

July 2019

ECG *Bulletin*



21st Century Chemistry: Disposing of our Nuclear Legacy. This edition features a report on our Distinguished Guest Lecture and Symposium held on 27th March 2019. Professor Melissa Denecke (IAEA) was our Distinguished Guest Lecturer.

Meetings. Valerio Ferracci reports on the ECG Early Careers Meeting and Roger Reeve on Latest Advances in the Analysis of Complex Environmental Matrices. We await #EnvChem2019: Chemistry of the Whole Environment Research Meeting on 15th October, and a Nantwich Museum exhibition celebrating Joseph Priestley and the International Year of the Periodic Table.

Environmental Briefs. Jasmin Urwick discusses microfibre release and environmental contamination, and James Day the toxicity and persistence of brominated flame retardants.

Also in this issue. Zoë Fleming shares with us how to engage audiences using a dry ice ocean acidification demo; Rowena Fletcher-Wood and Laura Newsome review two new books; we share the winning #EnvChem posters from the RSC Twitter Conference; Steve Leharne tells us about his career and interests; and Tomás Sherwen reports on new and promising findings in atmospheric halogen chemistry.

Contents

ECG Interview: Steve Leharne	3	
Book Review, by Rowena Fletcher-Wood	4	
Book Review, by Laura Newsome	5	
Meeting Report: Early careers researchers meeting, by Valerio Ferracci	6	
Meeting Report: Latest advances in the analysis of complex environmental matrices, by Roger Reeve	7	
Meeting Report: Clay minerals in the natural and built environment, by Laura Newsome	10	
Meeting Report: Twitter conference poster competition winners announced	12	
Meeting Report: Oxford Green Week, by Rowena Fletcher-Wood	14	
Meeting Report: 21st century chemistry: Disposing of our nuclear legacy, by Tom Sizmur	16	
Article: An increasing role for iodine in the atmosphere, by Tomás Sherwen	19	
Article: RSC journal highlights	21	<i>Cover image: Conceptual Image Of A Radioactive Nuclear Waste Barrel Or Drum Near Water In The Countryside / Shutterstock</i>
Public Engagement How To: Ocean acidification experiment, by Zoë Fleming	22	
ECG Early Careers Environmental Brief: A sea of synthetics: Microfibres in the environment, by Jasmin Urwick	23	
ECG Early Careers Environmental Brief: Brominated flame retardants: exposure routes, human impacts, and status, by James Day	25	
Upcoming meetings and exhibition	27	

ECG Bulletin

ISSN 1758-6224 (Print) 2040-1469 (Online). Published by the Royal Society of Chemistry's (RSC) Environmental Chemistry Group (ECG), Burlington House, Piccadilly, London W1J 0BA, UK.

See www.envchemgroup.com for articles published in the ECG Bulletin since 2007.

Executive Editor

Rowena Fletcher-Wood, Science Oxford

Commissioning Editor

Tom Sizmur, University of Reading

Production Editor

Clare Topping, Northampton General Hospital

Editors

Steve Leharne

Roger Reeve

Glynn Skerratt

Valerio Ferracci, Cranfield University

Laura Newsome, University of Exeter

Laura Alcock

Proofreaders

Rupert Purchase

Clare Topping

Environmental Chemistry Group

Website: www.envchemgroup.com

Twitter: @RSC_ECG

Facebook: RSCEnvironmentalChemistryGroup

Membership details: www.rsc.org/ecg

Chair: Tom Sizmur, University of Reading
(t.sizmur@reading.ac.uk)

Vice-Chair: Zoë Fleming, University of Leicester
(zf5@leicester.ac.uk)

Honorary Secretary: Glynn Skerratt, University of Staffordshire
(glynn.skerratt@gmail.com)

Honorary Treasurer: Valerio Ferracci, Cranfield University
(v.ferracci@hotmail.co.uk)

This and previous issues of the ECG Bulletin are available without charge at www.envchemgroup.com and www.rsc.org/ecg

Bulletin © RSC – ECG 2019

Registered charity number 207890

The ECG Bulletin is printed on paper made from wood pulp sourced from sustainable forests, and is suitable for archival storage. This issue of the ECG Bulletin was printed by Prismatic Print Solutions, www.prismatic.co.uk; 01444 239000.

All articles represent the informed view of the author(s) at the time of writing, not that of the ECG or the RSC. They were not peer reviewed and no guarantee regarding the accuracy or otherwise can be given by the author(s), the ECG or the RSC.

The *ECG* Interview: Steve Leharne

Steve Leharne, Professor Emeritus of Environmental Chemistry at Greenwich University.

What inspired you to become a scientist?

It was my school chemistry teacher, Mr Bennett, who first really interested me in chemistry. He was extremely inspirational, very calm and clearly believed that shouting to get the class to listen to him was a poor pedagogic approach.

How did you come to specialise in environmental chemistry?

It was, more than anything else, accidental. When I started my chemistry degree at Cardiff University back in 1970, I had a pretty poor understanding of environmental issues. We did, as part of the course, a short unit on radiochemical waste – and that was it. When doing my PhD (looking at plasticised PVC systems), I became increasingly interested in environmental issues and started attending Friends of the Earth meetings. It was when I started working as an analyst for a fine chemical company in South Wales that I started undertaking environmental analysis. This included measurements of workplace atmospheric methane and ammonia levels, and phenol run-off levels in a nearby stream. This, coupled with a healthy dose of self-directed learning, led ultimately to my academic position in environmental chemistry.

Could you describe your current job?

I'm retired now, but for 32 years I was employed at the University of Greenwich and its predecessor institutions. Initially, I taught units in Environmental Chemistry, and my research was focused on acid precipitation and lead pollution. However, because of my interest in colloid and surface chemistry, I gravitated towards surfactant facilitated remediation of contaminated soils and subsurface systems. From there, I became interested in the fate of non-aqueous phase liquids in soils and aquifers. My teaching reflected these interests, and I delivered units in contaminated land and contaminant hydrogeology.

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

Don't make the mistake of thinking that only some limited aspects of chemistry are important for the

practice of environmental chemistry. For example, I see increasing scope for the use of computational quantum chemistry for elucidating a variety of parameters that are important in environmental chemistry. These could be rate constants for very slow reactions or partition constants for emerging contaminants, for example.

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

We need to understand how environmental chemical processes may change as the climate changes. Microplastics, say, are clearly emerging as an important concern. A key issue is how we communicate environmental concerns to a sceptical public.

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

Without a doubt, it has been the friends I have made; I have enjoyed watching the career progress of those young researchers who have been trained in our laboratories.

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

No idea!

And what do you do when you are not working?

I love the outdoors – be it walking in the Lake District, mountaineering in the Alps, rock climbing in North Wales, canoeing in Canada or trekking in the Atlas mountains in Morocco.



Book Review

Hook your audience

Rowena Fletcher-Wood (Science Oxford, rowena.fletcherwood@gmail.com)

The remit of *Hook Your Audience* by Paul McCrory is clear from the outset: it is a book for interactive informal educators in any field, although the author is a scientist, and thus his anecdotes and examples are scientific. The text aims to collate “techniques [that] aren’t written down anywhere, in detail, for educators to follow” and introduce a shared language.

Teaching fellows and outreach workshop/stall providers could equally benefit from many of the tips, such as his section on the “lure of live experiences” that discusses how to draw your audience into dialogue and co-create a discovery-based learning experience. The guide is not a rulebook, rather it provides examples, suggestions, and invites the readers to reflect upon the success or failure of extreme practices.

The Presenter

Although the book is called *Hook Your Audience*, substantial page space is given to you, the presenter. Managing yourself is easier than managing an audience, and it is through you that the content is accessed.

McCrory includes tips on stage presence that vary from creating vulnerability (and thus likeability) to heightening and exaggerating your personality (“If you don’t feel like a cartoon character hamming it up, you’re not amplifying your emotions enough”), and analysing how others see you.

Elements that could be afforded more coverage include use of space and psychological devices such as a “funny spot” or “storytelling spotlight”, as well as voice manoeuvres, and manipulation of volume. The advice to video yourself is sound, but novice presenters will require more guidance on what to look for when they do.

New and refreshing content included the various reasons you may not be able to answer a question (e.g., “nobody knows!”), or the truth that style and substance do not have to be mutually exclusive. Most satisfying is McCrory’s undaunted definition of that indefinable quality – charisma. Charisma “relate[s] to how expressive, confident, powerful and present you are”, he says, doing exactly what the book sets out to do: sweep the mystique under the carpet and replace it with down-to-earth advice.

The Audience

McCrory powerfully advocates for listening to one’s audience. He evokes strong imagery such as “audience

barometers” – those expressive members of the group that a presenter may want to watch. Even silent audiences constantly communicate via nonverbal cues. This provides the presenter with power: power to select volunteers who are keen, but not too keen; power to bully them into too many calls-and-responses; power to manipulate their questions and answers to move forwards, or be brave and see where they go. The challenge of the performer is striking the balance between what the audience want (interaction) and what you know they need (structure, narrative arc). McCrory offers one key strategy for doing this through the use of internal hooks (the pure ‘interestingness’ of your content) and external hooks (tricks and stunts to keep the audience engaged).

I do not agree with all the points the author makes. He advocates the use of rhetorical questions to get the audience thinking, but unanswered questions can be a Chekhov’s gun on stage, distracting an audience and providing an unsatisfactory conclusion when they’re never answered. Equally, critical advice could save novice performers from making a disastrous faux pas when selecting volunteers: if you’re using an adult, obtain their permission (first, if you can). Picking the wrong teacher to tease on stage, for example, can weaken their authority in the eyes of the children and cause problems later.

Evaluation

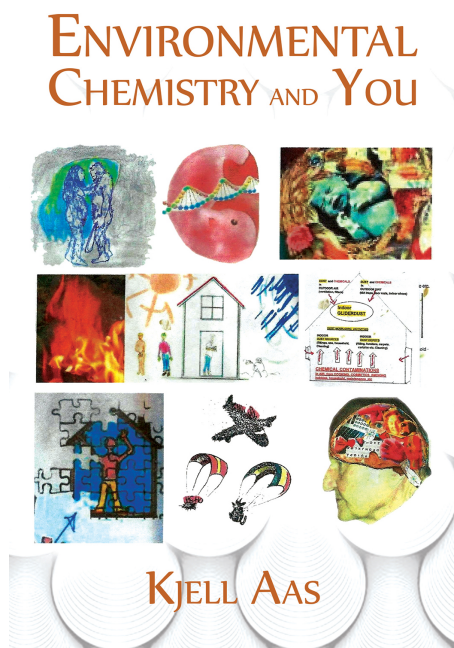
Perhaps my favourite part of this book is McCrory’s head-on dissection of misconceptions about the value of one-off educational experiences and the supposition that anything performed on stage is insincere. Many educational experiences, especially in schools, assume that all important outcomes are measurable, and thus neglect effective outcomes such as attitude changes and motivation. “Most schools have become victims of the tyranny of the measurable”, McCrory betrays: “if you can’t put a number on it, you can’t improve it”. This can also lead to presenter disillusionment – but it should not. Informal education, McCrory explains, can be successful precisely because it diverges from negative formal educational experiences, encouraging engagement and question asking rather than question answering. Nevertheless, he warns of bias: it’s tempting to judge your successes by the forms filled and audience members who interact – but what about the silent ones?

Summary

I reviewed an early draft of this text, and some of the writing needs tightening up, but other sections were excellently written, peppered with personal anecdotes that brought it to life and imaginative, active chapter headers. I look forward to the final edition that is due for publication later in 2019.

