RSC INTEREST GROUP
ENVIRONMENTAL CHEMISTRY

January 2020

Environmental Chemistry Group Bulletin

Extraction of Antibiotics in Solid Matrices. This edition features a detailed article by Jamie Harrower.

Meetings. This issue reports on six meetings: atmospheric and indoor air quality, plastics, sustainable water, public engagement, and sensors.

Plastics. These also feature in an article about the ban on straws, and a public engagement How To on separating out low-density microplastics by floatation

ECG Environmental Briefs. David Wray explores methods for geological analysis, whilst David Owen looks at polymer use in wastewater treatment

Also in this issue. Tom Sizmur reflects on the last year in his Chair's report and Dominik Weiss tells us about his career in academia. Two books reviews are included, one on groundwater geochemistry, one on science communication. Glynn Skerratt contemplates the life and discoveries of Joseph Priestley.

Upcoming meetings are announced, including our annual Distinguished Guest Lecture on **Disposable Attitude: Electronics in the Environment.**

Contents

Cover image: Aerial view of storage tanks in sewage water treatment plant. Josekubes via Shutterstock.

ECG *Bulletin*

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Environmental Chemistry Group

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Chair's report for 2019

News from the ECG

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

2019 has been an action-packed year for the Environmental Chemistry Group, with 13 scientific activities organised or supported. However, there is plenty more in the pipeline for 2020…

All change

In December 2018 we welcomed to the committee **Laura Alcock**, a development chemist at Edwards Ltd, and **Caroline Gauchotte-Lindsay**, a lecturer in environmental engineering at the University of Glasgow, broadening the industry experience and geographical spread of the committee north of the border. We also said goodbye to our outgoing Vice Chair (and previous Chair) Zoë Fleming, who has emigrated to Chile, and has sent us a video message from sunny Santiago that left us suitably envious. I would like to take this opportunity to thank her for her outstanding contribution to the committee since joining in 2012, and to wish her all the best for her future endeavours. The position of Vice Chair has now passed to Rowena Fletcher-Wood.

Meetings, Symposia, and Lectures

The first meeting of 2019 saw the return of our biennial meeting on the '**Analysis of Complex Environmental Matrices**' on 22nd February, organised by Roger Reeve with the Separation Science Group and the Water Science Forum. The keynote lecture was given by Dr Emma Schymanski from the University of Luxemburg on the use of environmental informatics to identify unknown chemicals and their effects. The next event is scheduled for 2021. Caroline Gauchotte-Lindsay will be shadowing its organisation and has agreed to take over fully for the following meeting in 2023.

Our annual '**Distinguished Guest Lecture**' was delivered by Professor Melissa Denecke from the International Atomic Energy Agency, which followed an exciting symposia of presentations from Joanna Renshaw, Mike Wood and Juliet Long on the topic of '21st Century chemistry: Disposing of our nuclear legacy' in the RSC, Burlington House on 27th March. Laura Alcock and Domink Weiss are organising our next Distinguished Guest Lecture and symposium, focusing on the chemistry behind disposables in our society.

Throughout the year, we have organised several other successful scientific meetings, including a meeting by Laura Newsome with the Clay Minerals Group of the Mineralogical Society on '**Clay minerals in the natural and built environment: formation, chemistry and applications**' at Newcastle University in May. Clare Topping organised a meeting on '**Plastics from Cradle to Grave and Resurrection**' at the SCI building in London in June in collaboration with the RSC's Toxicology and Food groups. A follow-up meeting will be run at the same location on 9th June 2020 (page 28). Valerio Ferracci organised two events in 2019, the first being an event on **Sensors and Networks for Environmental Monitoring** in collaboration with the RSC Automation and Analytical Management Group (with the next meeting already scheduled for 23rd June 2020, page 30), and the second event on **Indoor Air Quality** in September, alongside the RSC Toxicology Group and the Environmental Physics Group of the Institute of Physics. The ECG supported Bill Bloss to host the **European Workshop on Air Quality and Atmospheric Chemistry** in Birmingham in September, and Glynn Skerratt organised a successful meeting on **Sustainable Water in the 21st Century** in October in his capacity as the ECG representative on the RSC Energy, Sustainability and Environment Division Committee.

2019 saw us embark on a new venture as Steve Leharne hosted the first of what we intend to be an annual scientific meeting to bring together scientists from the UK and Ireland working across the entire spectrum of environmental chemistry at **#EnvChem2019: Chemistry of the Whole Environment Research Meeting** on 15th October in London. Keynote presentations were given by Mike Rivett and David Owen. We have started organising the next event (**#EnvChem2020**) to take place in York and have co-opted Tomás Sherwen from the University of York on to the ECG committee to help organise a two-day event in July 2020 to which we invite you to come and share your science (page 30).

Public engagement with science

The ECG has been active on social media in 2019, thanks to the efforts of Laura Newsome and Rowena Fletcher-Wood. Rowena also ran two public engagement events in Oxford on 'Blue Sky Research' during **Green Week** and at the **IF Oxford Festival of Ideas**. The ECG sponsored two prizes for the best poster in the Environmental Chemistry category of the **RSC Twitter Conference**, and Glynn Skerratt provided ECG support for an exhibition at Nantwich Museum to celebrate the life of **Joseph Priestley and the International Year of the Periodic Table**.

The ECG Interview: Dominik Weiss

Dominik Weiss is Professor for Environmental Geochemistry at Imperial College. His main research interests centre around trace metals in natural and man-made environments and, in particular, non-traditional stable isotopes and solution and surface processes.

What inspired you to become a scientist?

From early on, I was inspired by the work my father did as a synthetic organic chemist for a major pharmaceutical company, and by spending time outdoors with my family and friends. I was always interested in knowing how the physical world around me works – why is the sun emitting light, how does photosynthesis work, what about electricity? But, equally, I was motivated and drawn into science by serious threats to the environment. When I was young, it was the acid rain challenge. Today it is climate change.

How did you come to specialise in geochemistry?

I was interested in all aspects of science, so read natural sciences at the ETH Zurich. I had lectures with Walter Stumm – the author of the classic textbook Aquatic Chemistry – and this brought me into Environmental Chemistry. During my degree I spent much time mountaineering and was very interested in international development, so felt that specialising in soil chemistry and analytical chemistry would enable me to combine interests in fundamental science with my passion for outdoor and 'meaningful' work. I did my Master's thesis in soil chemistry and then was attracted to learn about isotopes and mass spectrometry through my PhD project. That led me into geochemistry.

Could you describe your current job?

I conduct active research (with a group of five PhD students and two fellows), teach at undergraduate level, do the usual departmental admin, and fundraise. Our group works experimentally and theoretically. We have an experimental and analytical lab and various computer programs and high-performance computing faculties.

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

For a career in academia, it is important to be led by real curiosity and interest. I would strongly recommend they read a lot and get solid advice from a mentor: a person who you look up to scientifically, but also on a personal level, enabling you to ask important questions and obtain guidance on the tricky politics of science.

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

Like everywhere in science, it is the perceived need to be applied, practical, and meaningful. This threatens research that is fundamental and basic. So often I am asked what the implications of my work are for the society. Trying to understand a process is not enough. Planted trees will only be strong if we understand the underlying mechanisms.

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

Collaborating with smart, enthusiastic, witty colleagues and students. I cannot tell you how happy this makes me. Then I think of the special feeling of discovery, learning new things, of publishing the research and seeing how people pick it up and how our findings make it into a text book, into a patent, into an app., into a software program, or into a policy document. I also love teaching and stretching young scientists with imagination in maths and chemistry.

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

I would love to be a carpenter, a mountaineering guide, a forest worker, a fisherman, cycling around the world, or a nurse, or a doctor. Oh and astronaut too; maybe even a politician.

And what do you do when you are not working?

Spending time with my family. I have the most wonderful wife and daughter – who is only four, so still needs lots of time. Most of what I love we can do together – cycling, travelling, playing music, reading and having friends and family over for a pint or a bulgogi. When I have me time, then I swim and do karate regularly to balance my desktop and brain-working life.

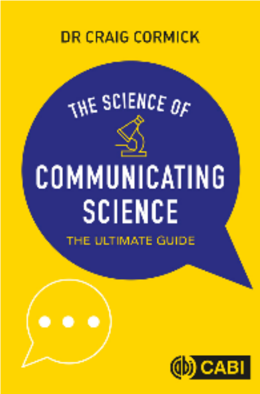
Book Review

The Science of Communicating Science

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

Dr Craig Cormick's *The Science of Communicating Science* promises "a rare book that combines academic rigour with the ease of reading a blog" – and it delivers. An easy-reading, funny, self-conscious miscellany, this text contains peer-reviewed wisdom on functional science communication techniques and affirms best practice strategies for the seasoned communicator.

At times, of course, it suffers the pitfalls of trying to match two forms, and the style is too frequently punctuated with puns and cartoon images. Although the chapters cover different topics (storytelling, media, risk…) the book is designed to be read systematically and in its entirety. Indeed, this is self-proclaimed in "Chapter 19: Valuing Values", when it states most of the relevant content has already been covered.



Specific advice

This text undeniably brings something utterly new to the literature: specific advice. There are numerous useful lists and examples, from body language to community engagement strategies. Disappointingly, much of the "science" is dubious opinion polls plucked at random from Australian, UK and US sources (although their limitations are acknowledged). More favourably, references are made to psychological and behavioural studies on motivated reasoning, information overload, value judgement, and the nuance of word choice for framing a concept. This material could be enriched with neuroscientific content, such as how stories affect the brain.

Industry problems in science

The target audience is primarily scientists obliged to do public engagement. As such, this book uniquely (and perhaps incidentally) highlights some of the key pitfalls, including (but not restricted to):

- Data reproducibility challenges
- Poor quality or fudged statistics
- Gender bias in career progression
- Scientific reluctance to admit failure
- Overrepresentation of cultural outliers (WEIRD Americans) in behavioural studies
- Funding models
- Media relations
- Impact and evaluation

Nevertheless, the book neglects its "fan boy/girl" audience – keen communicators, who buy more books on science communication than anyone else!

Media

This section contains a robust guide on how to construct press releases, but has gaps, such as the differences between public and scientific writing, and any reference to the 2011 BBC Trust Review, which first highlighted the partiality of reporting conflicting opinions in non-representative ways.

Public Disillusionment

Science communication is not only about speaking, but also listening: this marginalised aspect is carefully dissected. Where implementing science requires sensitive community engagement, Cormick reframes risk communication as a people-managing process. Be "a person first and a scientist second", he advises. "People don't care what you know – they want to know you care!" Trust, he claims, is paramount. However, the nature of this public and the community power struggles which often conflate scientific consultancy are also neglected.

Conclusions

Overall, whilst there are subtle contradictions in the text, Cormick provides a well-referenced, highly specific text based on a well-founded body of established scientific knowledge that fills several gaps in the existing literature. Most memorable are the first and last things said – or, so the book tells us.

References

1. Craig Cormick, *The Science of Communicating Science The Ultimate Guide*, CSIRO, Australia, 2019, ISBN: 9781789245141

2. Professor Steve Jones, The BBC Trust Review of Impartiality and Accuracy of the BBC's Coverage of Science, July 2011, Independent Assessment, Imperial College London. Available as a pdf online.

