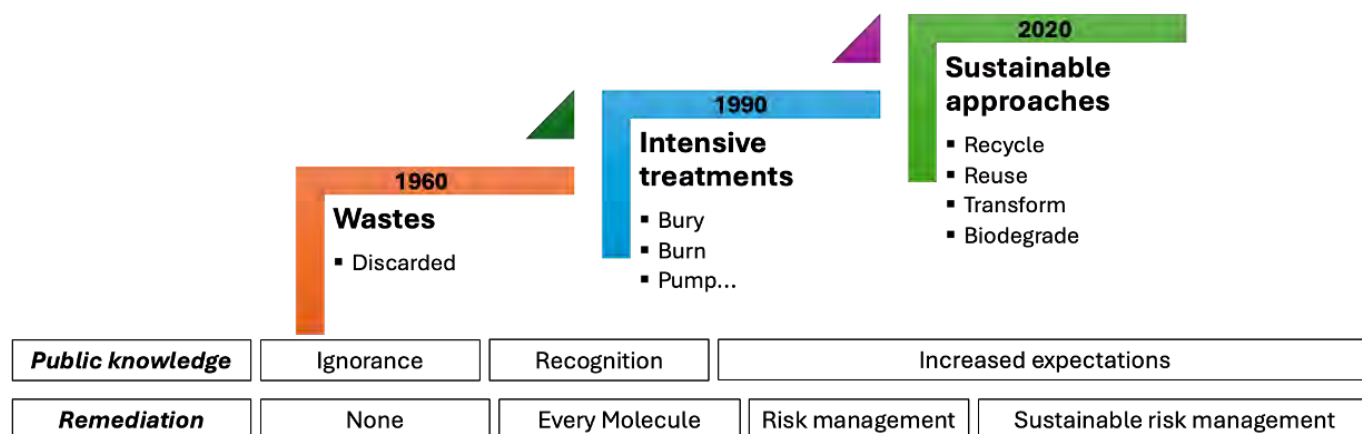
Dr Campo-Moreno concluded by informing the audience that further guidance could be found from the Sustainable Remediation Forum UK (SuRF-UK) website, or by reaching out to the Environmental Chemistry Group for advice on how to care for and improve the quality of soil at home for individuals.

Acknowledgments

Dr Pablo Campo-Moreno is a current member of the Environmental Chemistry Group Committee and a Senior Lecturer in Applied Chemistry at Cranfield University, specifically, the Cranfield Water Institute. His research includes soil and water quality and remediation. This talk was provided to Edwards Ltd as a general outreach activity, was well received and greatly appreciated.

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Evolution of contaminated land management as related to increasing awareness for sustainability (Adapted from?).

Article

DGL Feature: Microplastic and natural fibres

Dr Thomas Stanton (Loughborough University, t.stanton@lboro.ac.uk)

Microplastics (MPs) are one of the most well-known types of environmental pollution. A MP is any piece of plastic smaller than 5 mm (about the size of a circle on top of a Lego® block), and MPs come in a variety of shapes including beads, fragments, and fibres. These particles can be eaten by even the smallest animals, blocking their gastrointestinal tracts. MPs are also known to introduce chemical pollutants to the environments they pollute.

MP fibres (e.g., polyester, nylon, acrylic) are frequently recorded as the most abundant particle shape in environmental surveys of MP pollution and are associated with greater toxicological effects than other MP shapes. These fibres enter the environment primarily during the manufacturing and the washing of textiles made from plastics. Natural fibres (NFs) (e.g. cotton and wool) are therefore often promoted as greener and biodegradable alternatives to MP fibres. However, an emerging field of environmental science is now starting to look for both natural and plastic fibres and is consistently finding that >70 % of textile fibres in the environment are natural, not plastic.^{1,2}

The pathways of NFs to the environment are the same as MP fibres, and NFs have been recovered from aquatic archaeological sites centuries after their introduction to the environment, raising questions over the timescales of their biodegradability.³ Moreover, processing NFs for textiles involves extensive chemical and mechanical manipulation, producing fibres that are fundamentally unnatural.⁴ For example, mercerisation, a common treatment of cotton for textiles, including denim, changes the natural cellulose I polymer from the cotton plant to cellulose II – a polymer which is rarely found in nature.⁵ Despite this, concern for the environmental impacts of NFs lags far behind that of MP fibres.

It is vital that efforts to improve the sustainability of the fashion and textile industry are accurate and well-informed, necessitating a thorough assessment of the environmental behaviour and impacts of NFs. This represents a considerable gap in our understanding of anthropogenic particles in the environment. However,

this environmental science must also recognise its social context. The relationships between different fashion industry stakeholders, and their concerns about the impacts of industry change on consumers, have been identified as key systemic barriers to minimising pre-consumer textile fibre pollution.⁶ Being able to make environmentally informed fashion choices is also an economic privilege that is not available to everyone. To truly understand the problem of textile fibre pollution (natural or plastic), and inform enduring improvements to textile sustainability, therefore relies on truly interdisciplinary research spanning the environmental and social sciences.

The application of the Precautionary Principle to microfibre pollution has promoted natural over plastic fibres, across the textile industry, but the environmental sciences are starting to suggest that this is not the correct strategy. Thorough scientific investigation of natural fibres as pollutants is urgently needed to inform sustainability within the textile industry, but this science must be sensitive to the social environment and context of fashion's environmental footprint if it is to realise positive industrial and social change.

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Article

DGL Feature: The textile industry and the environment

Dr Raquel Prado (Ananas Anam, raquel.prado@ananas-anam.com)

The garment industry has been transformed in the last century. Clothing is no longer regarded just as a commodity for protection from the environment or to fulfil the requirements of human decency, but is now subject to the whims of fashion and therefore to be replaced as fashion changes. The result? In industrialised countries, overproduction of clothing, limited usage, and disposal to ever expanding, but scarce, landfill sites.

A Lenzing group report stated that only 8% of textile waste is recycled, with a potential 92% still ending up in landfill.¹ As a worrying example, 59,000 tons of garments are disposed in the Atacama Desert every year² and, in 2015, Greenpeace reported that Hong Kong disposes of 110,000 tonnes of textile products annually.³

In addition to the landfill contribution, in Europe, 42% of used textiles are discarded annually, and 80% of that is incinerated with no other extended life option. 93 billion cubic metres of water are used for textile manufacturing, and 20% of global wastewater is discharged by the fashion industry. A primary pollutant from textiles are microfibres – particularly microplastics. A single laundry of polyester clothes can discharge up to 700,000 microfibres, but polyester is not the only cause of microfibre pollution: cellulose-derived microfibres are also widely discovered in oceans due to textile degradation. Samples from the Galapagos had 12,300 microplastics per cubic metre (MP/m³) in sea water, of both polyester and cellulosic origin. The textile industry emits 121 million tons of CO₂e per year, of which 80% is from manufacturing, and corresponds to 10% of total global emissions.