Environmental chemistry and you

Environmental Chemistry and You, Kjell Aas, 2018,
Austin Macauley Publishing, ISBN-10: 178693681X,
ISBN-13: 978-1786936813



Meeting Report

Environmental chemistry of water, sediment, soil and air: Early career researchers meeting

Valerio Ferracci (Cranfield University, v.ferracci@cranfield.ac.uk)

Thirty two early career scientists from all over the globe convened in Burlington House on 21st November 2018 to present their research and hear about career opportunities available to environmental chemists.

Following an introduction by the organiser, Dr Tom Sismur (University of Reading), the first oral presentation was given by **Gagan Matta** (Gurukula Kangri University, India). Her work focused on water quality indexing for the river Ganga in Himalayan India, and raising awareness amongst the wider population with a view to improving conservation strategies for the river system. The next speaker was **Jay Bullen** (Imperial College London), who described the development and deployment of low-cost, portable instrumentation capable of discriminating between toxic and non-toxic forms of arsenic in groundwater. After this, **Marijke Struijk** (University of Reading) reported on the production, characterisation and application of clay-based absorbent materials for the removal of heavy metals from wastewater. The morning session closed with the keynote talk by **Laura Woodward**, Careers Specialist at the Royal Society of Chemistry. This presentation covered the fundamentals of job hunting, from where to look for jobs to writing a CV and preparing for interview. Ms Woodward stressed how candidates should focus on careers that they are genuinely interested in, as well as critically evaluating the transferrable skills acquired during their scientific training.

After lunch, **Alfonso Rodríguez-Vila** (University of Reading) gave an account of his work applying biochar to the soil from a reclaimed mine in Galicia (Spain), which was found to improve soil properties and promote plant growth. This was followed by **Navya Cherian** (Mahatma Gandhi University, India), who presented her work on the bioaccumulation of mercury in rice plants, based on field work in the coastal region of Kerala (India). **Siti Syuhaida Mohamed Yunus** (University of York) followed this with a presentation examining the fate of unused or expired medicines in and around York using Life Cycle Assessment.

Following a coffee break and the poster session, **Angel Hojatisaeidi** (London South Bank University) discussed her early results in developing and characterising a new class of sorbent materials for CO₂ capture based on boron nitrate. **Natasha Easton** (University of Southampton) then gave an account of measurements and characterisation of particulate matter from port-related activities in multiple sites across Southampton. The last presentation before the final keynote was delivered by **Tomás Sherwen** (University of York) on the application of machine-learning techniques to improve the accuracy of sea-surface iodide concentration measurements.

In her keynote talk, **Dr Monica Felipe-Sotelo**, Lecturer in Radiochemistry and Analytical Chemistry at the University of Surrey, gave an account of her career in environmental chemistry to date, stressing how every step in her journey has been driven by the desire to work on something with a positive impact on society, as well as by a fascination for the multidisciplinary nature of the field.

The day closed with the award of prizes for best poster to **Angeliki Kourmouli** (University of Birmingham) and for best oral presentation to **Jay Bullen** (Imperial College London), both shown in **Figure 1**.



Figure 1. Angeliki Kourmouli receives the prize for best poster from keynote speaker Dr Monica Felipe-Sotelo (left) and the ECG's Professor Steve Leharne presents Jay Bullen with his prize for best oral presentation (right).

Meeting Report

Latest advances in the analysis of complex environmental matrices

Roger Reeve (Environmental Chemistry Group, rgrreeve@gmail.com)

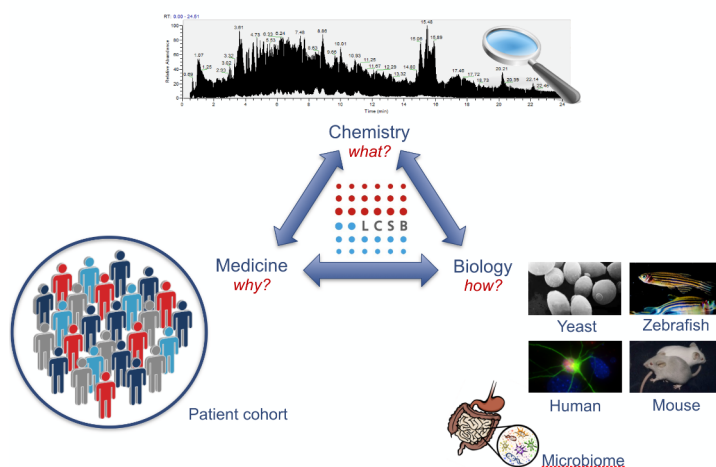
A report from a meeting held on Friday 22nd February 2019 at The Royal Society of Chemistry, Burlington House, London.

Over 60 delegates and speakers attended this one day meeting which was jointly organised by the Environmental Chemistry Group (Dr Roger Reeve), the Separation Science Group of the Analytical Division (Dr Lee Williams), and the Water Science Forum (Professor Graham Mills). It was the fourth in a series of biennial meetings looking at a wide range of instrumental analytical techniques involved in the analysis of environmental matrices, including sampling, clean-up, analysis (often by multi-dimensional chromatographic techniques and mass spectrometry), and computational data processing. Eight presentations were made by representatives from across academia and industry. The keynote lecture was given by **Dr Emma Schymanski** (University of Luxemburg) on the use of environmental informatics to identify unknown chemicals and their effects. There was also an exhibition by instrument manufacturers and laboratory consumables suppliers.

Dr Roger Reeve (Environmental Chemistry Group) opened the meeting, welcomed the delegates and chaired the first session. The first two lectures focussed on highlighting the need for computational techniques in chromatographic data analysis in compound identification and effect prediction. The first was given by **Dr Leon Barron** (King's College London) on 'Mixing

high resolution chemical analysis and machine learning in ecotoxicology for aqueous invertebrates'. Samples from water, fish (tissue and plasma/bile) and invertebrates (whole body) were analysed by liquid chromatography two dimensional mass spectroscopy (LC-MS/MS), suspect screening and machine learning (ML) by liquid chromatography high resolution mass spectroscopy (LC-HRMS), and metabolomics investigation by hydrophobic interaction chromatography (HILIC-HRMS). LC-HRMS was found to markedly aid new compound identification, while ML provided a good prediction of retention time on liquid chromatography stationary phases, which could then be developed into bioconcentration factors. ML algorithms have previously been used to reveal underlying trends for predictions in toxicology, but improvements in the quality and availability of data sets are needed for future development. As such, ML can support toxicological studies, but is no panacea.

Anthony Buchanan (SepSolve Analytical) gave the next talk, entitled 'Enhanced confidence in river water quality monitoring using passive sampling and GC×GC-TOF-MS (two dimensional gas chromatography, time of flight mass spectroscopy) with tandem ionisation'. In this talk, he outlined current analytical challenges, including 'priority' substances and emerging pollutants. He discussed how grab sampling may miss pollution events and, as such, passive sampling may be more suitable. The four week example investigation used a silicone rubber passive sampler for hydrophobic substances



found at eight locations across a river system. Flame retardants, musks, and pharmaceuticals were detected. Gas chromatography was conducted with a non-polar column for the first dimension and a polar column for the second dimension. Mass spectrometry was conducted via fast switching between harder and softer ionisation energies to improve confidence in compound identification, as required by legislation. This produced two MS datasets from a single run with no added analysis time.

After the coffee break, the session was chaired by Dr Lee Williams (University of Sunderland). He introduced **Dr Caroline Gauchotte Lindsay** (University of Glasgow), presenting 'Micro- and nanoplastic pollution of freshwater and wastewater treatment systems'. Dr Gauchotte Lindsay's group has been investigating the size and morphology of plastics including both fibrous and globular nanoparticles. Sediments under investigation were first pretreated, then examined under a scanning electron microscope (SEM) with energy dispersive spectroscopy (EDS). Care had to be taken to avoid particle fragmentation throughout pretreatment processes. Fibres comprised approximately 88% and 95% of all plastic pieces. Characterisation of water samples by Fourier transform infrared attenuated total reflectance spectroscopy (FT-IR) again showed fibres were dominant, although they proved challenging to accurately quantify, with plastics (58% polypropylene and 5% polyethylene) and cellulose (11%) identified, while the remainder was of unknown origin.

hexane/pentafluorobenzoyl chloride. In a second study, automation of the classical technique of liquid-liquid extraction (dispersive liquid-liquid micro-extraction) was used for semi-volatile organic compounds and pesticides.

The morning finished with the keynote lecture presented by Associate Professor **Dr Emma Schymanski** (Luxemburg Centre for Systems Biomedicine) on 'Environmental informatics to identify unknown chemicals and their effects' (see **Figure 1**). European, US and worldwide community initiatives to help connect chemistry and toxicity with environmental observations were discussed. She outlined the need for target, suspect and non-target screening to identify species of interest in rivers and wastewaters, and identified 364 targets in Swiss wastewater using solid phase extraction (SPE) and LC-MS/MS. Suspect screening involved the selection of candidates based on known and calculated physical properties. Several mass spectral libraries were needed to support this work, as each had unique entries. As such, the NORMAN network was set up within the EU for exchanging information, and validating and harmonising data on emerging environmental substances between research groups. Associate Professor Dr Schymanski described using the NORMAN suspect list exchange and its chromatography data bank (Digital Sample Freezing Platform).

Lunchtime provided an opportunity for delegates to network and inspect the sponsors' exhibition. **David Sharpe** and **Guy Jones** (RSC) gave a short presentation



Figure 2. Cape Verde Atmospheric Laboratory (courtesy Dr Katie Read, National Centre for Atmospheric Science, York).

Dr John Quick (ALS Environmental Ltd) continued with 'Exploring the advantages of automated sample preparation and GC-TOF for semi-volatile organic compound and pesticide analysis in environmental waters'. In this talk, he outlined the advantages of automation, including increased accuracy and precision, lower sample volumes, and fewer consumables required with associated benefits in cost and health and safety. For alkylphenols and ethoxylates, a sample was simultaneously extracted and derivatised using

on ChemSpider. This database of chemical information on small molecules amalgamates >250 data sources and is curated to ensure quality representation. It was used by a number of the presenters.

The afternoon session was chaired by Professor Graham Mills (University of Portsmouth). Professor **Alistair Boxall** (University of York) discussed 'Temporal and spatial variations in pharmaceutical concentrations in an

urban river system'. In his work, inputs to the Ouse River system (Yorkshire) were studied across 11 sites, and 41 pharmaceuticals monitored. A detailed model was produced predicting how concentrations varied over time at each of the sites. This model can be successively upgraded as more local details of the river system are introduced. Pharmaceutical monitoring was extended to a global network and correlation of results suggested a greater problem of high concentrations of pharmaceuticals in lower income countries.