Book Review

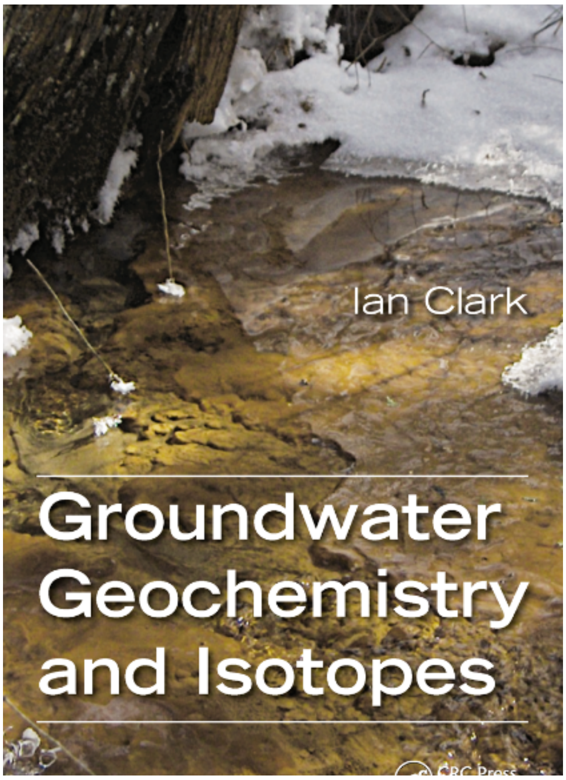
Groundwater Geochemistry and Isotopes

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

An introduction to understanding groundwater chemistry, groundwater processes, and the behaviour of stable isotopes and radioisotopes in groundwater.

This is an excellent reference book for anyone who wishes to discover more regarding the processes that influence groundwater chemistry and the behaviour of isotopes. Having recently been in a meeting where the behaviour of stable isotopes in groundwater was discussed, I thought this was an excellent time to review this book. Given the subject of the meeting, I decided it was best to start with **Chapter 7: Geochemical Evolution**. This chapter starts by describing the reactive components of aquifers (clay minerals, humics, iron and manganese oxyhydroxides, colloids, and zeolites) and the processes that occur during the evolution of natural groundwater geochemistry. These include processes such as cation exchange, adsorption, redox reactions, and the influence of salinity. The chapter concludes with a description of how to present geochemical evolution in a graphical format. Each of these topics was explained in a clear, easy to follow way, with helpful derivations of equations and Pourbaix diagrams. I liked how microbial activity was clearly linked to the development of reducing conditions, as well as the descriptions of how microbial activity influenced the fraction of stable isotopes such as ^{34}S, ^{18}O, ^{13}C, and ^{2}H in groundwater.

Next, I looked at **Chapter 9: Contaminant Geochemistry and Isotopes**. This chapter will be of particular interest to those working in the contaminated land industry. It starts by explaining the biogeochemistry of nitrogen compounds (including ammonia, urea, and nitrate) in groundwater, including sources from agriculture and wastewater. Next, it details the biodegradation of organic compounds such as hydrocarbons and organohalogens, contamination from which is the biggest issue impacting the UK groundwater environment. Subsequently, it describes the processes that influence contaminant behaviour in landfills and acid mine drainage. This is followed by sections on individual base metals (Cr, Mn, Co, Ni, Cu, and Zn). The issue of groundwater salinisation and isotope behaviour is covered in some detail, and the problems of groundwater contamination by arsenic and nuclear waste are afforded their own sections.



Returning to start of the book, it was useful to find that the introductory chapter contained clear explanations of aquifer geological components, and charge balance and of stable isotope fractionation calculations. **Chapter 2: Thermodynamics of Aqueous Systems, Chapter 3: Geochemical Reactions** and **Chapter 4: Isotope Reactions** covered the necessary basics required to understand groundwater geochemistry and isotope behaviour. Other chapters cover carbon dioxide and weathering, groundwater dating, and sampling and analysis.

In summary, this book is an excellent resource for those who have limited experience working with groundwater or who are studying this topic. I would also recommend it as a useful reference for more experienced practitioners.

Reference

Clark, I., *Groundwater Geochemistry and Isotopes*, CRC Press, Boca Raton, Florida, 2015, ISBN:9781466591738.

Meeting Report

Atmospheric Chemistry

Professor William Bloss (University of Birmingham, w.j.bloss@bham.ac.uk)

The 17th European Atmospheric Chemistry and Air Quality workshop was held at the University of Birmingham from 25-27th September 2019. Attended by over 50 researchers from across Europe, the workshop consisted of contributed talks, facility visits, and the conference dinner.

The meeting opened with **Tim Wallington** (Ford Motor Company) setting out progress and challenges in reducing emissions from vehicles. Tim outlined the advances made through use of catalytic converter technologies within petrol vehicles, and diesel particulate filtration. The discussion focussed upon impacts of the anticipated trend towards Electric Vehicles (EVs), with reduced at-tailpipe exhaust emissions, but potential for different brake, tyre and road surface contributions (reflecting regeneration and greater weight).

Subsequent sessions explored the detailed atmospheric chemistry responsible for secondary pollutant formation. **Dr Lisa Whalley** (Leeds University) showed results indicating the presence of a process, missing from the modelling information, that is able to sustain peroxy radical levels under polluted (high NO) conditions, with implications of greater O_3 formation. **Dr Alex Archibald** (Cambridge University) then went on to show that nitrate radical abundance was expected to increase in the future, and may begin to dominate oxidation of biogenic volatile organic compounds.

Subsequent sessions revisited vehicle emissions, looking at NO_2 levels in Wuppertal, direct HONO emissions from vehicles, and the effect of vehicle emissions on within-car levels of nitrogen dioxide, together with the significant reduction in personal exposure that could be achieved using activated charcoal impregnated vehicle pollen filters (**Professor Ulrich Platt**, Heidelberg University).

The first day closed with a series of talks looking at biogenic VOC emissions, and their response to recent heatwaves across Europe (with a case study of the Landes forest around Bordeaux). The final session of the day discussed the proposed ACROSS field campaign, slated to take place around Paris in summer 2022, and exploring interactions of natural (biogenic) and anthropogenic chemical emissions – anyone interested is invited to contact **Professor Chris Cantrell** (christopher.cantrell@lisa.u-pec.fr) for more information.

Day two of the meeting opened with talks looking at recent laboratory studies, ranging from self-assembly in atmospheric aerosols (**Adam Milsom**, Birmingham University), to the ability of metal-ligand complexes to moderate particulate matter cytotoxicity (**Chiaria Giorio**, Padova University), and details of the potential aqueous phase oxidation of isoprene epoxides (**Tobias Otto**, Tropos Leipzig).

The scientific sessions were complemented by a visit to the Birmingham Air Quality Supersite, a highly instrumented urban air observatory established on the campus, and the Birmingham Institute of Forest Research (BIFoR) Free-Air Carbon Enrichment (FACE) facility, a large-scale 10-year experiment to assess the response of a mature English oak forest to CO_2 levels anticipated in the second half of the 21st century. The FACE facility comprises three treatment rings 30m in diameter, within which CO_2 levels are maintained 100 ppm above present day levels through a complex dynamic injection system, allowing the ecosystem response to be compared with that observed in adjacent control and dummy rings. (www.birmingham.ac.uk/research/bifor/index.aspx).

> **The BIFoR Free-Air Carbon Enrichment facility [is a] a large-scale 10-year experiment to assess the response of a mature English oak forest to CO_2 levels anticipated in the second half of the 21st century.**

The participants look forward to next autumn's meeting, to be held in Germany.

The support of sponsors is gratefully acknowledged: the Royal Society of Chemistry, Environmental Chemistry Group; Natural Environment Research Council (NERC) WM-Air; and the European Solvents Industry Group.

Meeting Report

Plastics: From cradle to grave and resurrection

Clare Topping (clare.topping@gmail.com)

A joint meeting between the RSC's ECG, Toxicology, and Food Groups, and the Society of Chemical Industry (SCI) was held on 19th June at the SCI building in Belgrave Square, London. There were a variety of speakers as well as posters covering the whole life cycle of plastics, and their positive and negative impacts (**Figure 1**).

The talks in the first session were themed around "Plastics – Use and Abuse". The keynote presentation was given by **Stuart Foster** from RECOUP on "Plastics, Packaging and Politics". His talk covered many aspects of plastic waste, from a map of world 'dump sites' – most of which are coastal (explaining why so much plastic ends up in the oceans) – to a discussion of the 'Plastic Pact'. He also described the anomalies in the Packaging Recovery Note (PRN) scheme, reviewed Local Authority collection rates, and introduced the audience to the term 'bin juice'.

Ruth Stringer from Healthcare Without Harm spoke about the use of PVC in healthcare and other end uses. The toxicology of phthalates (amongst many other additives) used within PVC and other plastic products was discussed, together with the environmental and health impacts of PVC manufacture. Many interesting examples were presented, including the use of PVC in blood bags, where no replacement has yet been marketed because the phthalates that leach out of the bag enhance the life of the blood by altering the blood cell membranes. The good news is that a prototype replacement is currently being trialled.

Innovation in plastics recycling has focussed too much on virtue signalling and not on solutions.

The final presentation of the first session was on "Microplastics, Risk and Regulation", by **Julius Kreißig** (Wood plc.). This talk reviewed the risks from primary microplastics – those intentionally introduced to the environment, for example, in personal care and paint products – and those entering the environment from secondary sources such as wear and tear from tyres and road markings. In addition, potential solutions were discussed, such as capture of microplastics originating from tyres in storm drains, and setting maximum thresholds for fibre release from textiles.

Figure 1 The afternoon session chaired by John Williams Credit: Tiffany Hionas SCI

The second session of the morning, "Challenges for Plastics", consisted of talks by **Peter Reineck** about 'Why the Waste Hierarchy doesn't Work for Plastics and How to Fix it', and **Andrew Dove** (University of Birmingham) who introduced us to the topic of Chemical Upcycling of Plastics. Plastics were successfully developed as a light weight, low cost, high performance material to replace animal and mineral products. However, according to Peter Reineck, innovation in plastics recycling has focussed too much on virtue signalling and not enough on solutions. Andrew Dove explained the chemistry behind his work looking at 'green' organocatalysts that function at high temperatures. These selectively depolymerise mixed plastic waste, such as polycarbonate and PET, into their original monomers as well as added-value chemicals and materials for 3D printing.

After lunch, during which there was plenty of time to look at the posters on display, the conference continued with the third theme of "Post-use Challenges". **John McGeehan** (University of Portsmouth) described "Engineering Enzymes for Biological Recycling of Plastics". He spoke about elucidating the structure of

PETase (an esterase that catalyses the hydrolysis of polyethylene terephthalate (PET)) and thereby discovering how it functions, how it evolved and, subsequently, how to improve its ability to break down polyesters to their component monomers through targeted protein engineering. This talk was followed with one by **Richard McKinley** of Axion, discussing "Challenges in Consumer Use Packaging". Particularly interesting was the proven recyclability of thin plastic films to make household goods such as detergent bottles.

The final session of the day began with **Sally Beken** (KTN) updating the conference on the £20 million of funding for plastics announced by the UK government through Innovate UK in 2018. More details about Innovate and KTN's plastics and circular economy projects, together with the calls for funding, are available on their website (https://ukcpn.co.uk).

Presentations relating to the posters displayed during the breaks formed the final part of the programme.

A prize jointly sponsored by the RSC and SCI was awarded to the best poster and best presentation from the final session. These were presented by John Williams (Sinvestec LLC) who chaired the afternoon session. The winner of the poster prize was **Maria Pin-Nó** from the University of Nottingham (**Figure 2**), for her poster 'Production and Commercialisation of Pinene Acrylates and Methacrylates: A Sustainable Alternative to Common Monomers'. The prize for the best presentation was given to **Alvin Orbaek White** from the Energy Safety Research Institute (**Figure 3**) with 'How to turn Plastic Waste into a Commodity by using Nanotechnology'.