One of the primary impacts of natural fibres is on the land needed. 4% of global agricultural land is used to produce textile precursor fibres, mainly cotton. This does not seem significant, but climate change means that all arable land will be precious for food production, in the future. When examining the impacts of the textile industry, it is reasonable to expect that the production of new fibres should be moderate and somehow reduced, but the reality is otherwise. As a consequence of world population growth, the demand on textile fibres is

expected to rise at an annual rate of approximately 3% until 2030⁴. For 2018, the global textile industry used 100 million tons of virgin fibres, of which approximately 60% were petroleum-based.⁴ Production of cellulose-derived fibres has doubled in 10 years, from 3 million to 6 million tonnes. This demand on natural and fabricated cellulosic fibres is expected to continue to rise. The production of cotton, however, is not expected to meet this demand because of restrictions on farmland use and availability of irrigation water.

Anticipating the “cellulosic fibre gap”⁵

The cellulosic fibre gap relates to the global viscose fibre output, which stood at over 5.3 million tons in 2016 and is still expected to grow in the future as one alternative to cotton.⁶ The industry of petroleum-based textile fibres has experienced the same trend as cellulose-derived fibres, with an increase of 100% in 10 years and an annual production of 109 million tonnes in 2020, with polyesters such as polyethylene terephthalate (PET) most common.² The same line is observed in the leather industry, in 2020, the global leather goods market was sized at USD 394.12 billion and was expected to continue growing.⁷ However, the production of synthetic fibres in 2020 was affected by COVID-19. The pandemic caused a decrease in the production of every synthetic fibre compared to 2019 and, as such, the industry must be monitored for a number of years to determine if it will resume the same rate of growth, or if awareness of climate change has had an impact on how we consume and manufacture.

In countries where a collection infrastructure for garments is in place, the system is mainly designed to reuse, where the pieces are examined, separated, and inspected to assess the quality. Those pieces in good condition are sent to second-hand shops, charity shops, or shipped to less developed countries to be sold. Those in a poorer condition are shredded or used as rags. Recycling infrastructures are still limited, but emerging from laboratory to industrial scale. Some large brands and corporations have internal systems to recover and recycle their products but are mostly limited to cotton. In the case of leather, end-of-life options are significantly more limited, with waste usually disposed of in landfill or incinerated.^{4,8} For every kilogram of virgin cotton displaced by second-hand clothing, ~65 kWh of electricity is saved, and for every kilogram of polyester, ~90 kWh. Therefore, the reuse and recycling of donated clothing has a much lower environmental burden

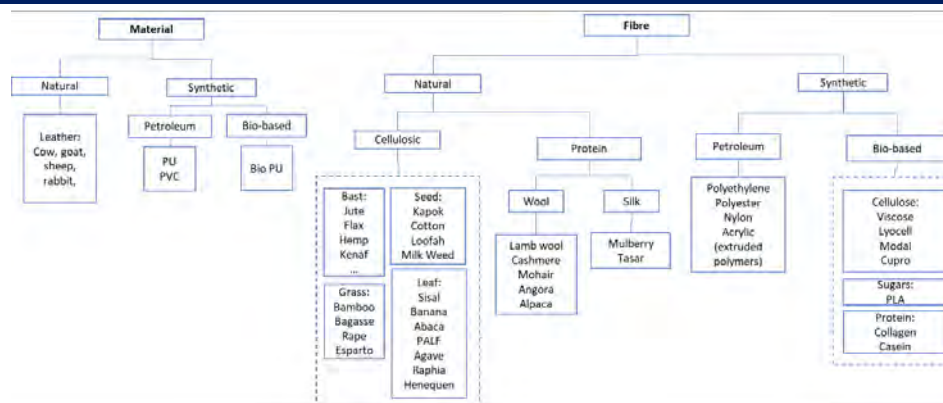


Figure 1. Garment composition possibilities.

compared with manufacture and sale of new clothing from virgin materials.⁹

Recycling textile fibres

According to Directive 2008/98/EC (European Parliament and Council of the European Union, 2008), recycling is any recovery operation where waste materials are reprocessed into products, materials, or substances whether for the original use or for different purposes.¹⁰ When recycling a material, there are two possibilities: to upcycle – when the product obtained by recycling is of higher value; or downcycle – when the product obtained by recycling is of lower value. To recycle, garments need to be disassembled into the different materials that compose the product. There are different techniques for material recycling: these can be mechanical, thermal, chemical, or biochemical recycling, including composting. Some authors consider incineration to obtain energy as another method of recycling, but in the context of this review, incineration is not considered as no valuable material is obtained, nor is natural, uncontrolled biodegradation.

In mechanical recycling, textiles are processed to produce smaller fibres. Materials and fibres that can be mechanically recycled include cotton, PET, and leather. Thermal recycling is limited to apply heat to melt fibres and reprocess them by extrusion, but never to incinerate to produce electricity. This can be applied to any thermoplastic material, such as PET and polyvinylchloride (PVC), most of which are petroleum-based. Some authors consider this as mechanical recycling.¹¹

Chemical recycling refers to chemical deconstruction, converting polymers into their primary monomers before repolymerising to produce the same, or a chemically modified polymer structure. This is commonly applicable to petroleum-based textiles. In addition, chemical recycling can also refer to dissolution and selective reprecipitation of fibres. This is more often applicable in natural fibres such as cellulose or cotton, producing mainly viscose.¹² Cellulose, cotton, viscose, polyurethanes (PU), polylactic acid (PLA), and nylon can be chemically recycled.

Biochemical recycling refers to depolymerisation or degradation via enzymes produced in a laboratory.

Enzymes catalyse depolymerisation without the presence of microbial degradation¹³, which is the first step in composting. Cellulose-derived fibres such as cotton, PLA and PU can be recycled by biochemical processes. The composting process releases valuable nutrients back into the soil, contributing to the growth of trees and plants. Composting is considered the most circular approach for end-of-life textile disposal according to Dame Ellen McArthur.^{14,15} There are many different mineralisation approaches that exist within the natural environment. Different enzymes are secreted by a broad range of microorganisms including fungi, bacteria, and actinomycetes.¹⁶

An efficient recycling process is considered when: more than 90% of the material is recovered, the recycling rate is higher than 20%, and the final waste is less than 5%.¹⁷ For mechanical recycling, the only way to have an effective process and obtain fibres with the same applicability of the raw material is to recycle materials composed entirely of the same fibre. When recycling a composite mechanically, the output is always a downcycle.

In thermal recycling, even the smallest contamination with a thermostable polymer can jeopardise the process. Chemical and biochemical recycling, meanwhile, opens up the possibility of upcycling to certain composite materials, through selective dissolution or enzymatic degradation. However, the recycling of blends has mainly been studied at laboratory scale, and no commercially viable separation, sorting, and recycling technologies are currently available for materials such as cotton and polyester blends.³ Garments are a complex mixture of materials and very often contain blended yarns or composites. **Figure 1** shows the variety of organic fibres that can form part of a garment excluding any inorganic material. Mechanical recycling for complex compositions is therefore always a downcycle, or even not applicable, with most of the applications being related to insulation specifically for synthetic materials such as polyurethane leather (PU) and nylon when they are in a matrix that makes separation difficult.¹⁸ The most studied fibres to be recycled are cotton and polyester, followed by viscose and wool, following the review by Sandin *et al.*¹², in terms of composites cow

leather, polyvinylchloride (PVC) and PU are most common.