Dr Katie Read (University of York) spoke next, introducing 'GC-TOF for remote monitoring – Cape Verde atmospheric laboratory'. Much of the talk discussed problems of atmospheric analysis in a laboratory located in the middle of the Atlantic (see **Figure 2**), despite using standard methodologies. Monitoring covered the whole range of atmospheric constituents from major components to species at parts per trillion levels. Air masses from a variety of origins and effects were observed from Africa, Europe and North America in addition to the pristine Atlantic air masses. Challenges included dust, salt, volcanic rock and corrosion in the aggressive environment. *In situ* measurement and sampling with subsequent laboratory analysis were used. Calibration posed difficulties. Few, if any, methods are available to generate known samples of analytes at the low concentrations needed and in controllable real world matrices. Generation devices (e.g. permeation devices) were used where species were known to be unstable in cylinders (such as ozone/oxygenated VOCs), with a blender to dilute to the specified concentration range. Existing GC-MS and new GC-TOF-MS analytical systems were compared. The results suggested that 50% more ozone was destroyed in

Professor Gary Fones (University of Portsmouth) presented 'Liquid chromatography/quadrupole time of flight mass spectroscopy screening of polar pollutants sequestered by passive sampling devices at the river catchment scale'. The potential for passive samplers used for long-term trend monitoring was discussed. Their advantages include locating sources of pollution and generating more robust time-integrated data compared to spot sampling, or 'snapshot' type grab sampling (see **Figure 3**), which may not be representative of conditions where concentrations of pollutants fluctuate or are not homogeneous. Since achieving legislated detection limits may be complicated when only low volume spot samples are collected, a polar version of the Chemcatcher passive sampler was chosen for polar pesticide analysis at 14 sites in the River Rother catchment system (West Sussex) over a two week sampling period. Liquid chromatographic analysis was used with Quadrupole Time of Flight (QTOF), selected for accurate mass, fragment and isotope information and a high sensitivity coupled with a large dynamic range, allowing 51 compounds to be detected.

The final session of the day was a presentation by **Wai-Chi Man** (ThermoFischer Scientific), introducing the 'Power of ion chromatography with mass spectrometry for polar pesticides in water'. Ion chromatography can be a suitable method for separating highly polar species as well as ionic species in water, including polar pesticides and disinfection chemicals such as haloacetic acids and inorganic oxyhalo- species. Ms Man demonstrated that sensitivity and selectivity could be increased by coupling the chromatograph with a mass spectrometer, whereupon polar pesticides in food and environmental samples could be determined well below Environmental Protection Agency (EPA) regulatory limits with no chemical derivatisation necessary and low chemical noise. She finished by asking whether slow separation of all possible components (including unexpected ones), or more rapid analysis with peak overlap of the main analyte with less likely species was better. The answer depends, of course, on the application, but reminds us of the multiple and sometimes conflicting factors that affect the selection of an appropriate analytical technique.

Synopses were prepared by Roger Reeve, Lee Williams and Graham Mills. The industry meeting sponsors were LECO, JSB, SepSolv Analytical and Shimadzu. Financial support is also acknowledged from Environment Sustainably and Energy Division of the RSC.

Keynote presentation slides are available online:

www.slideshare.net/EmmaSchymanski/rsc-environmental-cheminformatics-to-identify-unknowns-feb-2019

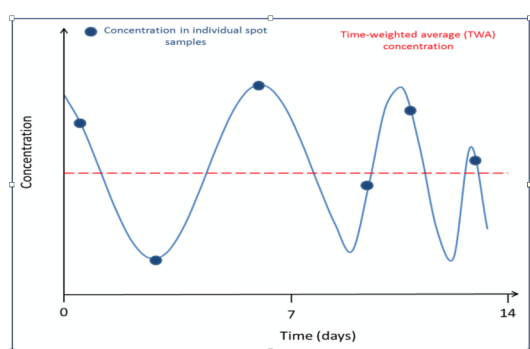


Figure 3. Difference between time weighted and individual spot sample concentrations (courtesy Prof Gary Fones).

this region than predicted by climate models, which may be due to catalytic destruction from natural halogens emitted by sea spray.

Meeting Report

Clay minerals in the natural and built environment: formation, chemistry and applications.

Laura Newsome (University of Exeter, l.newsome@exeter.ac.uk)

This joint meeting between the ECG and the Clay Minerals Group, an interest group of the Mineralogical Society of UK and Ireland, was held on 17th May at Newcastle University, and consisted of an exciting programme of talks and posters to highlight how clay minerals affect the chemistry of the environment.

The meeting started with a keynote presentation from **Professor Josef Breu** (Universität Bayreuth), who took us on a journey through his career in clay minerals, from his initial interest sparked by fishing trips, through to his development of synthetic hectorite, which can be spray coated to make a perfect 2D thin film with applications as nanocomposites, catalyst supports and microporous hybrid materials.

The following talk by **Kirill Shafran** (BYK additives) described the development and applications of Laponite®, a synthetic magnesian smectite clay. It was invented by Dr Barbara Neumann in 1962 and, to this day, is used in agriculture, surface coatings industry and personal care products. It is said to have a benign ecological and biological profile, breaking down in the environment to its constituent parts, magnesium, lithium and silicates.

The next speaker was ECG committee member **David Owen** (Treatchem Ltd), who provided a perspective on the industrial application of clay minerals. This included the use of kaolin in the paper industry (for improved brightness and smoothness) and the use of bentonite to help remove contrary products from pulp. He illustrated his talk with examples from his career of troubleshooting issues that involved a diverse range of fields such as impurities causing problems with paper quality and working with effluent treatment plants.

Nikolaos Apeiranthitis (Durham University) described how clay minerals play an important role in the recovery



Figure 1. The Urban Sciences Building at Newcastle University.

of oil from reservoir rocks, and how their presence might allow low salinity fluids to be used as the injectate.

Laponite®, a synthetic magnesian smectite clay ... was invented by Dr Barbara Neumann in 1962

This was followed by two talks on using Fe-bearing clay minerals to treat emerging contaminants in wastewater treatment plants. **Wojciech Mrozick** (Newcastle University) explained how redox-active reactive clays could remove micropollutants such as pharmaceuticals or endocrine disruptors from wastewater via oxidation or reduction mechanisms.

Panagiota Adamou (Newcastle University) showed that while peroxide treatment caused a slight reduction in the amount of bacterial DNA in wastewater, combined

peroxide and Fe-bearing clay minerals (nontronite) treatment of wastewater produced a much bigger decrease. In particular, a notable reduction in the observation of three antimicrobial resistant bacterial genes. Panagiota was awarded the prize for best student presentation.

After lunch, **Professor Susan Stipp** provided the second keynote presentation. Her work exploring the structure of clays aims to understand their properties in order to elucidate how chemicals behave once released into the environment. For example, clays may control the fate of pesticides in agriculture, sorbing and transforming toxic compounds, adsorbing nutrients which support plant growth, and remediating contaminants in some cases, such as the application of cationic clays including green rust.

Following the keynote, **Harry Brooksbank** (Newcastle University) talked about his research into Fe-bearing clay minerals to treat nitroaromatic contaminants.

In a completely different environmental application, **Amy Lewis** (University of Sheffield) described some preliminary findings from her research on how basalts can be applied to soils to enhance natural weathering and remove carbon dioxide.

Bhoopesh Mishra (University of Leeds) gave an invited talk on his work using X-ray absorption spectroscopy to evaluate how clay minerals form and their environmental impacts. For example, the formation of aluminium and iron colloids in lakes can control phosphorus cycling, and organic matter coated iron or manganese oxides and clays are the main sink for mercury in surface waters.

Combined peroxide and Fe-bearing clay minerals (nontronite) treatment of wastewater produced a bigger decrease in the observation of three antimicrobial resistant bacterial genes.

The last presentation of the day was given by **Jing Zhang** (University of Manchester) on the behaviour of molybdenum in iron-rich environmental systems such as acid mine drainage.

Many excellent posters on clay minerals were presented at the meeting, with relevance to the oil industry, antimicrobials, remediation and architectural conservation. The prize for best

student poster was awarded to **Jeffery Paulo Perez** (GFZ German Research Centre for Geosciences).

Overall, it was a thoroughly enjoyable day, with plenty of questions from the audience and opportunities for discussions and networking, and very interesting to hear about environmental chemistry from a mineralogical perspective. While clay minerals consist of very small particles, their importance should not be overlooked.

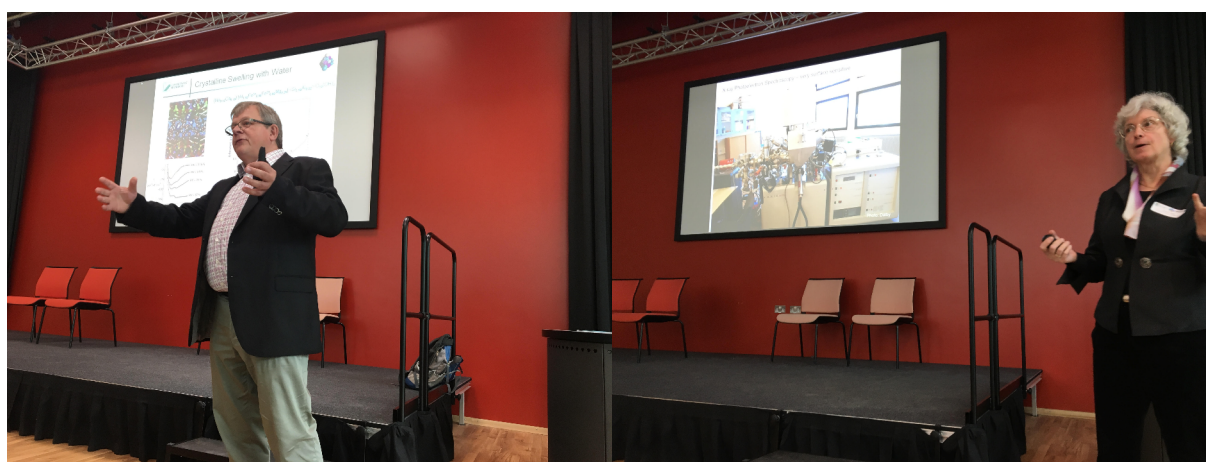


Figure 2. Professor Breu (left) and Professor Stipp (right) giving the keynote presentations.

Meeting Report

Twitter conference poster competition winners announced

The ECG sponsored two prizes for the environmental chemistry poster competition (#RSCPoster) at the Royal Society of Chemistry (@RoySocChem) Twitter conference on 5-6th March 2019.

Rhona Savin (@RhonaSavin) won best poster for her work on the modification of camphene for the synthesis of a renewable polyacrylamide. This addition polymer, whilst unlikely to be fully biodegradable, contains a breakable amide bond that produces a precursor of the original monomer, making it entirely recyclable. Twitter questions focussed on the sustainability, industrial applications and end-of-life pathways for the material. For the full discussion, see the Twitter entry at <https://twitter.com/RhonaSavin/status/1102884841475981313>.

The runner up was **Hannah Walker** (@hlwalker28) who is interested in gaining a better understanding of reactive oxidised nitrogen species in the UK's rural atmosphere. In her work with the Centre for Ecology and Hydrology (CEH), she is monitoring NO_y species that can act as precursors of other pollutants, including tropospheric ozone. Questioners asked about the sources and hazards of NO_y, from human health to eutrophication, and techniques employed to predict reactions and detect particular species. For the full discussion and further questions check the Twitter entry:

<https://twitter.com/hlwalker28/status/1102865240608387073>.

This conference is a 24-hour online event held entirely over Twitter to bring members of the scientific community together to **share** their research, **network**, and **engage** in scientific debate.