The feedback from the conference was positive with 92% of respondents rating the conference excellent or very good.

A follow-up conference will take place on 9th June 2020 which will build on these themes and further explore the future of plastics.

Figure 2 Maria Pin-Nó received the prize for the best poster. Credit: Tiffany Hionas SCI

Figure 3 Alvin Orbaek White received the prize for the best presentation. Credit: Tiffany Hionas SCI

Meeting Report

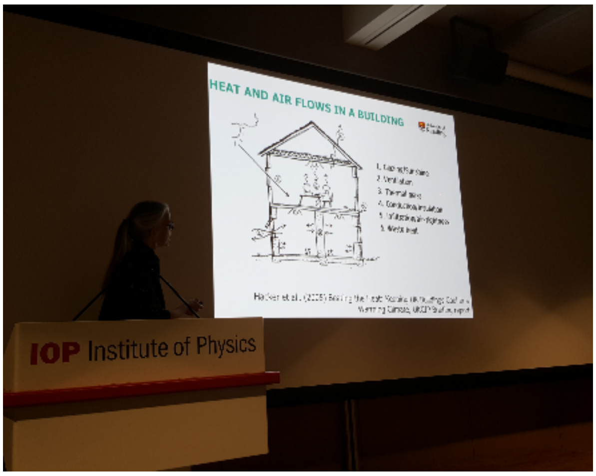
Indoor Air Quality

Lindsay Bramwell (Newcastle University, lindsay.bramwell@newcastle.ac.uk) and Valerio Ferracci (Cranfield University, v.ferracci@cranfield.ac.uk)

The RSC Environmental Chemistry and Toxicology Groups joined forces with the Environmental Physics Group from the Institute of Physics (IoP) to organise a one-day meeting on indoor air quality on 17th September. 35 delegates convened in the IoP's new flagship building in London to hear about the latest findings in indoor air chemistry and physics and discuss the challenges ahead.

The first speaker was **Dr Ben Barratt** from King's College London, who presented a fascinating introduction on the links between indoor and outdoor air. Ben shared findings from various studies, including one comparing nitrogen dioxide (NO_2) measurements from background monitoring stations, sensors installed outside and inside homes, and portable devices for personal exposure. The results clearly indicated that the usual demarcation between outdoor and indoor air quality becomes increasingly blurry when personal exposure is taken into account, with overall exposure consisting of a mixture between the two. Ben also presented the preliminary results from another study in which portable particulate ($PM_{2.5}$) monitors were attached to backpacks worn by school children in London to determine during which part of the day children were exposed to the most pollution. Initial results show clear spikes during their commute to and from school (outdoor), but also in the evening as a result of cooking (indoor). The highest concentrations of $PM_{2.5}$ were found on the London Underground and when someone was smoking or cooking indoors (~350 $\mu g/m^3$). In comparison, concentrations on a busy high street were much lower (~50 $\mu g/m^3$), yet these are the only emissions that current pollution curbing measures are addressing.

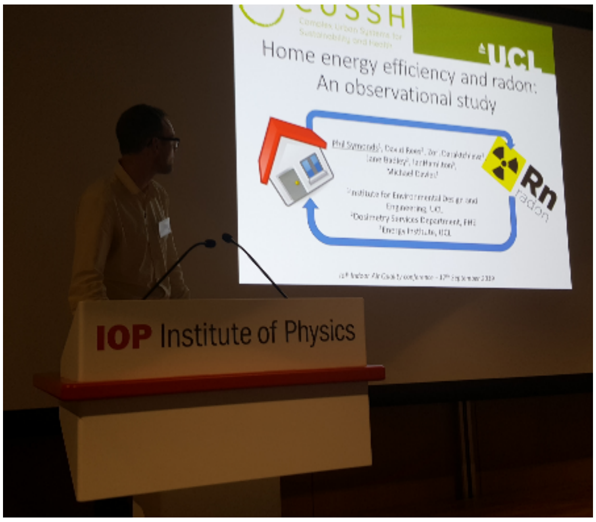
Professor Janet Barlow from the University of Reading spoke next on the topic of natural ventilation processes in urban buildings. This is particularly timely in the context of buildings becoming increasingly airtight in attempts to be more energy efficient – typically one third of heat is lost through air leakage. Professor Barlow introduced the main drivers of indoor ventilation (pressure and heat) and the other physical factors that affect it, including room layouts, wind speed and direction, glazing and sunshine, thermal mass, and human behaviour. In particular, she focused on an infiltration study carried out in an old office block on Marylebone Road, which used a number of sensors deployed in different locations (outdoors, indoors and in an internal courtyard) to characterise the rates of infiltration and its main drivers. She also discussed the REFRESH project, investigating the interactions between the built environment and its occupants. In particular, the project highlighted the poor management of indoor environmental conditions. Janet suggested that a clearly visible traffic light system (e.g. a wall clock) for a specific indoor pollutant could be used in shared indoor environments (e.g. offices) so that all occupants could be made aware of when to take remedial action such as opening a window.



Professor Janet Barlow (University of Reading) illustrates the main drivers of heat and air flow in indoor environments.

The first afternoon session was devoted to modelling and measurements of indoor air chemistry with talks from **Dr Nicola Carslaw** (University of York) and **Dr Coralie Schoemaecker** (University of Lille). Dr Carslaw introduced the main concepts of indoor air chemistry, stressing how the chemical regimes of these environments can be very different from those found outdoors, in particular with respect to the type and abundance of species and to the physical conditions (light, humidity, etc.). As a result, whilst most of outdoor atmospheric chemistry is initiated by the photochemical formation and reactivity of the hydroxyl radical (OH), indoor air chemistry is initiated by the reaction of ozone (O_3) with volatile organic compounds (VOCs). While outdoor air can affect indoor air via infiltration, the main sources of indoor air pollution are cooking and cleaning activities. In particular, the VOCs released by most commercial cleaning products (e.g. limonene, linalool and α-pinene), once oxidised by ozone, can form a number of secondary and tertiary products, some of which are harmful to health. As many key indoor chemical species are challenging to measure, models such as the Indoor Detailed Chemical Model (INDCM) are often the best tools for providing insight into the complex chemistry of indoor environments. Dr Carslaw also discussed the importance of indoor photolysis and, in particular, the use of UV lamps for extreme cleaning in hospitals to fight the spread of bacterial infections. Studies show that these lamps lead to high concentrations of OH radicals and, consequently, of highly oxidised (and potentially harmful) reaction products. This begs the question of whether or not we are creating a supplementary health issue. Dr Shoemaecker focused on the measurement aspects of indoor air chemistry, describing the various techniques used in field campaigns in indoor environments such as schools. Monitoring indoor VOCs by thermal desorption tubes has revealed that up to 60% of VOCs are emitted by the occupants in a lecture room. Squalene in particular, a polyunsaturated hydrocarbon, is naturally shed from human skin and readily reacts with ozone to form semi-volatile products that can be irritants. In addition, the increased surface-to-volume ratio found in an indoor environment means that surfaces can significantly influence the chemistry, as both sources and sinks of airborne species. Field studies have found that furniture, glued flooring and painted walls act as sources of trace species, notably formaldehyde and other VOCs. Comparison of observed concentrations with models such as INDCM have highlighted areas of uncertainty that are in need of further characterisation in indoor environments, such as surface uptake and deposition and photolysis processes driven not just by transmitted external light, but also by some types of artificial lighting (e.g. uncovered fluorescent bulbs).

The third and final session of the day started with **Professor Benjamin Jones** from the University of Nottingham, who focused on the relationship between building ventilation, indoor air quality and occupants' health. Following a retrospective on indoor ventilation through the ages including an explanation of how the ancient Egyptians built air shafts within the Great Pyramids, Ben focused on how to optimise ventilation rates for a large variety of building types. As it is difficult and time-consuming to measure the ventilation rate for every specific indoor environment (such as each classroom in a school), we are moving away from a fixed recommended value (or range of values) for ventilation rate (7.5-10 Ls^{-1}) towards a more dynamic approach in which a proxy variable (such as CO_2 concentration) is monitored and the ventilation rate adjusted so that the proxy does not exceed a particular threshold. The final part of the talk focused on a novel statistical approach aimed at selectively targeting specific indoor pollutants to maximise the health and economic benefits of good indoor air quality. This method identified particulate matter, formaldehyde and acrolein as the main priorities to improve indoor air.



Dr Phil Symonds (UCL) tackles the trade-off between energy efficiency and indoor air quality.

The last talk of the day was given by **Dr Phil Symond**s from University College London (UCL), who focused on radon gas in indoor environments. Radon is formed from the radioactive decay of uranium contained in a number of geological formations around the globe, and can seep into buildings from cracks in the foundations or flooring. Radon occurrence is higher in particular regions (Cornwall, for example), depending on the local geology. Radon itself is radioactive, and exposure to it is the second leading cause of lung cancer worldwide after smoking. Dr Symonds showed the results of the analysis of a large dataset consisting of radon measurements made in 470,689 UK homes between 1980 and 2015. This study found that energy efficiency measures tend to increase the airtightness of properties and thus have an adverse effect on indoor radon levels. For instance, homes with double glazing installed had radon levels up to 67% higher than those without. This study highlighted how the push to improve the energy performance of the UK's housing stock must not compromise indoor air quality.

Appropriately, the meeting was hosted in the new IoP building, which was designed with sustainability in mind. It features ground source heat pipes, solar panels and a green roof, together with a huge screen containing footage of the Moon's surface and a cloud chamber.

Meeting Report

Sustainable water in the 21st century

Glynn Skerratt (Sustainability Consultant, glynn@skerratt.com

This one-day conference was organised by the RSC Energy, Sustainability and Environment Division, as befits a global issue, hosting speakers who provided valuable insights into the topic from both the UK water sector and also from national, international and global perspectives.

At a global scale, the UN Sustainable Development Goal 6 (SDG6) relating to clean water and sanitation includes a target of clean, accessible water for all by 2030. As of 2015, 30% of the world's population does not have access to safe drinking water and 60% lack access to safe sanitation facilities. We have some way to go to reach our target, particularly considering that water scarcity affects 40% of the global population. By 2025, some 1.8 billion people are likely to experience absolute water scarcity and two thirds of the world will live under water-stressed conditions.

England's Environment Agency has reported that the country will be short of water within 25 years. The population of the UK as a whole is expected to rise from 67 million to 75 million by 2050. By 2040, more than half of our summers are expected to be hotter than the 2003 heatwave, leading to more water shortages and potentially 50-80% less water in some rivers.

With these dynamics in mind, each of the speakers focused on the importance of developing solutions to these intractable problems through the acquisition and interpretation of accurate chemical data; these data may then facilitate rational decisions on critical issues such as:

- Water conservation
- Catchment management/planning
- Managing water leakage
- Managing water risks
- Resilience
- Decentralisation of supply and treatment
- Water reuse
- The value of water
- The market in water
- Public health education
- Hygiene
- Sanitation

The first speaker was **Dr Martin Padley**, a Director of United Utilities, who drew out four particularly important issues affecting his company:

- The colour of the water – in NW England, there has been a marked increase in raw water colour/ dissolved organic carbon (DOC) variability over recent years.
- Extreme weather – the frequency of such events has demonstrably increased over the last 25 years.
- Taste and odour – with customers tending to use these organoleptic parameters to self-judge the 'safety' of their water.
- The presence of geosmin (*trans*-1,10-dimethyl-*trans*-9-decalol, a naturally occurring organic compound with a distinct earthy flavour) and the use of granular activated carbon to counteract it.