In a garment production process, there are several streams of waste, including from combing, cutting, and carding. Some of these fibres can be reintroduced to the process, some can be used as reinforcement, but others need to be recycled or degraded.⁴ Recycling in general has been more applicable for synthetic fibres that can be introduced into the textile industry, but when discussing textile recycling, natural fibres are gaining the space with the development of new technologies to dissolve and convert cellulose, the primary component of natural fibres such as cotton and linen. The research on the recycling of natural fibres has also increased due to their intrinsic properties such as superior moisture absorption, breathability, and excellent mechanical properties compared to synthetic fibres.⁶

However, recycling is not the only solution, and reuse should be the first option for everyone. Ananas Anam produce textile fibres from pineapple harvest waste. These fibres are extracted from the leaves of the plant, that are completely cropped after two harvests. The leaves are a metre long, and the fibres have a similar chemical structure to that of flax, with good mechanical properties. This makes them an interesting solution for a wide range of applications. Valorising a waste eliminates an environmental impact: land competition for food, and also decreases the demand for water and other resources that virgin natural fibres need.

But who are Ananas Anam?

Ananas Anam is an innovative company that specialises in processing pineapple leaf fibres (PALF) into sustainable textile solutions. In all that we do, we consider the impact of our decisions on our workers, customers, suppliers, community and on the environment. This ethos has achieved Ananas Anam status as a Certified B Corporation® and earned an endorsement by The Vegan Society and People for the Ethical Treatment of Animals (PETA). Our target is to reduce the environmental impact generated by the textile industry, addressing this by valorising agricultural waste from pineapple farming to offer our products as a solution to meet our clients' sustainability goals, such as Route to Net Zero. Ananas Anam is best known for creating Piñatex®: a pioneering natural and vegan non-woven textile.

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How To

Gardening: repelling pests and fertilising garden plants with minimal environmental harm

Laura Alcock (Edwards Ltd, laura.alcock@edwardsvacuum.com)

During the summer months, there is nothing more relaxing than sitting out in the garden during the evening sunshine – unless you are surrounded by biting insects. This is made all the more difficult when trying to avoid negative environmental impacts that can be common side-effects of insect repellents. This *How To* provides some suggestions for keeping gardens as the wonderful relaxing space they should be, without literally costing the earth.

Repelling biting insects

Nothing ruins an evening in the garden quite as much as a cloud of midges hovering between the patio and the door back into your dwelling. There are going to be bites and, by lunchtime tomorrow, they will be itching to the point of driving the victims mad!

DEET (*N,N*-diethyl-meta-toluamide)-based insect repellent is excellent for keeping biting insects away, but affects honeybee chemo sensing.¹ It can also (rarely) cause adverse skin reactions – particularly if you already have sensitive or damaged skin. These factors make it less desirable and human-made repellents are generally very effective against most insects – whether you want them around or not.

Choosing the right plants could drastically reduce the number of biting insects interrupting the pleasures of your evening, whilst encouraging pollinators to further improve the niceties. Plants that achieve this include lavender, alliums (including onions), catnip, bee balm, marigolds, lantana, scented geraniums (e.g., **Figure 1**), ageratum (floss flower), and pennyroyal.

Lavender strongly benefits from cutting and regrowth. Bunches of lavender leaves and flowers can be tied together and hung in a cool, dry area to dehydrate over a couple of weeks. These can then be used as a natural air freshener to bring fragrance indoors.

Some varieties of lavender are also edible – though not all – and can be used to decorate cakes or introduce unusual flavours to sweet treats. However, it is crucial to ensure that you know the specific varieties you have before introducing them to your diet.



Figure 1. *Pelargonium hortorum* 'Americana Dark Red' (red scented geranium).

Apart from acting as a deterrent for biting insects, many of these plants provide a welcome source of nectar for pollinators. As a result, the population and variety of bees, butterflies, hoverflies, moths, and other pollinators will likely increase in your garden, over time. In turn, birds (and, possibly, bats) will begin to visit where they may not have done so before.

Other plants can provide kitchen ingredients whilst repelling biting insects. Among these are garlic, onions, and sage – which are low maintenance and easy to start from seed. There are also the options of mint, rosemary, basil, lemongrass, fennel, and thyme.

Trimming the newer stems and leaving the older ones gives your garden the fragrance that keeps most biting insects away, whilst allowing the addition of flavour to your food. Eucalyptus is also fragrant, repels biting insects without adverse effects to pollinators and can (with proper training) be used for medicinal purposes.

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Interview

Interview with Environment Agency Former Chief Executive, Sir James Bevan

Niall Marsay (Cranfield University, n.h.marsay@cranfield.ac.uk)

From November 2015 to March 2023, **Sir James Bevan** served as Chief Executive of the Environment Agency (EA). His extensive career encompasses roles such as UK High Commissioner to India, Chief Operating Officer at the UK Foreign Office, and Visiting Fellow at the Center for International Affairs at Harvard. Within the Foreign and Commonwealth Office, he has held senior positions in Washington, Paris, and Brussels. Sir James holds a BA (Hons) in Social Anthropology from the University of Sussex. He received the Companion of the Order of St Michael and St George (CMG) in 2006 and was knighted in 2012. Additionally, he was granted an Honorary Doctorate by Sussex University in the same year.

Do you feel like the quality of the environment has changed in your lifetime?

I think some things are better, and some things are worse. Let's start with what's worse. I was born in 1959: I think that's self-evidently climate is getting worse, as well as biodiversity, which is in a real crisis. However, in terms of what is better, firstly, we have started to clean up quite a lot of damage that we have done over the last 250 years. The EA, which I used to lead, played a big role in cleaning up our water, soil, and air. By and large, all those things are better now than they were a few years ago in this country. I also think we now have a chance of successfully tackling the climate emergency, because we know what the problem is. We know what the solution is. We just need to do it. There is much more awareness among many people in the UK and around the world about the importance of the natural environment. That makes me optimistic that this might be the first generation to leave the environment in a better state than we found it.

In some of the recent talks. You stated yourself as an evidence-based optimist. Given that there's so much negative news on sewage pollution, emerging contaminants, and climate inaction, what evidence makes you an optimist?

Firstly, that we know that nature comes back much quicker than we expect if we let it. Working with the EA,

we've had to dig holes in the ground for flood or nature restoration schemes, and, astonishingly, you only need to leave those 6 months. When you come back, you can already see nature returning and restoring itself. By most measures, air, water and soil quality are better in this country than it was. That is down to a lot of regulatory work by various agencies and investment by water companies, businesses, and others. If you look at what we're doing now on climate, we now have a much better understanding of the problems and have some quite powerful interventions that can make a difference and turn things around.

Before you were the chief of the EA you were the UK High Commissioner to India. It sounds like a very different position. Was it a big transition, and were there any perspectives that were useful?