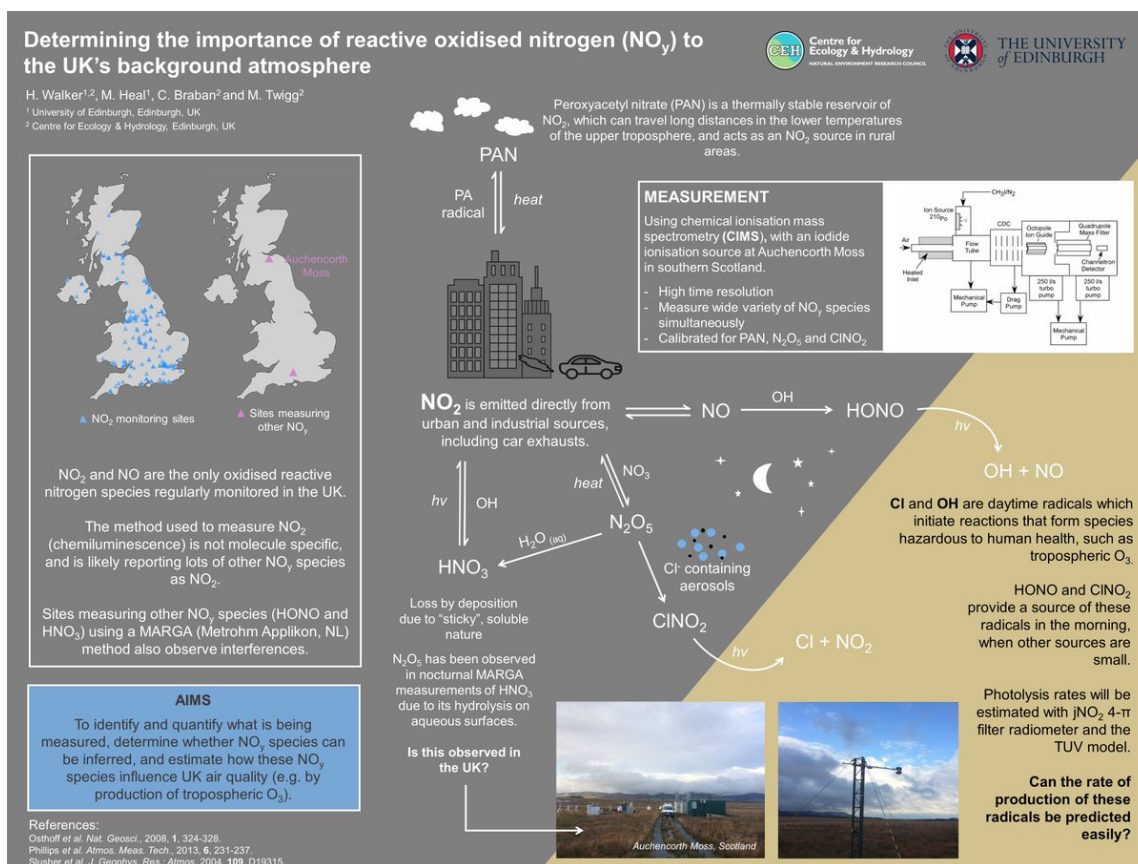


Figure 1 Runner-up poster by Hannah Walker (CEH-University of Edinburgh)

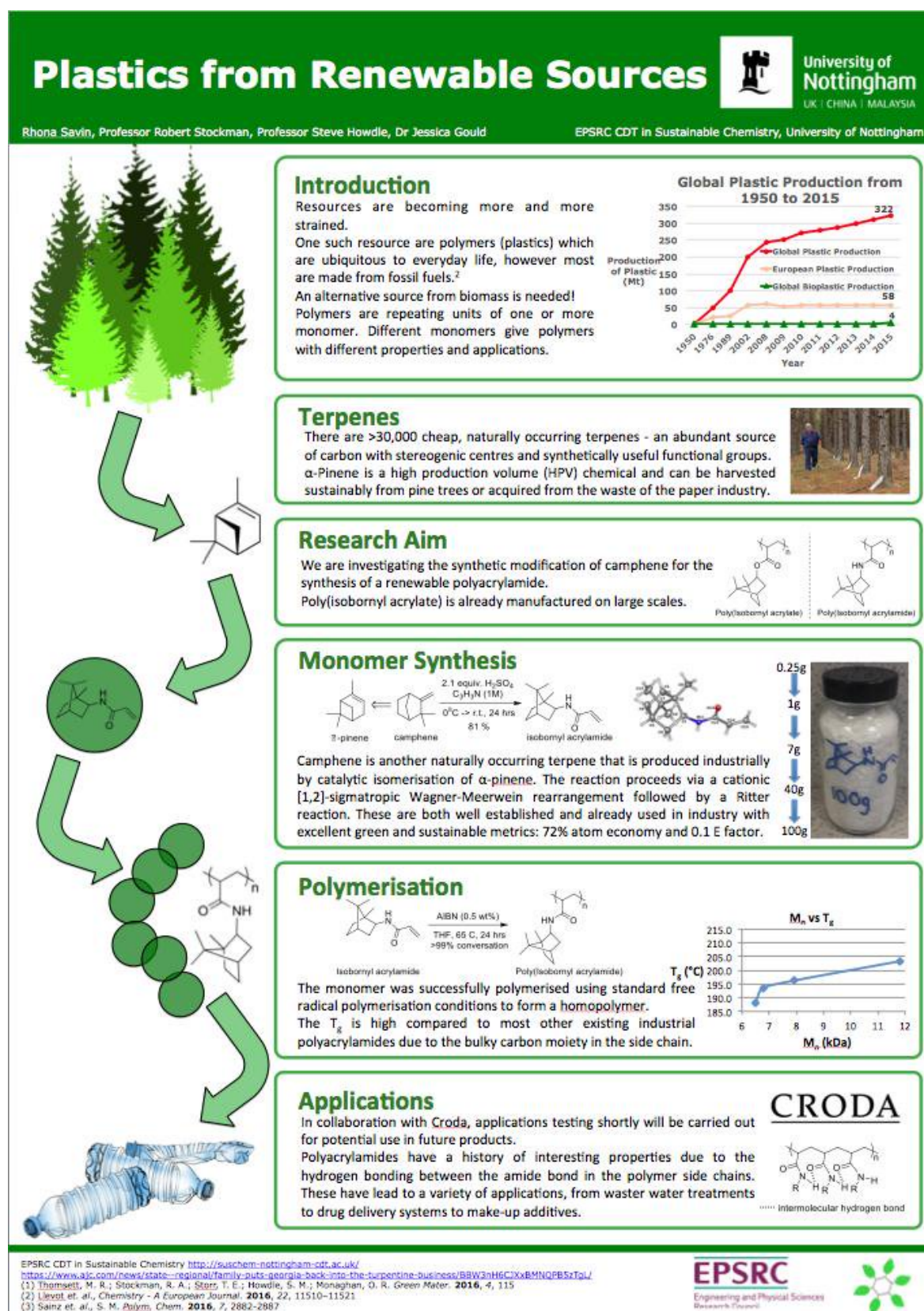


Figure 2. Winning Poster by Rhona Savin (University of Nottingham)

Article

Oxford Green Week

Rowena Fletcher-Wood (Science Oxford, rowena@scienceoxford.com)

Oxford Green Week, which ran from 8-16th June, saw pop-up green events appearing across the city, from recycling to food projects, wildlife watches to cycle rides, and amongst them was the ECG's outreach event at the Science Oxford Family Open Day. The event saw over 100 visitors, spread out across three activity sessions during the day.

The new Science Oxford Centre at Stansfeld Park is a purpose-built exploration zone, workshop space and theatre set in 15-acres of woodland. The theme is "see the world differently", and the exhibits are designed to get children and families designing their own experiments and making discoveries. During the soft launch period, Science Oxford are offering a series of family open days, and on 15th June they invited the ECG to run some fun, engaging activities for the public. Plunged into the Exploration Zone, we set up our activity alongside a series of exhibits, including scarf-shooting, circuit-making and puzzle challenges.

One of our activities was 'Microplastics': a hands-on activity where participants use lights, microscopes and tweezers to search through soil debris looking for traces of small pieces of plastic; we provided two soil samples: some light composting soil and the heavy clayey earth found in the woodland outside. This material proved of great interest to our visitors; indeed, one very young girl even began modelling with it. In addition to our usual equipment, we made use of the centre's new microscopes: some hand held probes attached to laptops and some higher powered ones for looking at insects, watching mechanisms, or (in our case) observing microplastics in petri dishes.

We also presented 'Ocean Acidification', a demo using dry ice and pH 8-9 water to



demonstrate the devastating effect of rising CO₂ emissions on our oceans. By using a large measuring cylinder for the experiment and filling it just half way with the water, participants were able to touch the vapour given off and learn more about the behaviour and properties of carbon dioxide.

Explore the earth, air and oceans all while chatting to environmental chemists. ID some mystery water samples, catch your breath using air monitors and clean up microplastics polluting our ecosystem.

Our third activity was 'River Water Testing', where a water sample from the Peak District and one from the pond in the Science Oxford woodlands were compared in terms of pH, water hardness and ammonia using test strips. Many of the adult visitors predicted that the local water would be harder because of their experience with limescale and shampoo-foaming challenges.

Finally, visitors were also able to explore some environmental monitors, including an air quality sensor and Geiger Muller Counter.

Visitors were guided by our fantastic volunteers, Omofolawe Otun, Niall Marsay, and Fero Ibrahimi, who gave up

their time to learn the activities and showcase their



research and that of other environmental scientists. We were also joined by Explorer Scouts from Abingdon: Michael Pritchett, Adam Newton, and Toby Littlejohn, who “science busked” round the centre, engaging visitors with the monitors.

The relaxed atmosphere meant that there was also plenty of time to engage with parents who were



interested to know more about environmental chemistry. This engagement included giving advice to parents with older children for work experience opportunities, additional reading, and university courses that included environmental science. We also discussed how environmental science is taught in schools, and further opportunities for local scientists to engage with the public, including with one visitor from the Environment Agency. One parent was very interested in how insects could impact the earth, from materials such as silkworm silk to replace plastics, to increasing biodiversity sites near farms to naturally reduce the demand for pesticides, to the impact on land use, energy and water consumption of replacing meat in the diet.

Volunteer with us

If you would like to participate in a similar activity, get involved in a future ECG outreach event. Our next event on the 19th and 20th October is part of the IF Oxford festival of ideas. During these two days, held at the

Westgate Shopping Centre and Oxford Town Hall, the ECG will present the activities mentioned in this report, and we are looking for volunteers. The IF Festival typically attracts thousands of visitors to these Explorazones over the two-day event. Email rowena@scienceoxford.com to get involved or make enquiries. Training will be provided on the day.

Bring outreach to you

If you'd like to run your own similar activity, please check out our previous Bulletins and webpages for details of the activities, including an outline and cost estimate for exhibits. Details of the 'Ocean Acidification' demo may be found on page 22 of this Bulletin, whilst 'Microplastics' is explained in the July 2018 edition, and both appear online at envchemgroup.com/resources. Risk assessments are also available online. You are welcome to replicate any of our outreach activities yourself, and we are always happy to answer questions about them. If you want our help running outreach activities for your event or would like us to help source volunteers, email rowena@scienceoxford.com.

Tell us about your activities

We know many of our members are already highly active with outreach activities. If you have developed an activity, you can disseminate it to other readers by writing a 'Public Engagement How-To', or creating a summary report to share your success. Please contact the editors for more information.



Meeting Report

21st Century chemistry: Disposing of our nuclear legacy

Tom Sizmur (University of Reading, t.sizmur@reading.ac.uk)

The role that nuclear power will play in our future global energy mix is still being debated. Emitting less CO₂ is often considered a safer form of energy production than using fossil fuels. It is also more reliable than renewable energies such as solar or wind, which only generate power under specific climatic conditions. Nevertheless, the generation of nuclear power has left a legacy of radioactive waste requiring safe disposal.