He went on to stress the need for effective process risk management and the importance of focusing on assets, processes and people to achieve this.

In the second presentation, **Neil Dewis**, a Director of Yorkshire Water, reviewed water use and water treatment past and present. The UK Government's 'A Green Future – the 25 Year Plan to Improve the Environment' focuses on the polluter pays principle, and thereby brings additional responsibilities for farmers in overseeing environmental aspects of land and catchment management. He developed this theme into a discussion of the concept of sustainable landscapes, involving stakeholder partnerships including water companies.

Dr John Carstensen, Head of Profession, Climate and Environment at the Department for International Development, considered water issues relating to international development. He outlined the complementary approach that the two previous presenters had described to SDG objectives and went on to reinforce the importance of water as a resource and the detrimental impact that climate change was already having. He discussed the relationship between water scarcity and gross domestic product (GDP) alongside water security issues – including economic development and, particularly, urbanisation. He summed things up by stressing the critical importance of taking an interdisciplinary approach when seeking a resolution.

Dr Priyanka Jamwal from the Ashoka Trust for Research in Ecology and the Environment in Bangalore discussed some of the practical issues facing quantification of water quality in India. The Indian water quality regulatory framework assesses quality and compliance using 1,245 monitoring stations. She described the rapid increase in the population of Bangalore over the last 20 years and discussed the benefits of passive sampling devices (some of which her NGO had developed with the University of Portsmouth), and the topics of citizen science and affordable sensors to make monitoring site-specific rather than generic. She also mentioned the importance of an interdisciplinary approach and highlighted the link between SDG6 and other SDGs.

Dr Rob Fuller a water sector adviser with WaterAid, the largest global NGO focusing on water, spoke optimistically about the achievability of SDG6. In his interesting talk highlighting the issue and consequences of unplanned urbanisation, he explained how planning in low income countries usually leaves a lot to be desired. He also discussed in some detail how remote sensing, chip-based analysis, citizen science and the increasing importance of 'utility on a phone' (using applications for payment and monitoring) will be playing an ever-expanding role in delivering SDG6.

The final talk of the morning was from **Dr Graham Alabaster**, Chief of Sanitation and Waste Management at UN Habitat. He explained the background to the development of indicators for the SDGs and the subsequent development of methodologies to capture both baseline and progress information. This itself is very much a work in progress, involving checking what methodologies and data are currently available and investigating discrepancies and mismatches between data sets that should be measuring similar things. He explained how helpful it was for professional bodies such as the RSC to engage and offer input into these tasks.

The afternoon session began with a talk by **Dr Hannah Rigby** from Imperial College, who described her work on the transfer of a number of organic contaminants to the food chain through agricultural land applications of wastes and the implications with respect to water sustainability issues.

Dr Tony Fletcher, an environmental epidemiologist from Public Health England, provided an interesting perspective on the formidable issue of perfluorinated compounds (PFCs) – especially perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). His talk included some very interesting case studies on the problems surrounding the persistence of these chemicals in the environment and in humans.

Dr Caroline Gauchotte-Lindsay from University of Glasgow spoke on emerging contaminants in drinking water and wastewaters – including xenobiotics such as nanoparticles or microplastics, pharmaceuticals and personal care products. She considered analytical methods that are now being used to measure the concentrations of some of these moieties and provided several examples of published results together with their implications. She went on to describe how such considerations can improve the understanding of water treatment plant operation and how this might factor in when designing upgrades and monitoring strategies.

The penultimate talk was given by **Anastasia Kaschenko**, CTO and co-founder of Majik Water. She explained how the age-old concept of dew harvesting had led their SME on a journey of discovery and innovation, investigating how such a seemingly simple technology might be applied and prototyped in low-income countries. She went on to describe how the company realised they had produced a technology without a valid business model, and she discussed how grappling with this disconnect had pivoted the company’s business planning to concentrate on drastically improving the efficiency of existing off-the-shelf materials and components. They now aim to reduce the cost of high-volume air to water units and to compress the lead time between technology development and its application.

The final speaker of the day was the recipient of the RSC ESED Sustainable Water Award for 2018, **Professor Dionysios Dionysiou** from the University of Cincinnati. His presentation discussed contaminants of emerging concern (CECs) and the detailed chemistry of advanced oxidation processes (AOPs). He examined various benefits and disbenefits associated with a number of aspects and types of AOP, explaining the importance of considering factors such as matrix, cost, energy, treatment conditions, transformation products, radical scavenging, toxicity and waste disposal.

Professor Dionysiou was presented with the RSC 2018 Sustainable Water Award by Dr Camilla Alexander-White, Senior Policy Advisor Environment and Regulation, Royal Society of Chemistry.

Presentation of the RSC Sustainable Water Award to Professor Dionusios Dionysiou

The proceedings highlighted the critical value of good data and evidence-based decision-making for achieving a future of sustainable water. Each of the inspiring presentations illuminated and reinforced strategies and tactics employed by the chemical industries.

Slides for the day's presentations can be found here: https://www.dropbox.com/s/snl0lq9cciii60x/Archive.zip?dl=0

Meeting Report

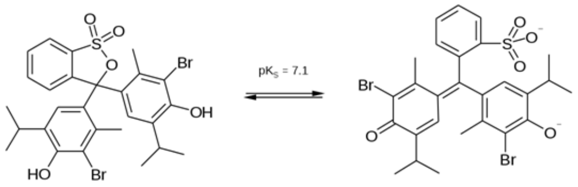
Oxford Festival of Ideas: a public engagement with science event

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

In one of over 100 events running as part of Oxford's 11-day Science and Ideas Festival (IF), members of the ECG ran the outreach stall "Blue Sky Research", engaging 560 of the 13,500 visitors.

On 19th and 20th October 2019 volunteers **Omofolawe Otun, Melanie Witt, Sanaa Rashid**, and **Guy Fletcher-Wood** supported the committee in delivering two hands-on activities and our spectacular Ocean Acidification demo. This dedicated team entertained a diverse audience including very young children, teenagers, experienced scientists (who were often parents) and other adults with an interest in environmental science. The stand was situated in two locations in Oxford: the Saturday activities were run in the Westgate Shopping Centre in central Oxford, whilst the Sunday venue was Oxford Town Hall. These sites enabled us to engage two different audiences; the first consisting primarily of passing shoppers who were unaware of the festival, and the latter drawing in those who had specifically come to explore the festival.

Participants searched for microplastics in soils, analysed the pH of tap water from different UK locations, used sensors to detect air quality and temperature, and a Geiger counter to quantify the background radiation in the venue. Visitors were especially keen to hear more about what chemists across academia and industry are doing to combat environmental change, and to find out what our volunteers were working on. Discussions with the public included the topics of some of our recent Distinguished Guest Lectures, such as the link between the hunt for microplastics in our soil samples to the prevalence persistent organic pollutants (POPs), their regulation, behaviour, and environmental impacts. The air quality monitor sparked some interest in the chemistry of diesel emissions and the energy storage and delivery options for hydrogen fuel and electric vehicles.



The two forms of bromothymol blue exist in solution in equilibrium at pH 7.1, and are colour sensitive to the pH variations of tap water.

Exhibition at the Westgate Centre, Oxford.

The Geiger counter provided an opportunity to introduce visitors to the banana equivalent dose and discuss biodiversity in sites such as Chernobyl National Park. Through the ocean acidification and water testing activities, discussions included what pH is, human changes to the natural environment, and the chemical reactions that underlie the colour changes we see in indicators. After playing with the IR temperature probe, several visitors were interested in its range, accuracy, and how electromagnetic radiation performed analyses, such as temperature measurements.

If you would like to find out more about our activities, please check out our previous *Bulletins* and webpages for details, including 'How To' guides for most of our public engagement activities. 'How to Remove Plastic with Dissolved Gas Floatation' may be found on page 25 of this *Bulletin*, whilst 'Ocean Acidification' is outlined in our July 2019 edition, and 'Microplastics' in our July 2018 edition. All our outreach exhibit information may also be found on our website, 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.

Volunteer with us

Please email rowena.fletcherwood@gmail.com if you would like to participate in a similar ECG outreach event in the future, or suggest one to us. We provide full training and are always interested in new exhibits and activities. If you want our help running outreach activities for your existing event or would like us to help source volunteers, please get in touch, providing details.

Meeting Report

Sensors and networks for environmental monitoring

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

Jointly organised by the RSC's Environmental Chemistry and the Automation and Analytical Management Groups, this meeting saw 53 delegates convene in Burlington House to hear the latest developments on environmental sensors.

The topics ranged from the development of sensor materials and technologies in the lab to the integration of sensors within networks and how to best interpret data from networks. The event also involved two exhibitors and seven poster presentations.

The first talk was delivered by **Krishna Persaud** from the University of Manchester, who introduced the latest advances in the application of low cost organic field-effect transistor-based (OFET) sensors to air quality monitoring. Krishna described the development of the first OFET sensors for NO_2 and CO detection and their pilot deployment in Manchester. Co-location with a local authority air quality station showed good agreement with reference instrumentation.

The next talk was given by **Tanya Hutter** from the University of Cambridge, describing the development of novel optical sensors for environmental applications. Tanya's work focuses on detecting trace volatile organic compounds (VOCs) using optical fibres coated in nanoporous materials. As the analytes adsorb onto the pores due to capillary condensation, the optical properties of the fibres are changed, and a signal in the mid-infrared can be obtained. These sensors are capable of high sensitivities thanks to the high surface area of the nanoporous material.

The last talk of the morning was delivered by **Matt Loewenthal** and **Harry Lloyd** from the English Environment Agency (EA), who described the network of water quality probes currently in place in ~2700 sites across England, each measuring a number of relevant variables in real time (e.g. dissolved oxygen, temperature, conductivity and turbidity). They then discussed a series of case studies in which the monitoring networks provide insights into water quality. These included an assessment of water quality and hydrometric data from the River Lea catchment in London, the impact of Storm Ophelia on Lake Windermere, and that of Glastonbury Festival on local water quality. The morning closed with presentations from the two exhibitors (Air Monitors and Enviro Technology), followed by lunch.

The first session of the afternoon focused on regulation, policy and standardisation. **Rob Kinnersley** from the EA discussed environmental sensors from the perspective of regulation, and stressed the need for improved temporal and spatial coverage to establish the impact of environmental policies. He highlighted how the latest generation of low cost sensors have the potential to fulfil this requirement, but need more robust validation. This was tackled by the following talk, in which **Nick Martin** from the National Physical Laboratory reported on the latest advances in the standardisation of low cost sensors for air quality monitoring. Nick explained how the relevant European Standardisation Committee (CEN) is currently developing a technical protocol assessing the suitability of low cost sensors for different types of environmental applications.

The final session of the day was opened by **Matthew Loxham** from the University of Southampton, who gave an account of the measurement and characterisation of particulate matter (PM) from port-related activities in multiple sites across Southampton. By deploying PM sensors in a number of locations, this work revealed the impact of shipping activities on the urban air quality and opened the way to a full source apportionment model.