I guess a common thread running through my career is a motivation to make the world a better place. Most of what I did in the foreign office was about trying to make the world a better place. When I was high commissioner of India, which involved working with the Indian authorities and other local actors to try and make India a better place. And the EA, which I have led for the last seven and a half years, is about creating a better environment. So, there is that underlying common theme. Another common theme, and the point of the EA, is to make a difference. So, one of the things I like about Cranfield University is that research is not just to help you understand the world, but to help make it better. It's about creating real-world impact. When I was working in India in my previous career, it was all about what can we do that will make a real difference to real people on the ground. I guess. Lastly, I would say that in India and then the other places that I lived with overseas you do see up close first-hand some of the challenges that might otherwise be academic. So, you know, climate emergency. We all know that's a big issue, but it wasn't, really, until I lived in India for a while that I saw the kind of real-world impacts on people who live in the Himalayas but also in the southern islands, the Bay of Bengal and the people in a Delhi. They're facing record-breaking temperatures now, almost every year. That was a common thread.

When I moved from being a diplomat to being a leader of a non-departmental organisation, I had to learn a lot more about climate, the environment, water, nature etc. But some things, aren't all that different, ultimately, if you're a High Commissioner or the Chief Executive, you are basically there to lead people to achieve outcomes. And that's what I've spent most of my life doing.

It's really good to hear that you had passion while you were there.

It's hard not to. I've found the most inspirational thing in the developing countries I have worked in. All developing countries have a massive challenge and, in some ways, the challenges are bigger now than they used to be. But what I found in every single one of the places I lived and worked in, the Democratic Republic of Congo, various parts of Africa, Algeria, and India, there are inspirational people at all levels of society. Often, women, doing it for themselves, making astonishing changes to either their local circumstances or to the nation. And having seen that throughout my career, that's another reason why I'm optimistic about the future, because all around the world I see astonishing people doing astonishing things that are uplifting humanity.

English water quality has been trending upward for the last few decades, but more recently it's stalled at good status for only 40 % of English waterways. How did we achieve those improvements and why are we struggling to continue improving?

It is better because we stopped putting most of our industrial pollution into rivers, untreated. Because the water companies, in particular, made massive investments to ensure that most of the pollution they treated did not end up in our rivers. Because a robust regulatory framework regulated what the water companies were doing, and the EA was given the resources necessary to affect that framework, so that people could be on the ground monitoring, and when required, holding polluters to account. And finally, because ordinary people wanted it to get better, putting pressure on politicians to demand higher standards and pass laws to achieve that.

So, why is it flatlining? Partly due to the way we measure water quality. 40% of rivers in England are in a good ecological status (the number that you get when you apply the Water Framework Directive (WFD) [EU-derived law]). The criteria that the UK helped write and which by and large is a very good directive. But the way the legislation is designed means for a river to reach good ecological status, it must pass a series of tests, and if they fail any one of those tests then they don't meet that status. So, we've got quite a lot of rivers which are passing most of the tests with an ecological status, and where you know you have thriving wildlife, which is a really good test. But they are still failing because of the technicality in the WFD. Many of the things that are causing rivers to fail under that directive are not going to change for a long time. For example, a common reason rivers fail is morphology. If humans have heavily modified the shape of the river, it will normally fail under the WFD criteria. And since most of our cities sit on rivers which have been heavily modified, it's going to be very hard, if not impossible, to restore those parts the rivers to their natural morphology. We need a more sophisticated framework. The other reason it's flatlining, is an increased pressure on our water ways. There are more people today, hence more sewage. We are getting

increased stress on the environment from the climate emergency, which impacts water quality. Other sectors of economic activity, notably farming, are also not properly regulated in ways that would reduce the build-up of nutrients in rivers. If we really want all our waters to get to good status (and we should aspire to that), we need to have robust regulation of all the sectors that are using it, not just some. We need the resources to allow that regulation to be implemented, which costs money. And so, there is a choice to make. We can spend that money on the NHS. We can spend it on motorways. But we cannot spend it on all three at the same time.

One of the government's regular defences of their environmental track record, is that funding for the EA has increased in the last decade. Is it correct that this was for the funding of flood defences while permitting and enforcement activity faced significant budget cuts in the last decade?

Yes. You're absolutely right; the EA's budget is larger than it has ever been. It is also true that,

- A. the EA has far more duties now than it ever did;
- B. inflation has eroded significantly the value of that budget and what the EA can do with it;
- C. 90% of that budget is ringfenced for reducing the risks of flooding which is very important.

Whilst the budget that we've had for building flood defences has increased, including in real terms, the budget from the Government for doing the other main thing that the EA does, protecting the environment, in particular enforcing regulation, has declined, which had an impact on the EA's ability to both monitor and enforce regulations. The EA still does a fantastic job with the resources that it has, but, ultimately, you get the environment you pay for. This doesn't have to mean all that extra money comes from the government because the fundamental principle should be the polluter pays. For example, if we want farming to have less impact on our waters.

We need to regulate farming more comprehensively. Farmers should pay for that because they are ultimately the polluter and so they get to pay the cost of monitoring and preventing that pollution. But that's a tough political judgement for any government. It's a tough life being a farmer. We want them to grow the food that we need. We don't want to put more burdens on them. On the other hand, we need to protect our rivers.

Do you think some of our improvements in pollution are because we have exported our waste to other countries?

There is an issue about our international responsibility. I'm not going to say [as the former chief of the EA], that I think Britain should not be exporting waste. We do export certain kinds of waste lawfully. Some of that waste is used in incinerators in Europe and other waste is recycled in places like India. But personally, as I'm open to say, I don't think this is either sustainable or the right thing to do. Quite a lot of waste gets diverted or is

illegally exported, and when it arrives in a third country isn't treated in the way we want.

And what about the heavy industries we rely on abroad?

One of the reasons that we do have a decent story to tell in terms of improved air, water, and soil quality is to do with the deindustrialisation of the UK, and development of a much more service-based economy than a manufacturing economy with relatively little heavy industry, which tends to be the most polluting and has certainly been a factor in improving our overall environmental record. But the biggest factor in terms of what our environment today is the standards that we set and that we are prepared to demand as a nation.

Emerging contaminants are an important area of research at the moment which include PFAS, pharmaceutical pollution, antibiotic-resistant genes (AMR), and microplastics among others. Are these on the EA's radar right now?

Yes, all those things are. PFAS, AMR, and microplastics are issues that are not just on the EA's radar, but are becoming increasingly important for the EA, the public, and therefore the government.

Why is that?

We now understand more about those materials and the consequences of them being in our water or our soils. We have already done the easy stuff: removed the really easy-to-prevent stuff from going into our waters, and now we're left with some hard-to-get-at things like PFAS or microplastics. But it's also going to be on the agenda because people are demanding better. When people realise what's going into their soil or water, they don't want it. That's a good thing. But it's a technical and political challenge. Are we prepared to pay as a society? Because either will pay for it through water bills going up, which is tough, or we will pay for it through increased taxation. In a way the technical issues are important, but easier to crack. Then the political and social issues.

Do you have any advice for academics or the wider society on how they can play an active role in improving the environment to the level that people are demanding?