The technical challenges and potential threats associated with disposing of our nuclear legacy formed the focus of the Environmental Chemistry Group's 2019 Distinguished Guest Lecture, delivered on 27th March by Professor Melissa Denecke (International Atomic Energy Agency) and supported by talks from Dr Joanna Renshaw (Strathclyde University), Professor Mike Wood (University of Salford), and Dr Juliet Long (Environment Agency).

Dr Joanna Renshaw opened the symposium with an introduction to the UK's nuclear legacy. She explained the basis of nuclear fission and then went on to provide an overview of the nuclear fuel cycle, emphasising that spent nuclear fuel, largely comprising enriched or depleted uranium, could be reprocessed (closing the cycle) or directly disposed of as radioactive waste. Radioactive wastes can be classified according to their levels of radioactivity: Low (LLW) or Very Low Level Wastes (VLLW), with less than 4 GBq (gigabecquerels) per tonne of α , or 12 GBq per tonne of β/γ activity, largely emanating from slightly contaminated materials produced in the decommissioning of nuclear sites. These require careful handling, but do not require shielding. These wastes can be disposed of in permitted landfill facilities. Intermediate Level Wastes (ILW) do require shielding, but are not heat generating, and so do not require cooling. High Level Wastes (HLW), however, require shielding and cooling and arise primarily from the reprocessing of nuclear fuel. Dr Renshaw explained that the Nuclear Decommissioning Authority categorise radioactive waste into 24 different streams according to

their radioactivity and chemical and physical forms, ranging from inert solids to liquids and sludges. Each waste stream requires separate disposal arrangements.

As the 2002 UK Government White Paper on 'Managing the Nuclear Legacy' states, this is "...one of the most important and demanding managerial, technical and environmental challenges facing the UK over the next century..." This White Paper led to the formation of the Nuclear Decommissioning Authority, and a budget of £121 billion to clean up the UK's nuclear legacy.

Next, Dr Renshaw focussed on the challenge facing the Nuclear Decommissioning Authority in the 21st century to decommission nuclear facilities, using Sellafield as an example. There are 15 reactors currently operating in the UK, and all are due to be shut down by 2035. The three primary strategies adopted to decommission nuclear facilities are either (i) dismantle the facility immediately, (ii) defer the dismantling for ~40-60 years, allowing the residual radioactivity to decay, or (iii) entomb the facility with no intention of ever completely removing the radioactive waste. Dr Renshaw concluded her talk by outlining the challenges faced in decommissioning Sellafield, particularly mentioning the 22 Magnox Swarf Storage Silos used to store ILW. Each of these is the volume of six double decker buses; decommissioning these will take 30 years.

Disposing of our nuclear legacy is "one of the most important and demanding managerial, technical and environmental challenges facing the UK over the next century"

Professor Mike Wood spoke next, introducing us to his work on radioecology and environmental radiation protection for wildlife, with a particular focus on research undertaken in the Chernobyl Exclusion Zone. He explained that, in order to assess the risk to wildlife from radioactivity, we need to understand (i) how wildlife are exposed to radioactivity, and (ii) how radioactivity impacts the organism in question, leading to questions such as 'How much radiation does it take to cause harm to wildlife?' and 'Is radiation good or bad for wildlife?'.

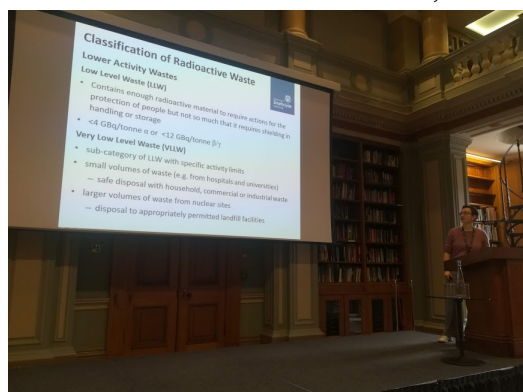
Professor Wood began his narrative by taking us back to the early 1980s and the town of Pripyat the Soviet Union (as was), where residents experienced a good quality of life. Then, on 26th April 1986 at 01:23, an explosion blew the roof off reactor No. 4 of the adjacent Chernobyl nuclear facility and, over the following 10 days, released radioactive material to the atmosphere. Changing

meteorological conditions during this time resulted in a patchy distribution of radioactive contamination throughout the Chernobyl Exclusion Zone. Iconic scenes included the 'Red Forest' in which the pine trees died and turned red. Today, a deciduous forest has regenerated, and the Chernobyl Exclusion Zone, which includes around 100 Ukrainian villages, has been taken over by nature as the forest invades ruins.

However, there remains considerable uncertainty about the effect of radioactivity on wildlife, leading to conflicting reports in the media. One report highlighted by Professor Wood identifies major declines in insect numbers as radiation increases, yet the doses extrapolated to zero insect population are similar to those naturally present in Cornwall. Since mammals are generally more susceptible to radiation than insects, this raises the question as to whether Cornwall is safe or not! To address this uncertainty, independently verifiable experimental methods are used that reduce disturbances caused by observations and avoid unconscious bias, beginning from the null hypothesis that large mammal abundances and diversity are not significantly affected.

To test this hypothesis, Professor Wood set up motion-activated camera traps in three areas of the Chernobyl Exclusion Zone that represent areas of high, medium and low contamination. This resulted in 250,000 photographs which feature wildlife such as red foxes, racoon dogs, red deer, grey wolves, Eurasian lynx, European bison, brown bears, and Przewalski's horses (a particularly rare breed that is seemingly common within the exclusion zone). The dataset from these images presents a considerable processing challenge. However, there currently appears to be no evidence to suggest that abundance or diversity differ between the low, medium and high contamination sites. Future work will study the age, structure and behaviour of wildlife in the exclusion zone and investigate whether radioactivity affects species interactions.

Dr Juliet Long, the Head of Legacy and Waste Issues in Radioactive Substances Regulation at the Environment Agency (EA), provided an independent regulatory perspective on the disposal of the UK's nuclear legacy. The EA has the responsibility to issue permits to nuclear sites to ensure all discharges are safe. This includes around 30 nuclear facilities, and ~2000 other sites permitted to discharge radioactive waste (including sites in the defence, oil and gas, manufacturing, hospitals and life sciences sectors).



Showing a photograph of the LLW Repository at Drigg in Cumbria from 2005, Dr Long demonstrated how limited our remaining storage capacity, is and explained that there was some concern over the safety case for the site, primarily coastal erosion from the Irish sea. Since anything buried in the ground eventually returns to the surface, the aim is to ensure that when it does reappear, it will not pose a threat. The policy, at the time Drigg was opened, required all LLW to go to this one site. However, this policy was changed in 2007, allowing radioactive wastes to be disposed at other permitted landfill sites around the country. Each site requires an individual safety case. As a result, we now have a diverse range of sites where LLW can be disposed of around the country.

Looking forward, considerable quantities of LLW are likely to be generated, including ~4.5 million m³ from civil nuclear decommissioning and up to 6 million m³ more from nuclear site clean-ups. This far exceeds the current permitted disposal capacity of ~1.2 million m³. Dr Long highlighted a potential problem whereby demand for disposal eventually outstrips

capacity. Much of the waste that will be generated by the decommissioning of nuclear facilities includes large concrete and metal structures. Our limited waste disposal capacity raises the question of whether some of these structures should be disposed of on site or left *in situ*.

In the final part of her talk, Dr Long discussed the issue of a Geological Disposal Facility, outlining reasons why the UK currently does not have one and the difficulties involved in generating the political will or social capital to identify a site where one could be built. The new government policy, published in 2018, is to dispose of higher activity waste deep underground. A selection process is now under way to identify a local community with a suitable geological setting that is willing to house such a facility. The EA would then regulate such a facility.

The 2019 Distinguished Guest Lecture was given by **Professor Melissa Denecke**. Professor Denecke's research focuses on what happens when there is a breach of a Geological Disposal Facility, or if there is water ingress. Until recently, she was a Professor of Chemistry at the University of Manchester, but now works for the International Atomic Energy Agency (IAEA) as part of a group spanning nuclear science, technology and its applications. She provided some examples of the work conducted by her new group using nuclear technologies to help achieve UN Sustainable Development Goals. This includes the use of isotopes to characterise groundwater and precipitation to support hydrological and climate studies. One example of this technology is the use of Kr-81, Cl-36 and I-129 to date groundwater and identify sites that contain very old groundwater suitable for a Geological Disposal Facility. However, in giving this talk, Professor Denecke represented herself and her personal career path, rather than the IAEA.

Providing an overview of the global nuclear waste inventory, Professor Denecke highlighted that waste volumes are small compared to those produced by non-radioactive power generation. A large proportion of the world's LLW has already been disposed of. Globally, ILW and HLW only represents 2% of the volume of radioactive waste, but 98% of the radioactivity. The international consensus is that a Geological Disposal Facility is the most appropriate option for HLW because the geology provides a barrier between the material and the biosphere. A typical design incorporates multi-barrier containment. The first country to provide a safety case for a Geological Disposal Facility was Switzerland, approximately 20 years ago.

Professor Denecke's research applies X-ray spectroscopy to investigate the barriers that may be employed in a Geological Disposal Facility and the waste itself. The techniques she uses help to determine the oxidation state of metals in a mixture without physically separating species. For example, it has been possible to determine that selenium is present as selenite (SeO_3^{2-}) and technetium is present as pertechnetate (TcO_4^-) in a glass fragment from the Karlsruhe Reprocessing Plant.

Her research included an investigation into uranium-rich tertiary sediment from Ruprechtov in the Czech Republic, a natural analogue of a waste disposal site.

Confocal μ -XRF (X-Ray Fluorescence spectroscopy) was used to generate 3D maps of the sediments and determine the elemental composition beneath the sample surfaces, which are typically oxidised. This technique was combined with μ -XRD (X-Ray Diffraction) and μ -XANES (X-ray Absorption Near Edge Structure spectroscopy) to focus on a single element and, for example, identify the speciation of uranium in the sediments. U(IV) was identified, likely present as a phosphate or a sulphate. By identifying these species, it is possible to apply thermodynamic data and generate a model to track the modifications to uranium after expulsion from the reactor, strengthening a safety case for geological disposal.

Thereafter, Professor Denecke highlighted the importance of colloid-mediated transport of radioactive contaminants, since colloids are able to travel through geological materials faster than water (as demonstrated by the use of tritium in tracer studies). Research was presented on the role of colloids as carriers for plutonium and the role played by natural humic substances that act as surfactants in groundwater and facilitate colloidal dispersion. At the end of her talk, Professor Denecke identified some of the exciting developments that she believes will drive the field forward, including the use of X-ray ptycho-tomographic imaging to create 3D images from 2D slices, and which can identify a layer of uranium in a solid object with a 13 nm resolution. She anticipated that future work would provide more opportunities for *in situ* investigations of materials at greater resolutions than those previously achieved, the combination of analytical techniques, the marriage of experimental and theoretical methods, and further development and use of models.



Professor Melissa Denecke receives her Distinguished Guest Lecturer medal from Dr Laura Newsome, ECG.