Rod Jones from the University of Cambridge spoke next and presented preliminary results from 105 air quality sensors spread across the capital for the Breathe London campaign. He showed how it was possible to use network data to decouple local and non-local (background) signals for each gaseous pollutant. Interestingly, comparison of the background signals derived from London with those from Cambridge and Paris revealed that regional trends showed little variation over large distances ($>$ 100 km).

The final talk of the day was given by **Amy Stidworthy** from Cambridge Environmental Research Consultants (CERC), and focused on integrating data from sensor networks in atmospheric dispersion models. Amy described how the high spatial resolution afforded by low cost sensors can help reduce the uncertainty in the emission values derived from these models, leading to more accurate emission inventories.

Article

The fate, occurrence and extraction of antibiotics in solid matrices

Jamie Harrower (PhD Researcher, Glasgow Caledonian University/James Hutton Institute, jamie.harrower@gcu.ac.uk)

Advances in analysis and sample preparation have allowed the detection of antibiotics in surface water in the range ngL^{-1} to μgL^{-1} (*1*). This has drawn interest due to current concerns surrounding antimicrobial resistance (AMR) and the occurrence of antibiotic resistance genes (ARGs) in the aquatic environment (*2*).

Overview of antibiotics

The discovery of antibiotics is considered one of the most significant scientific achievements of the 20th century. Antibiotics can be broadly divided into two different groups: bactericidal antibiotics (beta-lactams, cephalosporins, fluoroquinolones and sulfonamides) which destroy the bacteria directly, and bacteriostatic antibiotics (macrolides and tetracyclines) which prevent bacteria from dividing and multiplying (*3*).

The misuse and over prescription of antibiotics has aided the emergence of bacteria carrying ARGs. Scientific evidence suggests that many factors play a role in the development and spread of antibiotic resistance within the environment, such as antibiotics and ARGs accumulating within wastewater treatment plants (WWTPs) (*2*), the release of biocides, use of antibiotics in agriculture, and the direct animal to human transmission of resistant bacteria (*4*).

The World Health Organisation (WHO) and its Global Action Plan broadly outlines five strategic objectives to tackle AMR, which can be described as improving awareness and understanding of AMR, strengthening knowledge through surveillance and research, reducing the incidence of infection, optimising the use of antimicrobial agents, and ensuring sustainable investment in combating AMR (*5*).

Sources and fate in the environment

Antibiotics are only partially metabolised within the human body, and the fraction that is excreted by humans will enter the WWTP and follow one of three fates;

- biodegradation (*2, 6*),
- adsorption onto sewage sludge (*7, 8*),
- exit the effluent as the unchanged drug (*9, 10*).

This is the primary entry of antibiotics into the environment in the UK (*11*). There are, however, a number of other sources including landfill sites, septic tanks, improper disposal and hospital and domestic effluent (*2, 12*). Once in the environment, antibiotics can move and partition into different environmental compartments (water/solids).

The physicochemical properties of antibiotics heavily influence their chemical fate and behaviour at different aqueous pHs and within differing soil compositions. Metabolites, in turn, are able to partition and migrate into other phases in the environment, making it challenging to predict their behaviour and chemical fate (*13*).

Antibiotics usually have more than one acid dissociation constant (K_a) and can therefore form ionised and zwitterion structures (*14*). Unlike other hydrophobic contaminants, such as the polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs) or pesticides such as dichlorodiphenyltrichloroethane (DDT), the value $\log K_{ow}$ (log octanol/water partition coefficient) is not enough to measure chemical fate and distribution of antibiotics. It needs to be modified to take into account the ionised fraction. Even this approach may not be sufficient as the neutral species are highly polar. A study conducted by Tolls (*15*), demonstrated that antibiotics, despite being quite hydrophilic compounds, displayed a wide range of mobilities within soil based on their $\log K_{ow}$ values. This illustrates that other interactions, such as electrostatic, are potentially occurring, indicating that charged antibiotic structures are influential in chemical fate.

Aerial View of of storage tanks in sewage water treatment plant. Josekubes via Shutterstock.

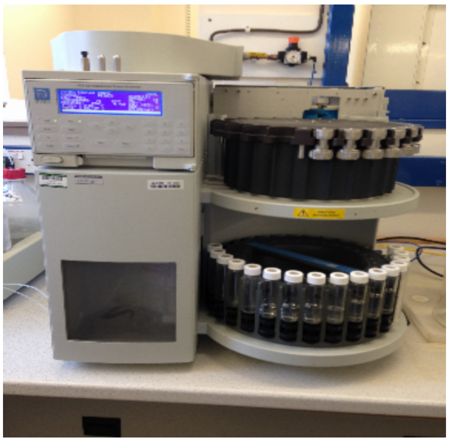
Occurrence in river sediment, sludge and soil

River sediments have been identified as a major sink for antibiotics, as the concentrations of antibiotics detected in sediments are often much higher than those detected in the water column (*16*).

Using extraction techniques such as accelerated solvent extraction (ASE), quick, easy, cheap, effective, rugged and safe extraction (QuEChERS), and ultrasonic-assisted extraction (further described below) antibiotics can be extracted from solid phases such as soil and sediment. Understanding what drives the interactions of antibiotics between phases is very important to determine compound fate and assess the risk they pose. In a study by Chen (*17*), a variety of pharmaceutical compounds, including antibiotics, were detected in water and sediment. Using the data, they were able to calculate $\log K_{ow}$ and $\log K_{oc}$ (organic carbon to water partition coefficient) (*18*). They concluded from the study that there was a correlation between $\log K_{ow}$ vs $\log K_{oc}$, and $\log K_{oc}$ vs molecular weight (MW) of compounds, indicating the importance of these parameters when considering inter-phase behaviour. This study detected five different classes of antibiotics: chloramphenicols, sulfonamides, fluoroquinolones, tetracyclines and macrolides. Sulfonamides demonstrated the highest concentrations in water samples (34-859 $\mathrm{ngL^{-1}}$). Tetracyclines (average concentration 18 $\mu\mathrm{gkg^{-1}}$ dry weight) and macrolides (12 $\mu\mathrm{gkg^{-1}}$ dry weight) dominated sediment samples. Similarly, Zhou *et al.* (*19*) investigated sediment-water interactions in organic contaminants and concluded that there was also a positive relationship between $\log K_{oc}$ and MW, suggesting that partitioning is driven by the physical properties of the contaminants.

Selective Pressurised Liquid Extraction

Selective Pressurised Liquid Extraction (SPLE) is an analytical technique used to extract organic contaminants from solid matrices at elevated temperatures and pressures. The sample cell for extraction consists of the sample, retainer/sorbent, Na_2SO_4 to remove moisture and filter papers (*20*).



Solvent extraction equipment used by the author

Studies such as Vazquez Roig *et al.* (*21*) have employed SPLE followed by solid phase extraction (SPE) as a clean-up step and liquid chromatography – mass spectrometry (LC-MS) to detect pharmaceuticals in soils and sediments, including several antibiotics (Ciprofloxacin, Norfloxacin, Ofloxacin, Oxytetracycline, Sulfamethoxazole and Tetracycline). The advantage of using SPLE is that it can be very selective at targeting specific compounds, but the drawbacks are that it requires a large amount of sample preparation and high solvent usage.

QuEChERS Extraction

QuEChERS was originally developed for extracting and recovering pesticide residues in fruits and vegetables (*22*). It requires the addition of Milli Q water and acetonitrile (15 mL) to a glass tub containing the soil sample. The sample is then agitated, and a buffer solution (AOC buffer – sodium acetate/magnesium sulphate) is added, and further agitated with a vortex mixer. The sample is placed in a sample homogeniser and centrifuged at 5000 rpm for 2 minutes. The organic fraction (acetonitrile) is then transferred to a glass vial and evaporated to dryness and analysed for the target analytes (*23*). Sample clean up by SPE after the extraction step is required. By utilising the QuEChERS Salvia *et al.* (*23*) successfully extracted a number of antibiotics, including sulfonamides, macrolides and penicillins.

The QuEChERS method is still a fairly new technique for extracting antibiotics in solid matrices, however, it is rapid, easily set up, and low cost.

Ultrasonication

Ultrasonic-assisted extraction (UAE) is another technique that has been used to obtain antibiotics from solid matrices (*16, 19*). The extraction step involves accurately weighing the sample (soil/sediment) into a glass tube, followed by the addition of appropriate working standards. Organic solvent (acetonitrile) and citric acid buffer are added, and samples then placed on a vortex mixer, followed by ultrasonication and centrifugation for 10 minutes. The supernatant liquor is then pipetted off and the organic fraction evaporated at 55°C to remove the organic solvent, and finally diluted to 200 mL using water. The extract is then further purified using two SPE steps involving a strong anion exchange (SAX) and a reverse phase HLB cartridge. Using the above technique, the authors (*24*) were able to detect and extract 17 commonly used antibiotics of four classes. The investigation concluded that river sediment plays an important role in acting as a sink for antibiotics, particularly tetracyclines and fluoroquinolones. Recoveries using this method were reported as being >75% for all antibiotics detected.

Sample preparation and analytical procedures

GC-MS and LC-MS are the most commonly applied techniques for detecting antibiotics within solid environmental matrices. Many studies have utilised the triple quadrupole mass detector (MS/MS), which offers the ability for enhanced mass fragment analysis of micropollutants. Sample pre-treatment is crucial when analysing trace contaminants at concentrations in the mg L^{-1} or μg L^{-1} scale in environmental samples, but is particularly important for extracting solid mixtures.

Legislation

The release of antibiotics into the environment will continue as humans and animals still rely on antibiotics. Therefore, the challenge to remove and prevent antibiotics entering the environment remains an international task.

The Water Framework Directive (Directive 2000/60/EC) aims to meet environmental quality standards in all surface and ground waters (rivers, lakes, transitional waters and coastal waters), with a focus to protect the ecology and wildlife. The directive 2013/39/EU, amending the Environmental Quality Standards Directive 2008/105/EC under the European Water Framework Directive (WFD) has introduced a 'Watch-List' monitoring mechanism to collect high-quality EU-wide monitoring data of potentially polluting substances in the aquatic environment. The Watch-List contains a number of organic pollutants, which should be carefully monitored by EU Member States. The first Watch-List was published in 2015, and now contains the antibiotics Erythromycin, Clarithromycin, Azithromycin (macrolides) and Ciprofloxacin (fluoroquinolone), all of which are regularly prescribed by the National Health Service (NHS).

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Article

The last straw

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

In 2001 and 2014, the Environmental Chemistry Group organised one-day scientific meetings on PVC and Persistent Organic Pollutants in the Environment (*1*) and Plastic Debris in the Ocean (*2*). In 2015, a picture of an entangled turtle was the inspiration that later led to the 2017 anti-straw campaign against the single use plastic items. The subsequent success of the campaign has sparked some controversy. This article explores its progression and pitfalls.

The public would claim they are motivated by environmental concerns, but there is reason to be sceptical – the decision to boycott plastic straws has broken no camels' backs. It has had little or no impact on the majority of individuals and, although making one small change might inspire another, there is also the potential to promote inactivity elsewhere. For example, making dietary changes such as reducing meat and dairy intake has been shown to be the most impactful change an individual can perform when it comes to environmental protection (*3*). Those who feel the environmental "motivation" is simply virtue signalling have suggested that an alternative motivation may instead be to safeguard a human food source (fish).

Are straws a big problem?