Yes! Be the change you want to see in the world. That was Gandhi's phrase. I think we often fail to recognise our own power as individuals. Let's take climate for example, all of us are a part of the problem. The way that we travel, what we eat, our homes, the amount of stuff that we have, where our pensions are invested, the people we vote for. All these things affect the climate for better or for worse, and each of us has agency in our own lives and things we can change, like how we get to work where we live, whether we keep the central heating at a certain level, how much stuff we need. My advice would be to recognise your own power and use it.

The second thing I would say to anyone who's interested in creating a better place is, don't do it alone. We also

have the power to build coalitions, whether that's just talking with our own family about how we can step more lightly on the earth, or creating a mass movement that lobbies the government to change their policy. We are more powerful than we think. Influencing others is a really interesting issue. It's often, not the people or the ways that you think that will be most effective, that actually are the most effective. For example, the water companies are doing a lot of research in to how you get people to change their behaviour. Be it reducing water usage or stopping the flushing wet wipes down the loo. Their main finding is that the best way to make an impact on adults is not to advertise to them, but instead to go into school and talk to the kids. Because the kids go home and pester their parents and their grandparents to change. If your kid is telling you to change your behaviour, you're more likely to do it than if some big institution is.

Does that mean the outreach work universities do is actually really important?

Universities are also powerful. I think they're particularly powerful when they are interested, not just in understanding the world, but in changing it, and finding ways to affect the world that are new and innovative. But just having the right answer to the problem is not a sufficient condition to solve it. You also have to go out and build a coalition. You need to tell people that what they need to do to address that problem. I think going out and talking about what you do and the benefits that can have for communities. That's really important.

There's a lot of young people who are passionate about tackling some of the big problems we face. For those focused on environmental issues, what do you think are the best careers that they might pursue?

I think there are many more options now than there were in my generation. One traditional form of influencing nature, climate, and environment is to work for a non-government organisation (NGO). A lot of big NGOs do great work in advocacy education, a whole bunch of things that we need to change the world. Some of them are more influential than others.

If I was a young person thinking about my career, I would go to work with an organisation that I felt was actually going to make a difference. So, I think if you want to go to the NGO world, you need to pick the right NGO. You might also want to think about going into the public service. Government, local authorities, and a whole bunch of other government organisations like the Environment Agency are interesting, and they're always looking for highly motivated and well educated, people to join them. Business can also be a fantastic option. More and more businesses are recognising the importance of sustainability. Both because it's the right thing to do and because it's the smart thing to do. There's a big demand for graduates who understand climate sustainability and nature. And finally, there's academia, if you want to go out and learn more about a problem and find a solution to that problem.

Hidden inefficiencies: The importance of identifying different contributions to overall catalytic activity

Bence Solymosi (University of Leeds, cmbs@leeds.ac.uk)

There are increasing concerns about the adverse health effects, including endocrine disruption, of persistent organic micropollutants. At present, industrial water treatment plants lack the technologies to remove these particular contaminants. The most common experimental approaches use oxidation by ozone or activated hydrogen peroxide, but these suffer from significant drawbacks, including high costs and the introduction of secondary pollution. A promising alternative is to use catalytic systems that require no activation, and thus maximise efficiency.

In these systems, adsorption and truly catalytic degradation are competing processes, but the former is much less desirable as it is limited by adsorption capacity. By separating these contributions and studying the structure-performance relationship that governs their ratio, it is possible to maximise true catalytic activity, which ensures high long-term activity.

Pollutants of emerging concern

Globally, 1 in 3 people do not have access to safe drinking water.¹ Households and the intensive industry and agriculture of developed countries often introduce persistent organic pollutants into their waste streams. The most common sources of these pollutants are pharmaceuticals, personal care products, pesticides, and antibiotics.² Most of these compounds are only partially removed by the seasonal biofilm build-up in water treatment plants.³

There is an increasing number of persistent organic micropollutants that have been shown to have potentially serious negative health effects, including endocrine disruption. Some of these include bisphenol-A, plasticisers, like nonylphenol, and poly- and perfluoroalkyl substances (PFAS). Many of these pollutants have been found in surface waters, groundwater, and drinking water.⁴ The ideal solution to this problem would be to prevent these compounds from reaching surface waters but failing that, there is a pressing need for sustainable, highly active tertiary water treatment solutions.

Challenges of current experimental water treatment methods

The most common experimental tertiary water treatment methods use coagulation-flocculation, adsorption on activated carbon materials, ozonation, advanced oxidation processes (AOPs), and various bioremediation processes.² Some of these methods do not destroy pollutants, just transfer or concentrate them into another phase, while others suffer from high costs and/or slow detoxification. Most AOPs use Fenton chemistry, a metal-catalysed oxidation process that generates powerful, non-selective oxidant radicals from hydrogen peroxide (H_2O_2) (see **Figure 1**). Catalysts are usually dispersed on a support as this stabilises the active component, makes separation easy and enhances activity. An attractive alternative to widely used mineral supports like zeolites are carbon materials as these can offer unique synergistic effects stemming from the excellent electronic and thermal conductivity of graphitic carbons and are generally quite cheap and abundant.

Acid oxidation

AOP research is generally done by using a dye as a model pollutant, and assessing how quickly the dye is removed by a catalytic system. Despite extensive research in this field, it is often overlooked that overall dye removal is made up of adsorption and truly catalytic degradation contributions, which are not equally desirable.

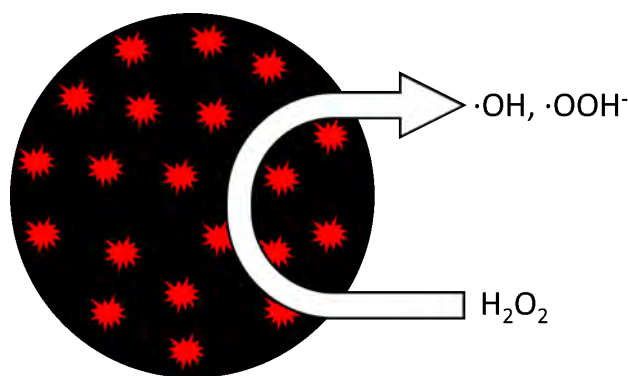


Figure 1. Mechanism of Fenton chemistry; hydrogen peroxide is broken down by the catalyst into reactive oxygen species (ROS), mainly hydroxyl radicals and superoxide radical anions.

A catalytic water treatment system that removes organics predominantly through adsorption will eventually get saturated, at which point a significant drop will be seen in dye removal, and the catalyst will require regeneration. It is therefore important to study the factors affecting the balance between adsorption and true catalytic degradation and to maximise the latter's contribution.

As a demonstration of the importance of this distinction, acid oxidation of the support was used to alter the ratio of adsorption to degradation in carbon bead-supported mixed metal oxide composite catalysts (see **Figure 2**).

The adsorption characteristics of the carbon beads were tested in an experiment where a commonly used azo dye was used as a model pollutant, and both adsorption capacity and kinetics were studied with untreated carbon beads (CB) and oxidised carbon beads (oCB). Morphological characterisation of CB and oCB samples reveals that acid oxidation reduced the surface area by 17.2% while the number of surface oxygen functional groups roughly doubled. As a result of acid oxidation, the overall adsorption capacity was reduced by 36.3%, while the adsorption rate was slowed down approximately 15-fold.