Article

An increasing role for iodine in the atmosphere

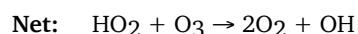
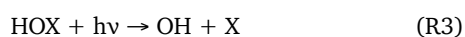
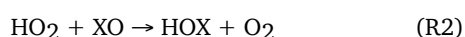
Tomás Sherwen (National Centre for Atmospheric Science and University of York, tomas.sherwen@york.ac.uk)

When people hear of halogens in the atmosphere, images of the ozone hole may come to mind. In the 1980s, destruction of ozone in the stratosphere – air over ten kilometres above the Earth – was all over the global news. The cause? Halogen-containing chlorofluorocarbons (CFCs). In recent decades, the ability of halogen species to destroy ozone in the region of air closest to the Earth, the troposphere, which we breathe day to day, has also received scientific attention.

Iodine in the troposphere

The chemistry of halogens in the troposphere differs from that in the stratosphere because of the lower energy of photons that make it down to the surface. In the stratosphere, the chemistry of chlorine dominates: here, the photon energy is high enough to break apart the strong bonds between chlorine and species such as carbon in CFCs. However, in the troposphere, the

chemistry of more weakly bonded bromine and iodine species dominates instead. Reactions 1-3 (where X = Br or I) show the main ozone destroying cycle of bromine and iodine in the troposphere.



The halogen monoxide radical forms by extracting an oxygen from ozone (O_3), then reacting further with a peroxy radical (HO_2) to form a hypohalous acid (HOX). The HOX rapidly breaks apart under light to regenerate the halogen radical, but not the ozone, thus destroying ozone.

Research in this area has mostly focused on the atmospheric chemistry of bromine until recent years, partially because instruments were able to measure it at

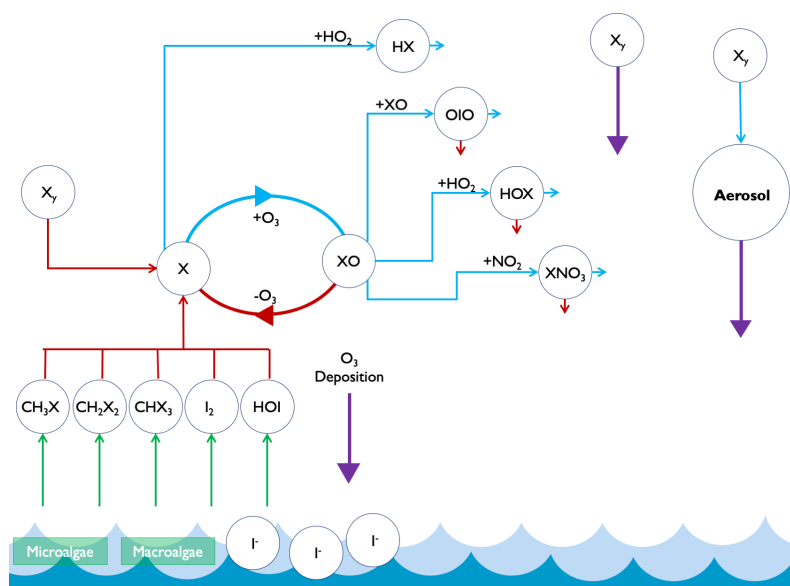


Figure 1. Schematic diagram of iodine in the atmosphere. Green lines show emission, Purple lines show deposition, Red lines show photolysis (breaking apart of species by light), and blue lines show chemical reactions.

atmospherically relevant concentrations earlier than iodine. However, evidence suggests that iodine may play a notable role too. Iodine in the atmosphere predominantly originates from oceanic sources. Micro- and macro-algae turn iodine into more volatile species (e.g. CH_3I , CH_2I_2) in seawater, which enter the atmosphere more easily. There are also abiotic production routes (producing HOI and I_2). This emitted iodine then undergoes gas- and aerosol- phase chemistry, and is mostly returned back to the ocean through deposition. Some of this iodine is deposited on land, where it is an important bio-nutrient, and vital to global populations which have both historically and recently suffered too low an iodine content in their diets, leading to thyroid-related medical conditions such as Goitre (1, 2).

Whilst sources of iodine in the atmosphere were previously thought to be almost entirely organic (e.g. CH_3I , CH_2I_2), laboratory work has shown one large source is abiotic sea-surface reactions involving ozone (3). This means that iodine emissions are linked to tropospheric ozone, which is both an air pollutant and climate gas. Global atmospheric models have demonstrated that this ozone-dependant source makes up the majority of emissions to the atmosphere (4). **Figure 1** offers a simplified schematic of atmospheric cycles of iodine.

A changing atmosphere, from preindustrial to present-day

The composition of the atmosphere has changed between pre-industrial revolution and present day. Two large chemical changes are increased emissions of both oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). NO_x increases have been driven by high-temperature combustion, such as in power stations, which can combine nitrogen and oxygen. Industry and transport sectors have led to large direct emission of VOCs, such as from exhaust pipes of cars. The two ingredients may combine to produce more ozone in the troposphere.

The increase in ozone from the preindustrial to present day leads to greater emissions of iodine. This occurs through abiotic sea-surface reactions that lead to HOI and I_2 emission. The increased iodine then leads to more chemical destruction of ozone in the troposphere (**Figure 1** and **Reactions 1-3**).

Whilst modelling work predicted this link between changes in atmospheric composition, increases in iodine emission and increases in ozone destruction (4), no historical observational records were known to confirm or disprove what the models said. However, within the last year, two studies have reported iodine concentrations in ice core records (5, 6). These two records, one in the Central Massif in France (**Figure 2**) and the other in Greenland, agree a three-fold increase since the 1950s. This is concurrent with the largest human-driven increases in tropospheric ozone. The overall trend is comparable to model predictions for the



Figure 2. Ice core drilling at Col du Dome. This is where recent ice-core evidence has reported a three-fold increase in atmospheric iodine since 1950, coinciding with the increases in the air-quality-gas ozone. Image credit: IGE-UGA's Bruno Jourdain.

same period (4, 7, 8).

An unfolding story

Excitingly, these recent observations lend additional weight to the theory that iodine acts to diminish the human-driven increase in ozone: a natural negative feedback. Although there are still many uncertainties, emerging evidence on iodine in the atmosphere suggests a notable role which has increased in response to human-driven changes.

References

1. Risher, John F., Samuel Keith, L., World Health Organisation and International Programme on Chemical Safety (2009). Iodine and inorganic iodides: human health aspects. World Health Organization. <https://apps.who.int/iris/handle/10665/43579>
2. Andersson M, de Benoist B, Darnton-Hill I, Delange F eds, World Health Organisation (2007). Iodine deficiency in Europe : a continuing public health problem. World Health Organization. <https://apps.who.int/iris/handle/10665/43398>
3. Carpenter, L. J. *et al.*, *Nat. Geosci.*, **6**, 108–111 (2013), doi:10.1038/ngeo1687
4. Sherwen, T., *Atmos. Chem. Phys.*, **16**, 1161-1186 (2016).
5. M. Legrand *et al.*, *Proc. Natl. Acad. Sci. USA.*, **115** (48) 12136-12141 (2018).
6. C. A. Cuevas *et al.*, *Nat. Commun*, **9**, 1452 (2018).
7. Prados-Roman, C., *et al.*, *Atmos. Chem. Phys.*, **15**, 2215-2224 (2015).
8. T. Sherwen *et al.*, *Atmos. Chem. Phys.*, **17**, 1557-1569 (2017).

Note: Former ECG committee members William Bloss and Stephen Ball described 'Iodine chemistry in the coastal marine atmosphere' in an article in the ECG *Bulletin*, July 2009.

Article

RSC journal highlights

The Royal Society of Chemistry's Environmental Science journals provide broad coverage of the latest research in environmental science and engineering.

Highlights from 2018

The Environmental Science family of journals collates a series of best papers every year that highlight some of the incredible science being published. The Best Papers 2018 were selected after evaluation by the journals' editorial and advisory board members, with final selection for the Portfolio's Best Paper being decided upon by the three Editors-in-Chief (Kris McNeill, Peter Vikesland, and Paige Novak).

The best paper was 'Machine learning provides predictive analysis into silver nanoparticle protein corona formation from physicochemical properties', by Matthew Findlay, Daniel Freitas, Maryam Mobed-Miremadia and Korin Wheeler (1). In this paper, the researchers utilised random forest classification to predict the composition of the protein corona that forms around nanomaterials. This work struck the judging panel as particularly important given the fact that these protein coronas are absolutely critical for determining a nanoparticle's fate and its impact on biota. This paper was published in Environmental Science: Nano.

Best papers from Environmental Science: Processes & Impacts and Environmental Science: Water Research & Technology were also chosen. Winning papers, runner-up best papers and best reviews can be found at <http://rsc.li/enviro-bestpapers>.



In other news, Paige Novak (University of Minnesota, USA), has become the new Editor-in-Chief for Environmental Science: Water Research & Technology. Paige moves to this new position having served as an Associate Editor for the journal since July 2014. Her research is focused on the biological transformation of hazardous substances in sediment, groundwater and wastewater. Kathrin Fenner (EAWAG) and Krista Wigginton (University of Michigan) join as new Associate Editors.

New for 2019

Symposia

The Environmental Science journals are delivering a series of talks from editorial board members, emerging investigators, and best paper winning authors at the 258th ACS National Meeting & Exposition in San Diego, and the 10th National Conference on Environmental Chemistry (NCEC) in Tianjin, both taking place in August 2019.

Themed Issues

In 2019, the Environmental Science journals are publishing several themed issues. To submit papers, please contact the Editorial Office (espi-rsc@rsc.org).

- PFAS (Per- and polyfluoralkyl substances, Guest Edited by Chris Higgins, Michelle Crimi, Lutz Ahrens, Ian Cousins and Jon Benskin)
- Indoor Air (Guest Edited by Delphine Farmer and Nina Vance)
- Capacitive Deionisation (Guest Edited by Jason Ren, Xia Huang and Peng Liang)

Read the latest themed collections at rsc.li/espi-collections.

Supporting Early Career Researchers

As per the Royal Society of Chemistry's mission, our Environmental Science journals are committed to supporting researchers at all career stages. Through an Emerging Investigator Series, the journals offer a platform for up-and-coming scientists to showcase their best work to a broad audience. Rising stars of environmental chemistry who have recently been featured in our Emerging Investigator Series include Laura Carter (University of Leeds), Karen Dannemiller (Ohio State University), Sarah Jane White (USGS, USA) and Kyle Doudrick (University of Notre Dame, USA). For more details about this Series and to apply for consideration, please visit <http://rsc.li/emerging-series>

Find out more...

Webpage: rsc.li/envsci

Register for e-alerts: rsc.li/alerts

Tweet: @EnvSciRSC

Contact the editors: espi-rsc@rsc.org

Reference

1. Findlay, M.R., *et al.*, *Environ. Sci.: Nano*, **5**, 64-71 (2018).

Public Engagement How To:

Ocean acidification experiment

(Zoë Fleming, National Centre for Atmospheric Science,
zoe.fleming@ncas.ac.uk)

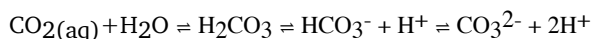
An interactive demonstration with colour change, bubbles and “smoke” that explains ocean acidification using dry ice as the CO₂ source. Even adults are drawn to this old-fashioned, mad scientist, overflowing-flask demonstration. **This exhibition guideline explains how to set up and introduce ocean acidification to the public.**



Theory

Ocean acidification is linked to the increasing amount of CO₂ that is present in the atmosphere (from fossil fuel combustion) dissolving in the oceans. There is a delicate balance between the carbon dioxide level in the atmosphere and the ocean, and the ocean is a sink for the excess CO₂ in the atmosphere. The down-side of this process is the formation of H₂CO₃ (carbonic acid) which inhibits shell growth in marine animals.