Boycotting straws empowers ordinary people – but to what extent? Data models are largely based on a mixture of aerial images of plastic waste in the ocean and a broad scope of different collection methods, such as measuring the volume, number or mass of plastic debris. These measurements are complicated by variations in transport and accumulation on a seasonal and annual basis (*4*), and the contribution of plastics less dense than seawater (~60% of all plastic debris) may be overrepresented (*5*). In this respect, the visibility of plastic straws is magnified because they float and are washed up on beaches, whereas more dense fishing nets are notoriously difficult to spot. Yet nets are estimated to comprise 46% of the Great Pacific Garbage Patch, by mass (*6*).

Straws are only a tiny part of the plastic waste problem

Straws are only a tiny part of the plastic waste problem, comprising a maximum 1,800 tonnes of the annual 8 million tonnes of plastic going into the oceans each year – or 0.02% (*7*). Indeed, removing plastic straws from the marketplace could increase the use of disposable plastic. Starbucks, for example, are replacing straws with spouted nitro lids that contain a relatively larger volume of plastic. Such a myopic focus on straws may serve only to disadvantage individuals who rely on these items. Moreover, paper, wood, glass or metal alternatives are frequently ineffective and may even cause injuries (*8*). They are also more expensive, and disabled people are disproportionally represented amongst those most socially disadvantaged by the substitution.

Big players in the plastic waste problem

On the other hand, abandoned, lost or discarded fishing equipment, known as 'ghost gear', accounts for around 640,000 tonnes of ocean pollution annually – or 8% of the total (*9, 10*). They make up as much as 70% of floating macroplastics (*11*), endangering 17,257 species of marine wildlife from whales, fish and turtles to seabirds and marine mammals such as seals (*12*). Rampant equipment abandonment of ghost gear undercuts the sustainability of fisheries, killing large numbers of sea life in the open ocean.

Microplastics account for 8% of the plastic debris located in the Great Pacific Garbage Patch (*6*). These small pieces of plastic debris are often derived from the breakdown of larger items, and formed a key focus of our 2014 symposium (*1*). They are a crucial vector for the transport of the key environmental contaminants called persistent organic pollutants (POPs). The solubility, reactivity, hydrophobicity and volatility of POPs causes serious environmental problems. POPs include species such as polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), halogenated flame retardants, and polybrominated diphenyl ethers (PBDEs) (*2*). These lipophilic chemicals readily accumulate in plastics and, when swallowed, migrate into the body fats of animals. POPs are also known to bioaccumulate up the food chain.

Solutions

Solutions to the plastic waste problem that extend beyond straw avoidance include policy changes in ghost gear monitoring and marking, reporting, and clean-up, community engagement, animal rescue operations, and the development of (and investment in) more sustainable business models. These operations would be assisted by more uniform and better data collection across the sector. On an individual basis, fish-eaters can then make informed sustainable choices.

Chemical analysis of microplastic fragments aims to identify the primary and secondary sources of persistent organic pollutants, their cycling and transportation. Environmental chemists are in a position to advise and implement remediation processes, including atmospheric dilution, burial, occlusion and sedimentation, chemical breakdown, and biodegradable substitutes (*2*).

In his 2014 Distinguished Guest Lecture on the topic, Professor Richard Thompson recommended a reformation in plastic design to plan for end-of-life biodegradation, recycling and energy recovery (*13*). In his call for end-of-life reuse and succession planning, he advocated a societal paradigm shift in our attitude to plastics, to which the ripples of the anti-straw campaign may claim some contribution.

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Meeting Report

Joseph Priestley’s journey of discovery – A celebratory exhibition

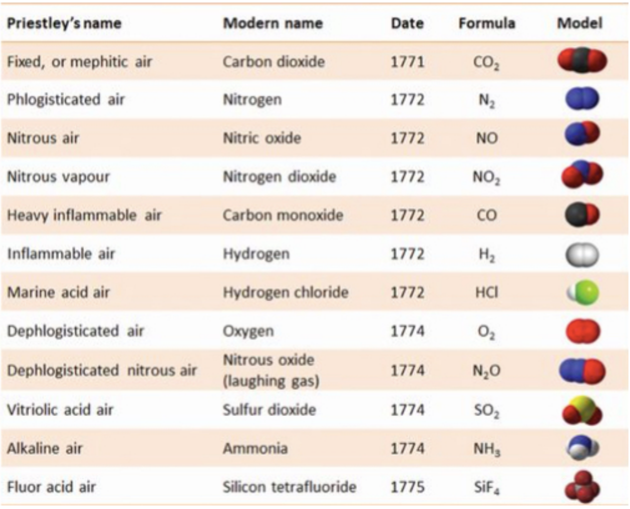
Dr Glynn Skerratt and Dr Helen Cooke (glynn@skerratt.com)

Most of us think of Joseph Priestley as the discoverer of oxygen, but across his life, he demonstrated much wider achievements. Had he not become a great scientist, Priestley would have been recognised and remembered as a philosopher and a pioneer of education and religious and civil liberty.

Early life

Priestley was born near Leeds, on 24 March 1733 – the eldest of six children in a family of modest means. His mother died when he was six, and Priestley was adopted by his aunt. He first revealed his interest in science at eleven, when he performed his first experiment by trapping spiders in bottles to see how long they could live without fresh air.

At nineteen, he was sent to Daventry Academy to prepare for joining the ministry. Daventry was a ‘dissenting academy’, set up for those barred from Oxford and Cambridge universities. Priestley became a ‘heterodox’ – a person who held a different religious opinion from standard beliefs and teachings of the time – and duly became a minister in 1755, appointed to Needham Market chapel in Suffolk. Many of the congregation disliked his ideas and boycotted his services, so in 1758, Priestley moved to preach at a Presbyterian chapel in Nantwich in Cheshire, where he was more welcome. Here, he found time to open a school teaching a curriculum that included science and, unusually for the time, permitted both boys and girls. He encouraged older students to carry out experiments and to demonstrate these to their parents. Whilst in Nantwich, he wrote a pioneering book on English grammar, earning enough to buy scientific equipment for his experiments, such as a small air pump and an electric machine. He taught his more senior pupils in to use the instruments themselves and maintain them.



Priestley’s name	Modern name	Date	Formula	Model
Fixed, or mephitic air	Carbon dioxide	1771	CO_2	
Phlogisticated air	Nitrogen	1772	N_2	
Nitrous air	Nitric oxide	1772	NO	
Nitrous vapour	Nitrogen dioxide	1772	NO_2	
Heavy inflammable air	Carbon monoxide	1772	CO	
Inflammable air	Hydrogen	1772	H_2	
Marine acid air	Hydrogen chloride	1772	HCl	
Dephlogisticated air	Oxygen	1774	O_2	
Dephlogisticated nitrous air	Nitrous oxide (laughing gas)	1774	N_2O	
Vitriolic acid air	Sulfur dioxide	1774	SO_2	
Alkaline air	Ammonia	1774	NH_3	
Fluor acid air	Silicon tetrafluoride	1775	SiF_4	

Joseph Priestley’s gases

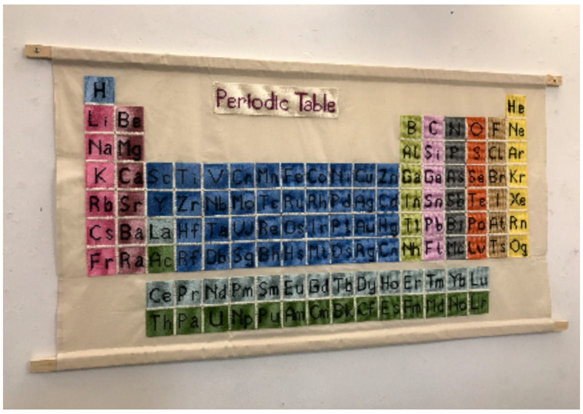
In 1761, Priestley was appointed to Warrington Academy, where he married Mary in 1762, and had four children. He established his scientific reputation by publishing a treatise on electricity. Six years later, he moved to Leeds for five years, continuing with his science and ministry.

Major discoveries

It was in Leeds where he investigated carbon dioxide and the carbonation of water. He later went on to explore the composition of water, the mechanism of photosynthesis and respiration, and investigated no fewer than 12 distinct gases, including oxygen. This prompted Humphry Davy to say, “No other person ever discovered so many new and curious substances”.

Moving to Calne in Wiltshire, he worked under the patronage of Lord Shelburne 1772-1780, when many of his important scientific discoveries were formulated. Indeed, it was in 1774 that, whilst heating mercury calx (red oxide of mercury) in a glass tube using a burning glass to focus sunlight, he discovered ‘dephlogisticated air’. The Theory of Phlogiston originated in 1669, and argued that a metal consisted of an inflammable ‘phlogiston’ and ‘calx’, or ash. In Priestley’s experiment, the mercury calx was assumed to be pure mercury metal, and thus heating it meant that phlogiston was taken from the surrounding air in the tube, thereby leaving ‘dephlogisticated air’. This led to six volumes on Experiments and Observations on Different Kinds of Air (1774–86).

Later in 1774, while touring Europe with Shelburne, Priestley described his discovery of ‘dephlogisticated air’ to the French chemist Antione Lavoisier. Lavoisier found that Priestley’s ‘dephlogisticated air’ would react with metal to form calx. Three years of experimentation later,



A periodic table created by Nantwich Museum's Craft Group

Lavoisier renamed the gas as oxygen and published his experiments, forming the basis of what we now know as oxidation and reduction, and finally putting the Phlogiston Theory to rest.

Later life

In 1780, Priestley became a minister in Birmingham, where he stayed for 11 years. He joined the Lunar Society and, alongside fellow Lunar Men such as Erasmus Darwin, James Watt, Matthew Boulton and Josiah Wedgwood, changed the face of 18th century England with their debates encompassing philosophy, arts, science and their individual achievements; building canals, factories and managing international businesses. However, resentment towards religious dissenters was building, culminating in the 1791 Birmingham Riots (aka the Priestley Riots!). Priestley and his family fled to safety before their home was ransacked and burnt down. His library, scientific equipment, and papers were destroyed.

Exhibition panels in the museum's Millennium Gallery

Dr Fabio Parmeggiani from Manchester University preparing an open lecture as part of the museum's Priestley exhibition.

Priestley, feeling increasingly unsafe, emigrated to America in 1794. He continued his scientific work there, dying in Northumberland, Pennsylvania, in 1804.

From Nantwich to Oxygen: a Journey of Discovery

From 14th August until 26th October 2019, Nantwich Museum ran a successful temporary exhibition celebrating Priestley's time there, to honour his life and works. It coincided with the International Year of the Periodic Table celebrations, marking the 150th anniversary of the Mendeleev periodic table. A number of groups within the Royal Society of Chemistry supported the exhibition.

Priestley once said, "…at Nantwich, I found a good-natured, friendly people, with whom I lived three years very happily". The school he established continued for over 80 years after he left, welcoming 30 boys and six girls from 'dissenting families'. Priestley worked at the school for six days each week, 7am-4pm, with an hour for dinner. We have much more than Priestley's enduring brilliance at chemistry to admire and thank him for.

Further reading

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Public Engagement How To:

How to remove plastic with gas floatation

David Owen (Treatchem Ltd, ynys.services@gmail.com)

A demonstration of how pressurised gas dissolved in water can separate out low-density microplastics by floatation.

Theory

Low-density microplastics usually have a density greater than, but near to, that of water. By attaching bubbles to the plastics from pressurised gas dissolved in water, the microplastics can be made to float to the surface where they may be scraped off. Some microplastics may be more difficult to float if they contain heavy fillers such as magnetite (e.g. toner in photocopiers) or barium sulphate.