The combination of reduced surface area and a higher concentration of polar functional groups explains why adsorption driven mainly by apolar interactions between graphitic surfaces and the aromatic groups in the dye molecules was significantly hindered.

The saturated adsorbents were then regenerated by consecutive hot water washes, which is a commonly used method for this purpose⁴. Saturated CB released about 3 % of the adsorbed dye, while the same value for oCB is 9.5 %, both of which are very low, and indicate that adsorption would be virtually irreversible in practical applications.

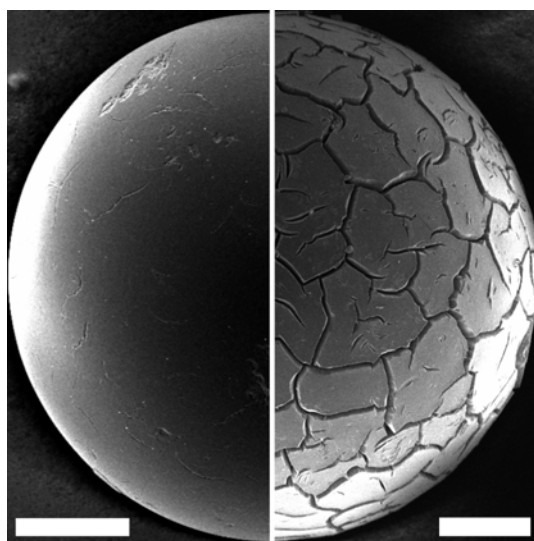


Figure 2. Scanning electron micrograph of untreated (left half) and acid oxidised (right half) carbon beads. Scale bars represent 100 μm .

Catalytic activity

A catalytic organics removal experiment was used to measure the activity of CB and oCB supported catalysts, where ROS generated from H_2O_2 are used to degrade a dye in a neutral aqueous medium. The above differences in surface morphology and surface chemistry translate into surprisingly large differences in catalytic activity. Most research only considers overall dye removal which, in the case of the CB supported catalyst, is 93.4 % of the dye in 60 minutes, compared to 85.9 % in the case of the oCB supported one. However, if overall dye removal is separated into its different contributions, the oCB supported catalyst is observed to be roughly 3-times more active. In the case of the CB composite, only 24.3 % of dye removal comes from true catalytic activity, which raises to 71.6 % for the oCB composite (see **Figure 3**).

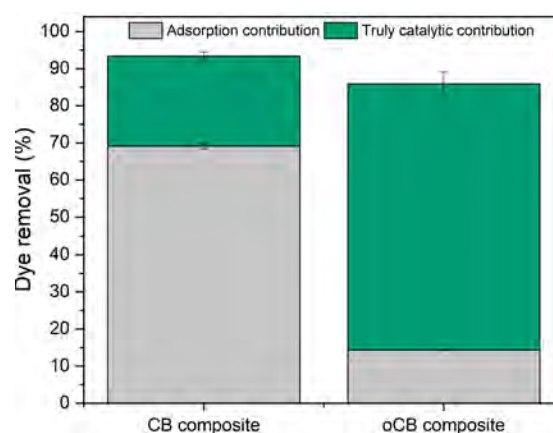


Figure 3. Comparison of different contributions to overall organics removal after 60 minutes between CB and oCB supported catalysts.

Further experiments are necessary to examine how this translates into long-term catalytic activity when the same batch of composite catalyst is reused multiple times. Nevertheless, these results are a strong indication that it is crucial to minimise adsorption of organics in macroscale carbon supported AOP catalysts in order to maintain long-term catalytic activity and reusability.

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Implications of HF exposure to human health during lithium-ion battery fires at disposal sites

William James (University of Reading, Williamjosephjames1999@gmail.com)

Hydrogen fluoride (HF) is an inorganic toxic pollutant produced when lithium-ion batteries (LIB) combust. Direct contact can cause skin irritation, and inhalation at high concentrations can be fatal. With the growing potential for LIB cell technology to help achieve carbon net-zero targets, production is predicted to increase exponentially in the near-future. This brief extrapolates spatiotemporal data of existing landfill fire case studies to model a risk assessment of HF exposure in the event of a fire at a LIB cell disposal site.

Lithium-Ion batteries – a silver bullet?

Electric vehicles are zero-emission, making their LIB cell technology key in meeting global targets for improved air quality and greenhouse gas reduction. However, as demand for LIB cells intensifies, so do the risks to human health. Damaged LIB cells can explode through self-catalysing exothermic reactions (thermal runaway), discharging harmful substances, such as flue gas (CO).¹

Hydrolysis reactions (**Figure 1**) can occur in high humidity environments, potentially producing large amounts of HF. When HF dissolves in water, it produces a toxic aqueous hydrofluoric acid solution.¹ HF is corrosive and can cause serious damage to internal organs if inhaled.² Therefore, it is crucial that the life-cycle implications of LIB cells are considered as the application of this new technology, and its disposal, can have grave implications if improperly managed.

Knowledge on the extent of HF exposure during a large-scale LIB fire is limited; indeed, simulating a fire of such magnitude for data is not economical, let alone environmentally safe. One of the only known experiments using the minimal lethal dose, 50% (TDLo50) found that acute ingestion of 143 mg/kg HF can result in irreversible coronary artery cell death and heart dysfunction.¹

HF exposure can however vary greatly depending on concentration and amount. Clinical evidence, following a 100% HF spill in Korea, has been recorded² and can be used to model the potential risks of high concentration HF inhalation.

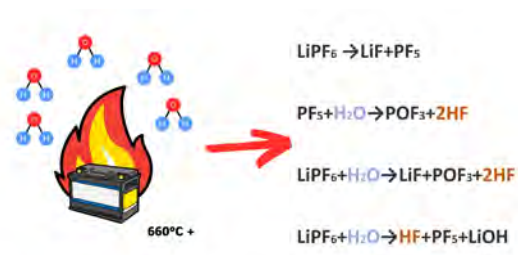


Figure 1. Potential products generated in an LIB fire.¹

Hydrogen fluoride exposure

Clinical results² revealed that proximal location to HF increases the severity of health implications, including the worst-case scenario – fatality. Prominent symptoms of close proximity HF exposure include shortness of breath, bleeding in the lungs, and vomiting.

Fluoride ions (F⁻) are lipophilic and hydrophilic making them highly reactive and easily absorbed into the circulatory system. HF absorption at high concentrations through the lower respiratory tract can increase fluid retention in the lungs causing pulmonary oedema. Moreover, HF can cause dermal corrosion, leading to haemoptysis. Gastrointestinal symptoms occur after HF is discharged from blood vessels into the upper tract, and then into the gastrointestinal tract through capillary circulation. Chronic exposure can lead to skeletal deformation, as approximately 99% of the fluoride not excreted through urine and, after 24 hours, is stored as fluorapatite in bones.²

Symptom severity dramatically decreases with respect to distance and delay in exposure. Following a spill², glucose levels, a blood indicator of HF exposure, were more within the normal range in distal (>1 km away) patients (100.1 ± 20.9 mg/dL) compared to proximal (within 100 m) individuals (113.0 ± 48.5 mg/dL). Also, shortness of breath was shown by 27% of patients admitted to hospital earlier on, compared to only 14.7% in late patients. Symptoms in late patients were not severe enough to need gluconate inhalation therapy to treat the respiratory damage caused by the HF exposure². Indeed, gaps in the clinical report means further research is necessary. For example, atmospheric measurements were not taken systematically and are likely inaccurate, meaning exact concentrations of HF were uncertain at the time.² Therefore, whilst sociodemographic data, such as age and gender were recorded, a comprehensive investigation is necessary to

establish an extensive treatment plan dependant on the age and existing health conditions of those affected by HF exposure. Whilst adults may be involved in the immediate proximal emergency response, children living in local residential areas are potentially more susceptible to HF exposure and treatment may be more urgent.