Dissolving CO₂ in seawater increases the hydrogen ion (H⁺) concentration in the ocean and thus decreases ocean pH, as follows:



See https://en.wikipedia.org/wiki/Ocean_acidification for further details.

Calcium carbonate minerals are the building blocks for the skeletons and shells of marine animals and ocean acidification can cause it to become undersaturated in these minerals. Corals are also very sensitive to pH (as well as temperature changes).

The ocean's pH has decreased by 0.1 pH units since the industrial revolution and as the pH scale is logarithmic, this change represents a 30% increase in acidity.

Set up

Pour a small amount (100ml) of NaOH solution (see kit list for concentration) into the flask. Add sufficient indicator to produce a strong alkali colour. Add a few dry ice pellets and watch the solution bubble as sublimation (solid to gas) of CO₂ gas occurs (it is very visible as the freezing temperatures condense the water, making it appear as a white, cold gas that escapes). The indicator will change to the acid colour during the reaction. A new solution needs to be prepared each time so keep a waste container nearby.

Challenge

What does the colour change tell us?

Resources required

Dry ice (to be kept in an insulated box)

Kit list

- Round-bottomed flask (or large cylinder)
- Universal Indicator solution
- 1 litre 0.1 M NaOH solution
- 2 litres water (to dilute NaOH:H₂O, 1:2)
- Dry ice pellets
- pH table with scale for the indicator you use
- Large container to pour excess solution from each experiment
- Pictures of healthy coral and coral damage at lower pH

Exhibition Cost

About £80 when using 2 bags of dry ice. Your nearest chemistry department could probably give you some for free. BOC delivers to the exhibit location but you may need to open a new account with any new delivery address. A 10kg bag costs around £30, but the delivery will be extra!

Exhibition weight

About 25kg

Exhibition size

About 1m³, depending on flask sizes

Things to look out for

Remember to be aware of the health and safety challenges of this experiment, and have trained staff handling the dry ice wearing insulated gloves.

A sea of synthetics: microfibres in the environment

Jasmin Urwick (University of Reading BSc Ecology and Wildlife Conservation student, jasminurwick@hotmail.com)

Plastic pollution is a global issue with many different sources. This Environmental Brief focuses on synthetic microfibres released during domestic washing processes and the impact this has on wildlife and humans.

Plastic pollution encompasses a range of contaminants from different sources. Recent research and news articles have been dominated by microplastics due to their impacts on the environment, particularly marine and freshwater habitats. Synthetic microfibres (MFs) have been used in textile production for over 50 years, and have now been identified as a major source of plastic pollution (1). Globally, synthetic fibres account for 60% of fibre production and include polymers such as polyamides (e.g. nylon), polypropylene (PP) and polyesters (e.g. polyethylene terephthalate (PET)) (2, 3).

Synthetic MFs have been detected in a number of aquatic and terrestrial environments across the world, highlighting the need to tackle this pollutant at the source. There is growing concern over the process of washing textiles as a pathway for MFs to enter the aquatic environment, with Browne *et al.* (2011) being the first to identify this as a source of plastic pollution (4).

Several studies since have attempted to quantify emissions of fibres via wastewater from domestic washing machines. Pirc *et al.* (2016) investigated the MF emissions of a new polyester fleece textile after 10 successive washes. Their results indicated that fibres continued to be released over the entire lifetime of the product, suggesting 70 mg of MFs are released annually per person in northern climates. However, multiple variables such as frequency of washing and use of other MF products, dependent on an individual's lifestyle, could affect this value (5). Napper *et al.* calculated that an average 6 kg load of washing could release up to 700,000 MFs into the environment (1). MF emissions also vary seasonally, as more clothing is worn and washed during winter months than in summer (4).

Impacts on wildlife

In contrast to the larger types of plastic pollution that can entangle animals, synthetic MFs have internal implications to wildlife that may be less obvious. They

typically have a diameter of <5 mm, placing them into the microplastics category (1). This small size mimics prey species resulting in the ingestion of MFs by predatory organisms. Not only can this cause physical damage to digestive system, but also negatively affects the food chain at a number of trophic levels (3). This has been found to increase mortality rates in species including the freshwater water flea (*Daphnia magna*) which has been observed ingesting polyester fibres as illustrated in **Figure 1** (2).

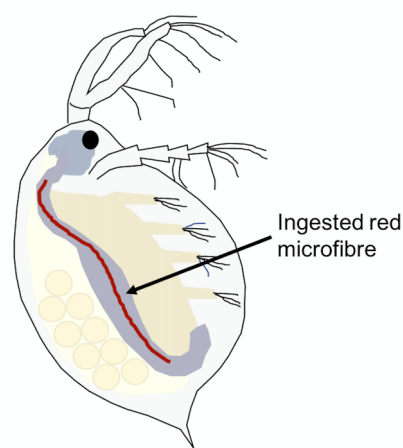


Figure 1. Drawing of *Daphnia magna* shown to have ingested a red PET fleece fibre.

The shape of MFs may also lead to differing effects on wildlife in comparison to more commonly studied microplastics, which tend to have a rounder shape (2). There is growing concern over the ability of microplastics, such as MFs, to act as a concentrator of pollutants, releasing even more toxic chemicals into the organism following ingestion (6).

Whilst much of the media focus of microplastics has been on threats to marine ecosystems, there is clearly evidence that freshwater and terrestrial species are also at risk. MFs can persist in sewage sludge that is used as agricultural fertiliser, exposing terrestrial organisms in the soil. This can then enter river systems via surface runoff, and ultimately enter marine environments (2).

Impacts on human health

The ability of MFs to enter the food chain is not only a risk to wildlife, but humans too. There is evidence of

human food sources such as blue mussels and honey containing microplastics (2). The ingestion of microplastics could lead to leaching of toxic chemicals used in the treatment of MFs, for example, fabric dyes or sewage contaminants (4, 5). Studies have also suggested that MFs inhaled by humans have the potential to become associated with developing tumours (4).

What are the solutions?

The release of MFs is largely due to a process called pilling. Small balls of fibres collect on the fabric's surface which can then detach during washing and enter the environment, as show in **Figure 2** (1). Research into the release of MFs via domestic washing machines agree that the process of washing needs to be adapted to reduce emissions. There is currently a push towards designing filters for modern washing machines that will collect the MFs shed during the cycle. However, there are concerns over how the collected MFs will then be disposed of to prevent polluting both aquatic and terrestrial habitats (1).

The colour of most MFs makes them relatively easy to identify, however colours such as black and brown become harder to distinguish from natural fibres and therefore more likely to be missed (4). Whilst there is still the need to prevent the spread of MFs in sewage sludge, the use of small mesh filters during wastewater treatment could help prevent synthetic MFs discharging directly into aquatic habitats (2).

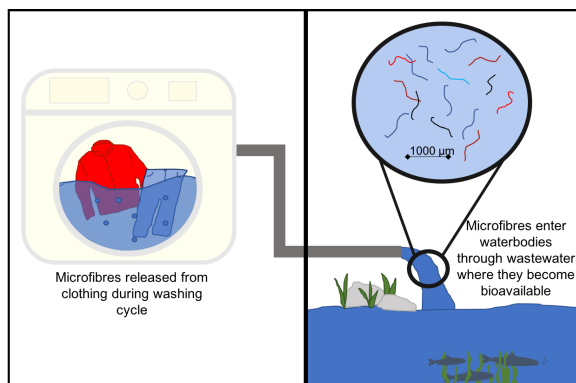


Figure 2. Diagram showing microfibres released during domestic washing process entering a waterbody via wastewater.

It should also be acknowledged that clothing design must be re-evaluated if we are to reduce our emissions of synthetic MFs. Between 1950 and 2010, the production of textiles and clothing using synthetic fibres increased from 2.1 million tons to 50 million tons per annum (2). There is a clear distinction between the amount of MFs released by textiles made from purely synthetic materials

compared to those of a synthetic-natural combination. Research conducted by Napper and Thompson (2016) found that pure acrylic fabric released ~80% more fibres than fabric combined with a natural material such as cotton (1).

Processes involved in the production of textiles also act as a source of fibres being released into the environment. Companies are encouraged to consider different knitting techniques and controlled washing and drying methods to reduce the number of fibres released once the product is in the care of the consumer (2).

Despite these discoveries, the effects of microplastics such as MFs are still largely unknown. Further research is needed to facilitate advances in washing machine technology and clothing design to limit emissions. To support these changes, adequate policies specifically targeting plastic pollution must be introduced. Educating consumers about the impacts of particular clothing items and encouraging behaviours that may limit MF emission, such as less frequent washing, will also help to reduce the impact of synthetic MFs on the environment (2).

Whilst this brief focuses on the release of MFs through domestic washing, the design of other products such as fishing nets and personal care products could also be improved by this research and reduce their contributions to MF emissions (3).

References

1. Napper, I.E., Thompson, R.C., *Marine Pollution Bulletin*, **112**, 39–45 (2016). doi.org/10.1016/j.marpolbul.2016.09.025
2. Carney Almroth, B.M., Åström, L., Roslund, S., Petersson, H., Johansson, M., Persson, N.-K., *Environ Sci Pollut Res*, **25**, 1191–1199 (2018). doi.org/10.1007/s11356-017-0528-7
3. Gago, J., Carretero, O., Filgueiras, A.V., Viñas, L., *Marine Pollution Bulletin*, **127**, 365–376 (2018). doi.org/10.1016/j.marpolbul.2017.11.070
4. Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., Thompson, R., *Environmental Science & Technology*, **45**, 9175–9179 (2011). doi.org/10.1021/es201811s
5. Pirc, U., Vidmar, M., Mozer, A., Kržan, A., *Environmental Science and Pollution Research*, **23**, 22206–22211 (2016). doi.org/10.1007/s11356-016-7703-0
6. Jemec, A., Horvat, P., Kunej, U., Bele, M., Kržan, A., *Environmental Pollution*, **219**, 201–209 (2016). https://doi.org/10.1016/j.envpol.2016.10.037

Brominated flame retardants: exposure routes, human impacts and status

James Day (University of Reading BSc Environmental Science student, james.day@student.reading.ac.uk)

Brominated flame retardants (BFRs) are common organo-halogen components of polymers found in a wide range of consumer products such as plastics, textiles and electronics, where they are incorporated to reduce combustibility and fire risk (1). They are effective, cheap and have a negligible impact on the properties of the polymer (2). However, their toxicity, bioaccumulation and persistence in the environment have been established and several BFRs are included in the list of Persistent Organic Pollutants (POPs) (2).

The toxicity and persistence of BFRs stem from their ability to diffuse out of surfaces and undergo long range atmospheric transport (Figure 1). Given their widespread use and the variety of exposure pathways, BFRs have a lasting legacy that affects most global environmental compartments (3).

Recent history and status

There are more than 75 different commercial BFRs, grouped into four main classes: polybrominated diphenylethers (PBDEs), polybrominated biphenyls (PBBs), hexabromocyclododecanes (HBCDs) and tetrabromobisphenol A (TBBPA) (4). This variety of

chemical structures results in a wide range of physiochemical properties (1).