Typically, the gas (air or nitrogen) is pressurised to about 5 atmospheres. For this demonstration and in the interest of safety, carbon dioxide is used, as commercial ‘fizzy’ water is readily available as a source of compressed gas dissolved in water. Sometimes, when dealing with very small pieces of plastic, a modest amount of a chemical known as flocculant is added to make the particles agglomerate to trap the bubbles.

A similar process, known as induced air floatation, uses low-pressure gas bubbled into the water through a sinter or frit. This is less efficient but can work adequately dependent on the material to be floated.

Set up

Chop or grate several coloured straws as small as possible and put about half a gram of the pieces in a jam jar-sized container (e.g., a tall 500 mL beaker). The container may be glass or see through plastic. Add roughly 100 mL of water to thoroughly wet the plastic so that it sinks and is not supported by surface tension. Drain off as much water as possible leaving the wetted plastic behind.

Take a bottle of fresh supermarket fizzy water and, through a long-necked funnel, add approximately 500 mL to the container, ensuring is added to the bottom of the container via the funnel. Remove the funnel and gently swirl the water for 10 seconds to allow the dissolved gas to release around the plastic. Put down the container and observe. The plastic pieces will float up to the surface and leave the bottom layer clear.

A further experiment can show that by adding small amounts of flocculent solution, floatation occurs much faster.

Challenge

Float out the plastic.

Kit List

- 2 litre bottle(s) of supermarket fizzy water
- Coloured straws or nylon thread
- Scissors/grater/ domestic blender
- Jam jar or beaker
- Long necked plastic funnel capable of reaching the bottom of the jar when filling
- Solution of flocculent, if needed, along with small syringe to dose the water
- Disposable plastic gloves if using flocculant
- Roll of paper towel to dry up spillages

Exhibition Cost

<£50

Exhibition weight

The weight is largely dominated by the weight of the water bottles used.

Exhibition size

Would fit into a printer paper box.

Resources required

MSDS of flocculent.

Things to look out for

Ideally have a separate table at viewing height so that more than one viewer may see what is happening. It will take up to 3 minutes for floatation to occur without flocculent. Flocculent solutions of 0.1% are viscous and sticky, so have paper towels handy and use disposable gloves to avoid contact with skin.

ECG Environmental Briefs **ECGEB No 21**

Environmental analysis – Digestion methods for geological materials

David Wray (University of Greenwich, d.wray@greenwich.ac.uk)

The analysis of geological materials has been a core sub-discipline of the chemical sciences for more than a century. Analytical methods have evolved to become more rapid and sensitive. However, many of the preparatory techniques have only seen marginal development, largely due to the challenging natural properties of the materials under investigation. Related to this is the continuing need to work with potentially harmful reagents such as hydrofluoric and perchloric acid.

Historically, analysis of geological materials was carried out using classic wet chemistry procedures followed by gravimetric, spectroscopic or colorimetric quantification. Many of these methods still underpin more modern approaches, if only because of the continuing need to convert solid samples into liquids before their introduction into modern instruments.

Digestion using acids

Geological samples invariably contain silicate minerals for which dissolution requires the breakdown of the silicate lattice. The only acids readily capable of fully dissolving silicates are hydrofluoric acid (HF), combined with an oxidising acid such as nitric acid, a combination of nitric and hydrochloric acid as aqua regia, or perchloric acid. The risks to health and safety associated with these acids must be considered: HF whilst relatively weak ($K_a = 6.6 \times 10^{-4}$), has the potential to be extremely harmful because it causes the decalcification of bone; perchloric acid is a powerful oxidising agent when hot; and aqua regia, in addition to being a strong oxidising agent, will self-pressurise a containing vessel. Safer alternatives are being evaluated, most notably ammonium fluoride or ammonium bifluoride (*1*), but these are not risk free.

By far the best combination for open beaker digestions remains a combination of HF and perchloric acid (*2*), wherein HF readily dissolves silica to form SiF_6^{2-}, which is then lost from solution as SiF_4 gas. HF on its own is rarely used because of the potential to form insoluble fluorides such as CaF_2. The relatively high azeotropic boiling point of perchloric acid (203°C) improves digestion efficiency and assists in the removal of SiF_4. If organic material is present in a rock sample, then initial digestion with nitric acid is recommended before the $HF/HClO_4$ mixture is added. If a perchloric acid compatible fume cupboard is not available, then aqua regia can be substituted, although it is not as efficient. However, it can dissolve gold and other platinum group metals, which may not be fully digested with $HF/HClO_4$.

There are limitations associated with the approaches described above: the use of HF may will result in the loss of volatile fluorides such as those of B, As, Ge and Sb (as well as Si), and the use of a chloride-containing acid under heat will result in at least the partial the loss of Ge, Hg, Sb, As and Sn as volatile chlorides. To retain volatiles, PTFE 'bombs' or, more recently, a HF resistant sealed vessel within a purpose built microwave digestion system, have been investigated. The latter approach, although with a higher initial investment, has gained popularity because of its efficiency and ease of automation. Manufacturers advise against the use of perchloric acid in microwave digestion systems because of its violent reaction with organic compounds when hot and the risk of producing unstable perchlorate salts should a vessel part-fail and dry out during the digestion cycle; aqua regia or nitric acid are recommended instead. At the end of the digestion process, samples are cooled whilst sealed to encourage the condensation of volatiles, which are then removed by rinsing. This leaves the analyst with the challenge of dealing with an HF-rich solution and its associated safe handling challenges. Two options present themselves: either progress directly to an instrument with an HF-tolerant sample introduction and fume extraction system, or to complex the free HF with saturated boric acid. The use of boric acid increases the

Fused disc manufacture: molten flux and sample mixture poured from the crucible into the disc casting platen.

dissolved solids in the final solution (~2.8g of boric acid per 100mL of solution is used (*3*)) and, therefore, dilution is required prior to ICP analysis. Fluoroboric acid (HBF_4) is produced reversibly, and by increasing either the hydrogen ion concentration or the concentration of divalent cations, such as calcium, it is possible to hydrolyse HBF_4 and release HF (*4*).

A well-documented limitation of all acid digestion approaches is the challenge of dissolving acid-resistant mineral phases including rutile (TiO_2), tourmaline ($Na(Mg,Fe,Mn,Li,Al)_3Al_6Si_6O_{18}(BO_3)_3(OH,F)_4$), beryl ($Be_3Al_2Si_6O_{18}$), zircon ($ZrSiO_4$), chromite ($FeCr_2O_4$), and cassiterite ($SnO_2$), all of which are important repositories of key trace elements in geological samples. Whilst the heat and pressure of microwave digestion has improved matters, the challenge remains. This is exemplified by Potts *et al*. (*5*), who demonstrated that an uneconomically long (48 hour) HF-based digestion in a sealed bomb at 180°C was required to extract zirconium and related elements.

Whilst some geochemical studies invariably require the quantification of total elemental abundance, the use of partial digestions without HF are widely used in geoexploration and geoenvironmental studies on a fit for purpose, cost and safety basis. Modern microwave-assisted digestion systems are capable of digesting 40 or more samples simultaneously primarily using nitric acid, sometimes in combination with hydrogen peroxide, with aqua regia for metals in the platinum group (*6*).

Fusion-based preparation

Combining a small quantity of powdered sample with a flux, followed by heating in a platinum/gold (95%/5%) crucible, produces either a fused glass disc for analysis by X-ray fluorescence spectroscopy (XRF), or a solution for analysis via ICP. This is a core preparatory technique in the geosciences. Fusion fully breaks down most common geological minerals prior to instrumental analysis without the loss of silicon, including many samples that are resistant to acid, and it is therefore advantageous from a safety perspective. The use of small amounts of light element fluxes (e.g. 0.5g sample : 6.5g flux) overcomes the limitations of using pressed pellets of rock powder in XRF, where critical penetration depth effects and absorption/enhancement of the X-ray signal perturb results. Because of dilution effects and the sensitivity of XRF instruments, fused discs tend to be used for quantification of the most abundant elements samples. Pressed pellets are used for the determination of elements present at lower concentrations, typically less than 0.1 wt %, and careful matrix matching between standards and samples is required. Fused disc production is readily automated and takes approximately 20 minutes using a modern fusion instrument. Flux composition may be dependent upon sample type (*7*). Our laboratory routinely uses a 50:50 mixture of lithium metaborate and lithium tetraborate combined with a small amount of lithium bromide to act as a non-wetting agent for the platinumware.

Because of advances in the sensitivity of ICP-based analytical techniques, allowing quantification of elements such as the lanthanides, flux and sample solution has proved useful in producing diluted samples that reduce the risk of 'salting up' the nebuliser. We routinely quantify 50 elements this way, and achieve excellent results in proficiency testing round robin evaluations. The flux usually consists of lithium metaborate mixed in a 5:1 ratio with the sample powder. The molten, fused mixture is poured hot into a quantity of stirred, dilute nitric acid, causing the fused bead to shatter and dissolve within 30 minutes. Some automated fusion instruments can be modified to produce fusion-based solutions instead of fused discs; for simplicity and economy, we fuse samples in pressed graphite crucibles heated in a muffle furnace. This approach generates 36 fusion solutions per day. The approach precludes the quantification of volatile elements such as mercury, arsenic and cadmium.

At low abundances, noble metals may be quantified via the related nickel sulphide fire assay technique (*8*). The pellet from this preparation is typically dissolved in acid and analysed with ICP, negating the need for the less common quantification by neutron activation analysis.

Whilst no one preparatory method provides the 'silver bullet' for quantification of all geochemically important elements, improvements in the sensitivity of analytical techniques have allowed analysts to quantify elements at ever lower concentrations, providing stricter standards of cleanliness are adhered to in the laboratory and higher purity reagents used. Nevertheless, geoscience reference materials must be included alongside unknown samples to validate the chosen prep method and sampling strategy remains critical.

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ECG Environmental Briefs **ECGEB No 22**

Water soluble polymers' role in improving the clarification of water

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Water must be clarified for many applications. This requirement encompasses potable water, industrial water supply, and the treatment of industrial and sewage effluents. All of these water clarification operations must meet measurable standards to suit their specific use.

In the last fifty years, much progress has been made in the changing types of treatment chemicals used for water clarification. New products have replaced older technologies such as cationic substituted starch, resulting in enhanced performance. The environmental impacts of processes have been improved to reduce the amount of waste solids generated and to allow the safe release of certain materials back into the environment.

Coagulation

Raw, potable water can be taken from a variety of sources such as rivers, reservoirs, underground aquifers or lakes. Depending on the turbidity, suspended solids, and colour, primary treatment entails coagulation (charge neutralisation) to provide a colourless water, free of suspended solids and suitable for secondary treatment by filtration and sanitisation. Higher valent coagulants, such as aluminium salts, are good coagulants and flocculants.

Raw water quality

Raw water quality is assessed by measuring:

- turbidity
- colour
- pH
- alkalinity; and
- temperature.

In the past, coagulation was achieved through the use of aluminium or ferric salts of sulfate or chloride. The trivalent metal ion neutralises the anionic charge associated with the dispersed material in suspension and solution. Once neutralisation is complete, the particles self-agglomerate after intimate mixing. This agglomeration produces very small, discrete flocs, which slowly settle to leave a clear, supernatant liquid. Flocs are nominally composed of the metal hydroxide $M(OH)_3$, along with the contaminant species from the raw water. This treatment generally works well. Nevertheless, complications arise when the process is scaled up.