LIB fires and the extent of HF exposure

A single LIB in an enclosed room under standard conditions (25 °C and 1 atm) will produce 10-100 ppm HF in the event of an explosion. Assuming 100% atmospheric absorption, exposure time will span one day.¹ Yet, real-life disposal site fires can last from months 3 to years 4 and broadcast plume smoke containing dioxins and other toxic materials to local communities many kilometres away from the source.^{3,4} Disposal sites could store thousands of cells, which can potentially generate fatal concentrations of HF in the event of a fire. As global temperatures increase with climate change, the hotter temperatures may exacerbate the probability and risks of thermal runaway reactions in damaged LIB cells. This has grave implications for low- to middle-income countries typically located in hot, arid subtropical regions that may import and dispose of batteries for a source of domestic income. Under-funded waste management programmes may find thousands of LIB cells improperly disposed of in landfills that poorer communities depend on for their livelihoods⁴, putting human life at greater risk of HF inhalation during a fire. Notably, developed countries with wet climates such as Canada are just as at risk; PF₅ hydrolysis, which produces HF, is more likely in high humidity environments (**Figure 1**). Whilst severity of HF exposure decreases with time and distance from the source, risk assessments should consider ambient conditions such as wind speed and direction when assessing disposal site locations, to mitigate the risks of exposure to local communities. Optimal site locations would be away from residential areas; determining the dominating wind direction would also help in ensuring sites are located where plume smoke would travel away from populated areas. GIS systems can be used to predict plume trajectory^{3,4}, and could therefore be used to map out potential evacuation plans and plot medical emergency response sites in areas likely to be heavily affected by HF exposure.

Preventative measures

Risks of LIB cell combustion can be reduced by using high-power ultrasonic waves to delaminate and deactivate any active materials in the battery's electrodes⁵ (**Figure 2**). Yet, electrode deactivation may not eliminate the risks of combustion, as external heat sources could ignite electrolyte leaked from damaged cells. Therefore, disposal methods, such as recovery and recycling, would ensure waste batteries are disassembled and repurposed for further use. Battery components are either chemically extracted or physically removed and are processed based on their possible uses in other systems such as streetlights and other energy storage devices.⁶ By screening each battery, damage can be

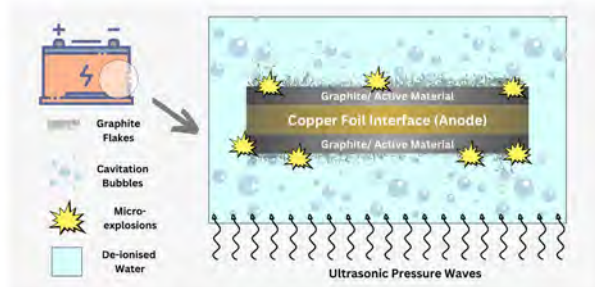


Figure 2. Diagram visualising Ultrasonic Cleaning of an LIB cell (Adapted version from⁵).

identified, and appropriate handling processes can be employed, significantly reducing the probability of fire accidents, and ultimately the chances of HF generation and exposure.

Conclusions

LIB cells are an emerging green technology that have the potential to help reach decarbonisation goals. However, HF exposure during a LIB cell battery fire can have grave health implications if inhaled. LIB cell disposal site locations and the ambient environmental conditions must be carefully considered to protect local communities that could be exposed to HF in case of a fire accident. Pre-screening and deactivating batteries can help prevent the risks of combustion. The gap in clinical sociodemographic knowledge regarding HF exposure must be addressed to ensure proper medical responses in the event of bodily contact with HF. This includes considering age, sex, and other possible existing health problems that may exacerbate exposure.

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Synthetic microfibres – how textiles can pollute waterways, organisms, and food

Gemma Milner (University of Reading, Gemma.lou.milner@gmail.com)

Plastic pollution is an ongoing worldwide issue, with a multitude of sources and harmful impacts. This Environmental Brief focuses on the sources and impacts of synthetic microfibres (MFs).

Globally, there is an awareness of plastic causing harm in different habitats, but research into MF impacts as a form of plastic pollution is novel. Microfibres are usually defined as <5mm in diameter.¹ These can have natural or synthetic origins, but this brief will focus on synthetic.

Example MFs include polyester, acrylic, polypropylene, nylon, and polyamide.^{1–4} Synthetic MFs are an anthropogenic pollutant that are mostly shed from textiles, like clothing, during production or laundering^{1–7}. Over 40 million tonnes of synthetic MFs are mass produced annually, as textiles, for the demands of the fast fashion clothing industry, making anthropogenic behaviours as one of the largest sources of this pollutant.^{2,3,6} Polyester is the most commonly used synthetic MF globally.⁴

MFs have land-based sources, and these fibres become pollutants when they enter pathways like Wastewater Treatment Plant (WWTP) effluent, or discharge from washing machines, entering the oceans as seen in **Figure 1**.⁵ Recent research has suggested that deep sea sediments can accumulate MFs as degradation rates slow down due to lack of UV.⁴ Another pathway for these pollutants is ingestion by organisms.⁵

MFs have the potential to cause harm to organisms within the environments they pollute, an issue accelerated by a rising human population.^{5–7}

Impacts on wildlife and plants

MFs are slow to biodegrade; aquatic organisms struggle to digest MFs, which they mistake for food, and MFs will remain in their tissues, or digestive tracts, and cause damage.^{2,5,6} Some studied adverse effects include gut damage, disturbed metabolism, alteration of feeding as stuck MFs make organisms feel full, and tissue and DNA damage and necrosis.²

MFs affect more than aquatic wildlife, as polluted waterways can be used in terrestrial agricultural applications, such as crop irrigation.¹ This can pollute crop soils with MFs, affecting soil organisms and plants which absorb these MFs.¹ However, there is limited research on how plants are impacted despite crops being a product for human consumption. Ingestion as a pathway for MFs harms receptor organisms. For example, MF bioaccumulation can occur through trophic levels, like **Figure 2**.⁶

Impacts on human health

Humans may ingest MFs from dietary habits like eating plants with MFs from irrigation, fish with MFs from bioaccumulation, or drinking water. MFs can damage tissues in humans, as ingestion allows MFs to travel to tissues or enter the circulatory system.^{6,8} Research has identified that people who struggle with Inflammatory Bowel Disease (IBD) have a higher concentration of MFs