General production of these chemicals started in the early 1970s with PBBs/PBDEs becoming commercially successful. Before long, the first major negative impacts were seen when accidental exposure to PBBs in rural environments in Michigan (US) led to degradation and adverse human health effects (4). As a result, in 1979, PBB production ceased in the US, and then in Europe in 2000 (4). PBDEs include 209 congeners, depending on the position and number of the bromine atoms. After a brief increase in production of PBDEs due to the PBB ban, these were also phased out in the US and banned in Europe by 2008, following risk assessments (3). HBCDs and TBBPA have since filled the gap left by the banned species, with the latter being the most highly produced BFR globally. Currently, HBCDs are listed as a 'substance of very high concern requiring authorisation' under EU legislation and have joined PBDEs in the list of persistent organic pollutants (POPs). The production and use of TBBPA is still unregulated (3, 4).

Most BFRs do not bind to the products they protect (with the partial exception of TBBPA). This means that their potential for leaching and volatilisation is very high. Consequently, BFRs have been found in breast milk, cord blood, fish, animal tissue, and in-house dust and sediments (1, 3).

Human impact

Human exposure to BFRs occurs mostly through in-

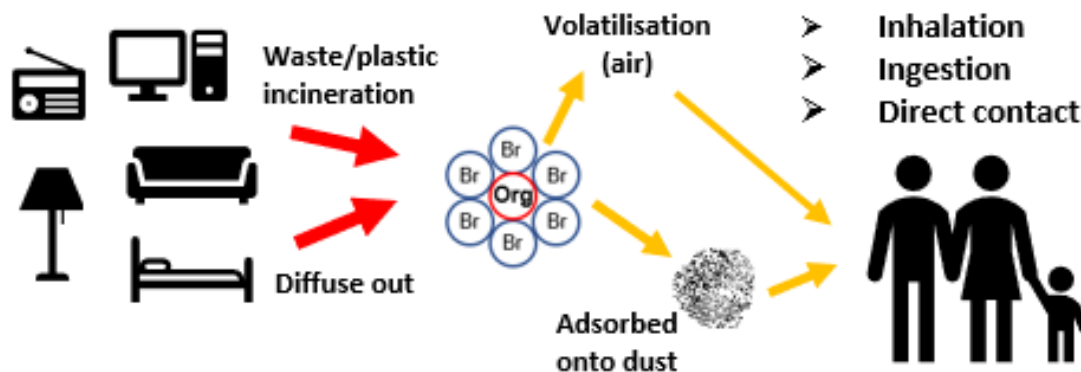


Figure 1. Graphical representation of BFRs diffusing out of materials or released upon incineration. Exposure pathways for people may occur from direct contact with the chemical species or from contact with contaminated dust.

house dust, but also from the ingestion of contaminated animal products and vegetables (5). Repeated studies have shown that PBDEs disrupt hormone homeostasis and neurological development, with lower birth weight and cancer among their consequences (1, 6). A study by Usenko *et al.* (2016) found high variability in the effects on humans exposed to the most commonly used BFRs (TBBPA, HBCD). They reported that exposure to TBBPA may pose a greater risk to human and environmental health than previously banned PBDEs (1). Indeed, subsequent studies (5) found TBBPA and HBCDs to have endocrine-disrupting properties and negative impact on neurological function and reproduction. Recently, two-year National Toxicology Program studies (designed to identify potential human carcinogens) found that mice exposed to TBBPA developed uterine and liver cancers (6).

BFRs are highly lipophilic and, as such, contaminated

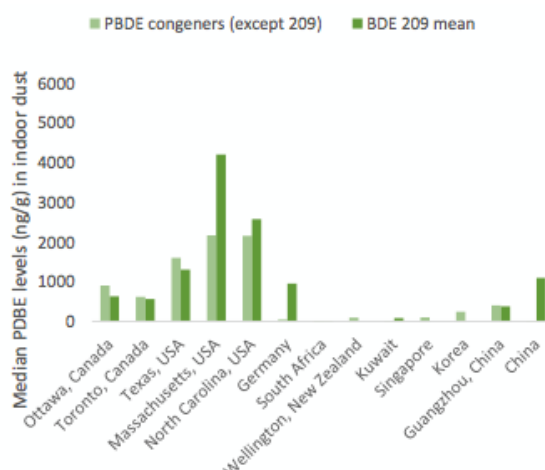


Figure 2. Comparison of PBDE levels (median) in indoor dust in the world (studies conducted 2006-2012, with BDE209 data missing for NZ) (STD error). Data from (7).

breast milk can contribute to up to 35 ng/kg bodyweight of BFRs in infants, whilst the average intake for toddlers through ingestion of dust has been estimated at 3 ng/kg bodyweight. Actions such as hand-to-mouth and object-to-mouth activity increase children's exposure to dust containing BFRs, leading to them being at much higher risk overall (4, 5).

Dust pathway

Studies have shown the main source of PBDEs found in human blood and milk to be indoor dust rather than dietary intake (7).

Concentrations of BFRs found in dust samples are much higher than those found in human blood/tissue and milk (Figure 2), and vary significantly across the globe. This reflects the large variance in worldwide market demand of BFR classes by region (e.g. US vs Asia), legislation prohibiting the use of particular compounds and voluntary cessation of production (5). For instance,

average levels in US indoor dust (Figure 2) are significantly higher than in other countries. Concentrations of BFRs in fish, one of the most heavily contaminated food groups, show the clear disparity between contaminant levels in food and dust (Table 1) (8). This indicates that close proximity to materials containing BFRs where we live and work (desks, computers, phones, cars, upholstery, etc.) is a significantly more important exposure route than food.

Table 1: BFRs (ng/g) in sediment and fish (ng/g wet weight) from areas of high contamination globally (Great Lakes, Baltic Sea, Western Scheldt, etc) compared to concentrations found in indoor dust from EU, USA & China (Data from 8).

BFR	Sediment	Fish	Dust
BDE47	0.06	1.6	280
BDE209	20	0	1300
HBCD	0.6	0.5	270

Conclusion and foresight

BFRs have an important impact on the healthy function of a human body. They are detectable during prenatal development at relatively low concentrations, but this increases in children up to toddler age (who are at increased risk of exposure and accumulation). The lasting effect of legacy BFRs is apparent through their continued global persistence and high accumulation in dust. Of significant concern is the rise in 'novel' BFRs replacing banned ones, which has not been accompanied by data on their toxicity. Worryingly, a study in China has found that concentrations of novel BFRs found in food are similar or higher than those of legacy BFRs (4).

References

- Usenko, C. Y., *et al.* *Toxics*, **4** (3): 21 (2016)[Online].
- Waaijers, S. and Parsons, J. R. *Current Opinion in Biotechnology*, **38**, pp 14-23 (2016).
- Nkabinde, S. N., *et al.* *Science of the Total Environment*, **622**, pp 275-281 (2018).
- Čulin, J. *Science of the Total Environment*, **636**, pp 919-926 (2018).
- Hendriks, H. S. and Westerink, R. H. S. *Neurotoxicology and Teratology*, **52** (B), pp 248-269 (2015).
- NIEHS. [Online]. U.S. Department of Health and Human Sciences. Available at: https://www.niehs.nih.gov/health/materials/flame_retardants_508.pdf [Accessed 7th December 2018]. (2016)
- Zhu, N., L, Y., *et al.* *Ecotoxicology and Environmental Safety*, **111**, pp 1-8 (2015).
- Boer, J., *et al.* *Chemosphere*, **150**, pp 461-464 (2016).

Upcoming Meeting

Indoor air quality

Where: Institute of Physics, 37 Caledonian Road, London N1 9BU

When: 17th September 2019

Synopsis

The average person spends up to 80-90% of their time indoors, and prolonged human exposure to pollutants in indoor environments has become a health concern. However, our understanding of indoor air chemical processes lags substantially behind that for outdoor ones.

This one-day conference aims to address some of the current open questions in the field, exploring the relationship between indoor air quality and indoor-outdoor air exchange, building energy efficiency and design, and occupant health, as well as providing an overview of current research on the measurement and modelling of airborne species in indoor environments.

Confirmed Speakers

Janet Barlow (University of Reading)

Nicola Carslaw (University of York)

Hannah Gough (University of Reading)

Ian Hamilton (University College London)

Benjamin Jones (University of Nottingham)

Coralie Schoemaeker (University of Lille)

Phil Symonds (University College London)

Registration

Details will be posted at <https://events.iop.org/indoor-air-quality>

Upcoming Meeting

Sustainable water in the 21st century

This event is organised in partnership with the RSC's Environment, Sustainability and Energy Division, Toxicology and Agriculture interest groups, and Water Science Forum.

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

When: 1st October 2019

The role of the chemical sciences in forming policies and choosing strategies.

This one day conference will take an holistic view of the unique position of the chemical sciences in facilitating the supply and treatment of water. It will cover policies, strategies and technologies for supplying safe water to where it is needed and minimising the environmental costs of providing and treating water whilst maximising social benefits.

It will also consider methods to optimise water conservation, the use and reuse of water and wastewaters, the importance of extracting value from water, and the likely drivers that will affect the

cost/benefit of applying these technologies in the future.

The event will focus on exploring pathways and techniques that depend on the chemical sciences to supply and treat water in a sustainable way, achieving the maximum societal benefit with the lowest intergenerational consequences.

Registration

Details will be posted at

www.envchemgroup.com/upcoming-meetings.html

Upcoming Meeting



Meeting organised by the Environmental Chemistry Group of the Royal Society of Chemistry

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

When: 15th October 2019

#EnvChem19 provides a forum for early career and established researchers, working in environmental chemistry to share their latest research findings.

The meeting will combine presentations from keynote speakers with oral presentations selected by the organising committee and a poster presentation session.

The themes of the meeting include:

- Environmental processes and chemical fate
- Environmental analysis and investigation
- Emerging contaminants
- Toxicology and risk assessment
- Environmental management and sustainability

Key Dates

2nd September – Closing date for the submission of oral and poster abstracts

10th October – Registration closing date

Registration

Member £50

Non-member £60

Student Member £25

Student Non-member £35

For further details, abstract submission and registration
<http://www.rsc.org/events/detail/39094/envchem2019>

Upcoming Exhibition

Nantwich Museum to celebrate the life of Joseph Priestley and the International Year of the Periodic Table

Glynn Skerratt (Environmental Chemistry Group, glynn.skerratt@gmail.com) and Helen Cooke (Chemical Information and Computer Applications Group)

When: 14th August – 26th October 2019 (admission is free)

Where: Nantwich Museum, Nantwich, CW5 5BQ

Later this year, the ECG, CICAG, and the North Staffordshire and South Cheshire Local Section of the RSC will be supporting an outreach project led by and held at the Nantwich Museum. It will bring together various themes which we hope will engage and inspire the Museum's visitors to increase their knowledge of chemistry and the Periodic Table.

In his recent *Chemistry World* article (12th Dec 2018), Roger Highfield (the Science Museum Group's director of external affairs) described approaches to public engagement with science, including use of local interest "hooks". Nantwich Museum is popular within the local community and with visitors to the town. With its primary focus on local history, the Museum hosts permanent and temporary exhibitions, schools' events, talks, and produces publications. Whilst historical topics

are generally more popular than science, this exhibition crosses disciplinary boundaries by exploring the life of Joseph Priestley, who lived in Nantwich from 1758-1761.

Priestley was a non-conformist minister and teacher in Nantwich, and it has been suggested that his scientific teachings there were the first ever science lessons. Priestley discovered oxygen after leaving Nantwich; this story will be used to introduce the periodic table.

The exhibition, talks, panels and, with help from Heidi Dobbs (RSC's Midlands Education Coordinator), molecule/element trail for children, provides interesting content for all age groups. The Museum's volunteer Craft Group has even made us a patchwork periodic table!

Contributing partners include the Catalyst Museum and Keele University.