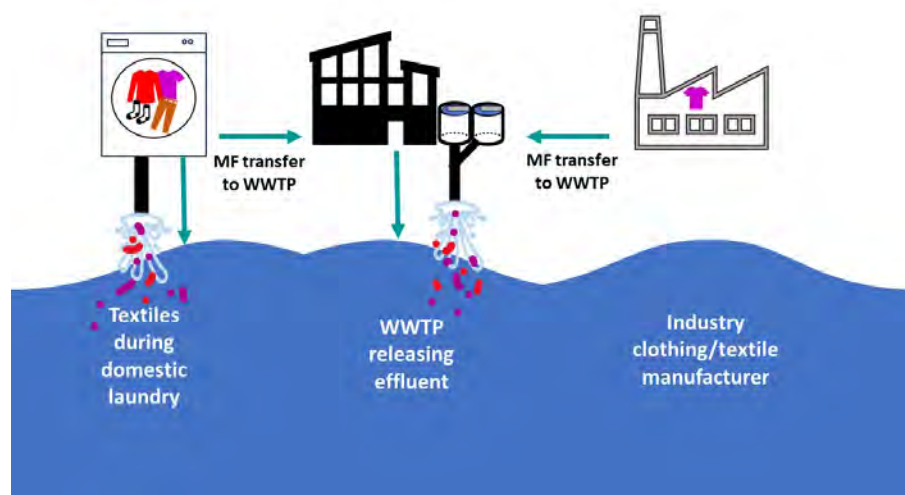


Figure 1. Graphic showing sources of MFs and how they enter the marine environment.

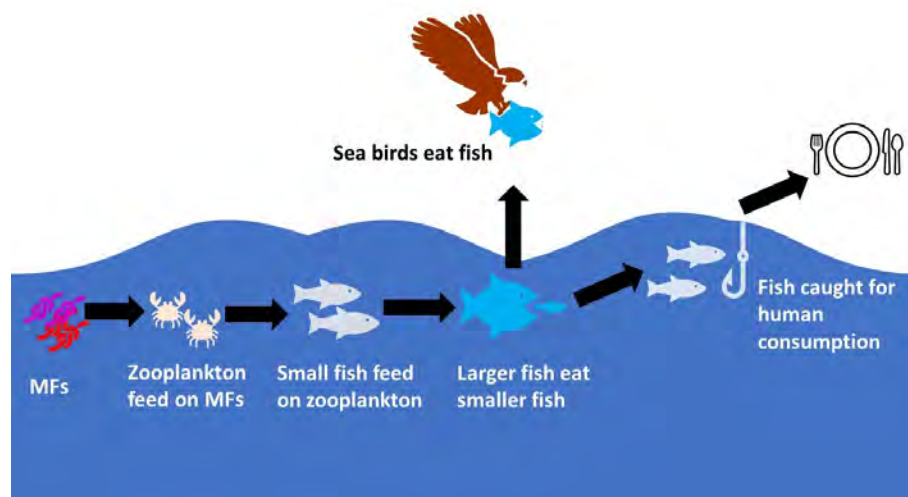


Figure 2. Graphic showing how MFs can travel and accumulate via food chains. Humans are intertwined in this through dietary choices.

in their faeces. MFs causing inflammatory responses occurs in some organisms.⁸ However, there is little research investigating human health impacts from MF exposure.

Risk mitigation

Risk mitigation is critical to reduce potential harm to organisms and ecosystems.³ Individuals may help by making conscious shopping choices, as MFs with a lighter dye colour will shed less.^{6,7} Reducing wash frequency, or using gentler cycles, can ease mechanical stress on MFs to reduce shedding. During the wash cycle, consumers can collect shed MFs with a fibre catcher.⁷ However, the clothing industry should share the responsibility due to producing the pollutants. Industries can use fibre impact assessments to better understand the environmental impacts of materials.⁷ This strategy could be used alongside improved textile design, as the structure, weave method, dye colour, and more, have impacts on MFs shedding levels.^{3,5,6,7}

From another industry perspective, it is known that filters in domestic washing machines, or in WWTPs, are not designed to capture MFs.⁵ Although consumers could use fibre catchers, design of appliances and WWTP filtration should focus on ultrafiltration to catch MFs before they enter other waterways, as this has been effective in some WWTPs.^{3,5,7} Additional measures of reducing risks include remediation, such as extracting MFs directly from sewage before reaching other waterways.⁵ Some mitigative methods can be incorporated into legislation, like the Plastics Treaty UNEA 5.2, which seeks to end plastic pollution.³

Conclusion

Synthetic MFs cause acute harm to wildlife and human health as they enter pathways, like the ocean, irrigation water, ingestion, and more, and are able to bioaccumulate via trophic levels. Effects are better known in aquatic organisms, but further research is needed into the marine environment and how atmospheric deposition is involved.³ Research suggests that higher MF concentrations in humans can lead to

diseases, yet research is limited for other harmful effects.⁸

Solutions for risk mitigation can be implemented at consumer and industry levels, but governments need more legislative strategies like the Plastic Treaty, or better engineering like ultrafiltration. Synthetic MF pollution will remain until solutions are more commonly used.

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Upcoming meetings

Circular Chemistry: Carbon Capture and Storage

Where: The Royal Society of Chemistry, Burlington House, London, W1J 0BA

When: 9th September 2024, 9:30-17:30

Synopsis

This meeting, jointly coordinated with the Applied Materials Interest Group, aims to provide an opportunity to learn about:

- Techniques and processes in development for the capture and storage of carbon dioxide.
- Uses for captured carbon and storage solutions.
- Energy specific applications and processes of carbon capture and storage.

- Other natural mechanisms and potential impacts of carbon capture and storage.

Registration

Registration details tba.

Registration includes:

1. Attendance at the sessions
2. Refreshments throughout the meeting
3. Lunch and networking session.

The Place of Chemistry in a Doughnut Economy

Where: The Royal Society of Chemistry, Burlington House, London, W1J 0BA

When: 14th October 2024, 11:00-16:30

Synopsis

How can we meet the needs of society while staying within the ecological boundaries of our planet? This ECG event will include a discussion coming from “provocateurs” on this topic followed by a workshop engaging chemists, policymakers, community members and other experts. This meeting will be run as a hybrid event.

Registration

Register here: <https://tinyurl.com/ynmu9m78>

RSC members: £50

Non-members: £70

Student rate (members): £35

Student rate (non-members): £55

Online attendance: 30% off above rates.

Air Quality in the 21st century

Where: The Royal Society of Chemistry, Burlington House, London, W1J 0BA

When: 9th December 2024, 10:00-17:00

Synopsis

Building on the success of the Monitoring Ambient Air conference series, this event will present an update on a range of relevant topics, providing a broad and up-to-date survey of the measurement, regulatory and scientific issues affecting air quality. The conference will be held in collaboration with DEFRA's Air Quality Expert Group (AQEG) with a number of presentations focused on the group's recently published reports.

Abstract Submission

A call for abstracts will be announced in September 2024, where we will invite delegates to present their latest research as either a platform presentation or as a poster.

Registration

Registration details tba.