Eco footprint

The coagulant demand of a water treatment system reflects how much cation M^+ is needed to remove the contaminants. This presupposes that there is enough alkalinity in the water to allow the hydrolysis of the metal salt, and that the final pH is within the range of maximum insolubility of the metal: around 6-8 for aluminium and 5+ for ferric ion. For some surface waters, such as moorland runoff or water from granite-like bedrock, sodium hydroxide or lime must be added to augment the low natural alkalinity. Trivalent metal salts are relatively acidic, and if the dose required adds more acid than the natural alkalinity of the water, the pH will drop below pH 5, whereupon no precipitation will occur.

The density of sludge produced during water treatment by coagulation is very high due to the retention of water by the metal hydroxides, even after treatment. Usually no more than 35% dry matter is attainable under ideal conditions of pressure and time. However, the performance of most mechanical dehydration systems normally returns sludge with somewhere between 10% and 28% dry matter. Originally, the water treatment industry used drying beds where sludge was fed into a lagoon and solids sank to the bottom before excess water was decanted off. The remaining sludge concentrate would then be disposed of to landfill. The amount of sludge produced was large by any standard and represented a major disposal problem. However, with the introduction of stricter laws on waste disposal, the chemical industry developed new polymeric technologies to tackle these inherent problems.

Polymer solutions to sludge management

Potable water treatment is somewhat of an anomaly. Although synthetic coagulants were available for use in potable water, concerns about residual product in water were expressed by potential users. At the same time, aluminium levels in treated water became a major health concern with aluminium linked to Alzheimer's disease. The water companies responded by increasing the quality of process and analytical control of product water to ensure absolute minimum amounts of aluminium. Alternatively, they changed to ferric based coagulation.

The net result was that little product technology change has been in the industry. In the UK, metal salts are predominately used for drinking water clarification, and polymers tend to only be used for sludge dewatering. There may be extra solids removed from these wastewaters, thus adding to the amount of sludge produced. Here, organic polymers have reduced the need for, or replaced, the large volumes of metal salts otherwise required for coagulation, whilst other polymers are used to improve floc size and strength, making sludge dewatering more rapid and simple.

Coagulants

Synthetic organic coagulant systems were introduced approximately 50 years ago with the advent of polyamine-type compounds, of which there are two types: condensation polymers of organic secondary amines with epichlorohydrin to produce relatively low molecular weight polymers, usually sold as liquid products with a solid content of up to about 50%; and polyDAMAC (poly(diallyldimethylammonium chloride), a free radical polymerisation product of relatively low molecular weight, a liquid product sold in varying concentrations. These polymers have a very high cationic charge, often referred to as having ‘100% charge density’. This charge density is provided by pendant quaternary ammonium groups on the backbone. They act as coagulants, but remain in solution without precipitation as a salt. They are adsorbed strongly onto the contaminants. The polymers do not require alkalinity to function; nevertheless, pH usually needs to be maintained between 5 and 10 for optimum performance. The polymers do not add significantly to the solids burden and they structure the flocs to optimise efficient draining. They are also ultimately biodegradable, and are permitted for use in potable water within certain dose rate limits.

The primary sludge produced by these coagulants is still slow to dewater without further treatment. For rapid dewatering and high ultimate dryness by mechanical means (pressing or centrifuging), another type of synthetic polymer is needed to enhance drainage. The products that became commonplace to resolve this issue are known as flocculants.

Flocculants

Flocculants are used to rapidly dewater sludges, act as process drainage aids in the paper industry, and generally improve clarification to such an extent that the size and capital cost of high throughput water treatment plants is significantly reduced.

Many flocculants are polyacrylamides (“polys”) produced from the copolymerisation of acrylamide with a substituted acrylamide, usually with a pendant quaternary amine group, to make a random linear copolymer with a specified cationicity. Anionic copolymers can be similarly made using acrylic acid as the co-monomer.

Anionic and cationic polymers have different uses. Cationic polymers produce stronger flocs to facilitate subsequent handling. Anionic polymers flocculate mineral solids where large flocs are produced at low dose rates. The various products that can be made have distinctive flocculation characteristics dependent upon cationicity, molecular weight and structure. By introducing chain branching and cross-linking monomers, complex structures can be synthesised which provide beneficial effects such floc shear resistance, useful for centrifuge applications.

The products now available cover a massive range of processing properties. For example, 100% polyacrylamide powder product is slow to dissolve and makes low concentration solutions requiring large dissolving systems. This meant that smaller users had to spend capital on equipment to use the products. The introduction of emulsion products was a timely innovation which allowed much greater market penetration. The polymer is formed in a solvent oil carrier liquid, which contains the reactants. The oil is emulsified with dispersants to form a very stable emulsion. After an initiator is added under inert atmosphere, the polymer is formed and contained in the oil droplets. The product contains up to 40% active product and is stable for extended periods of time. Higher concentrations may be achieved by evaporating some of the water as an azeotrope to leave 50% solids. The main benefit is that this product can be pumped and dosed. It may be inverted so that the active material is released from the oil into water. This lowers the ageing time and the ease of handling.

Summary and Conclusions

Without the introduction of polymeric coagulants and flocculants, water clarification and sludge dewatering would be very problematic both economically and environmentally. The environmental impact has been enormous, from sewage sludges to be dewatered or dried for incineration to industrial wastes that need volume reduction prior to landfill. Such is the ubiquitousness of these chemistries that they are now regarded as commodities. Many people, including chemists, are unaware of their existence, let alone their contribution to modern society. To the customers, they are a ‘black box’ product with an air of alchemy. However, high level of understanding of the mechanisms by which they work is nearly always needed for actual applications of this technology to obtain optimum results.

Upcoming Meetings

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

When: 9th-10th July 2020

Where: University of York

Synopsis

#EnvChem2020 provides a forum for 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.

Look out for further details on our website: http://www.rsc.org/events/detail/42767/envchem2020-chemistry-of-the-whole-environment-research

Registration

Early Bird Member	£145
Early Bird Non-member	£170
Early Bird Member Students	£120
Member	£165
Non-member	£195

The cost includes lunches and the conference dinner. The cost of accommodation is not included.

Plastics, from cradle to grave – and resurrection II

A joint one day meeting held in collaboration with the Toxicology and Food Groups and the SCI.

Where: SCI, 14/15 Belgrave Square, London SW1X 8PS

When: 9th June 2020

Synopsis

Following on from the successful conference held last year, this second meeting has been organised to expand on the key themes of that meeting.

The conference brings together academic and industrial speakers with a thematic link between the current use of plastics, toxicology and standardisation, the complex issues with respect fit for purpose sampling and analysis, and the future of plastic usage.

Abstracts for the poster session are welcomed.

Information and registration (including early bird and low wage discounts): https://www.soci.org/events/plastics-from-cradle-to-grave--and-resurrection-ii

Topics include

- Plastics – overview of the past year
- Toxicity (or not) of plastics and microplastics
- Plastics in a clinical environment
- Plastics and the natural environment
- Analysis of plastics/microplastics – challenges
- Alternatives to plastics and plastics removal
- Natural alternatives
- Plastics and design

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

A one-day meeting for PhD students, postdoctoral researchers, and early career scientists in industry.

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

When: 11th March 2020, 9:30-17:30

Synopsis

This meeting provides an opportunity to share your research in a supportive environment, network with fellow early career scientists, and hear about the career opportunities available to environmental chemists.

Abstract Submission

We invite you to present your latest research as either a platform presentation or as a poster.

Please use our template to submit an abstract to Dr Tom Sizmur (t.sizmur@reading.ac.uk) by **9am on Monday 17th February 2020.**

Template: http://www.rsc.org/events/download/Document/a8f6e06a-29b9-43a3-9564-239a448e6cbc

A prize will be awarded for the best oral and poster presentations.

Keynote Speakers

Dr Laura Carter

Laura Carter is a fellow in Soil Science at the University of Leeds. Her research focuses on understanding the fate and uptake of emerging contaminants, with particular focus on soil-plant systems. She has recently been awarded a UKRI Future Leaders Fellowship (£1.2M) to investigate the risks of emerging contaminants in agricultural systems, following land application of sludges and wastewater.

Antony Poveda

Antony originally studied neuroscience at the University of Manchester. This was followed, eventually, by a Masters in Science Communication from UWE. He has been part of the team running the online STEM engagement project *I'm a Scientist* since 2015. In that time Antony has supported hundreds of scientists in taking part, helping early career researchers engage school students across the country whilst developing their own communication skills.

Registration

This event is FREE for RSC members who submit an abstract for a poster or oral presentation before 9am on Monday 17th February 2020 (a code will be provided that enables registration without charge).

Otherwise, registration is:

Early Bird Members: £25 (free to join as an RSC member)

Early Bird Non-members: £45

Members: £35 (free to join as an RSC member)

Non-members: £55

EARLY BIRD is available before **17th February 2020**, and standard registration before **2nd March 2020**.

Registration: http://www.rsc.org/events/detail/41784/environmental-chemistry-of-water-sediment-soil-and-air-early-careers-meeting

Sensors 2020

A joint one-day meeting held in collaboration with the Automation and Analysis Management Group (AAMG)

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

When: 23rd June 2020

Synopsis

This meeting will focus on the latest development in all types of sensor technologies, with particular interest in those with environmental applications. It will include poster presentations and exhibitors.

Further details on the technical programme, including confirmed speakers, will be announced on ECG and AAMG **webpages:**

http://www.rsc.org/events?MemberNetwork=7&PageTitle=7

http://www.rsc.org/events?MemberNetwork=27&PageTitle=27

And ECG s**ocial media**: @RSC_ECG

Registration

Members: £65 (free to join as an RSC member)

Non-members: £95

Students: £35

International Global Atmospheric Chemistry Conference (IGAC)

The 16th conference in this series

Where: Manchester University, 176 Oxford Rd, Manchester, M13 9PL

When: 13th-18th September 2020

Synopsis

The International Global Atmospheric Chemistry (IGAC) Project will hold the 2020 16th IGAC Science Conference (IGAC2020) in Manchester, 13th-18th September 2020. The conference is hosted by the universities of Manchester, Leeds, York and Lancaster, and NCAS, chaired by Hugh Coe.

The conference theme is *Understand the Past/Present, Prepare for the Future*, and will include plenary sessions on the following themes:

- Atmospheric Chemistry Fundamentals
- Integrated Observations, Modelling, and Analysis
- Air Quality and Impacts
- Atmospheric Chemistry at the Interfaces
- Future Perspectives and Policy

More details: http://igac2020.com/

Green infrastructure and the chemical sciences

This one-day conference organised by the Water Science Forum, with support from the Environmental Chemistry Group.

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

When: 24th April 2020

Synopsis

This conference will discuss how the chemical sciences are used to monitor and evaluate the effectiveness of green infrastructure (GI) in the attenuation of a wide range of commonly occurring and emerging aquatic pollutants. By reviewing and examining a range of case studies, and the data obtained from these, attendees will gain an insight into both the effectiveness and efficiency of a number of different approaches to GI.

A number of different aspects will be discussed including the application of GI to catchment management and the attenuation of both agricultural contaminants and urban/road runoff pollution. The use of GI in the removal of specific pollutants such as phosphate ion, ammonia, metals, glycol, hydrocarbons and refinery wastes, pesticides and pharmaceuticals will also be discussed.

GI dates back to 2013, when two European Commission documents, Green Infrastructure — **Enhancing Europe's Natural Capital (COM(2013) 249)** and **Building a Green Infrastructure for Europe** described its social, environmental and biodiversity benefits for addressing climate change adaptation and mitigation.

GI is becoming an increasingly important component of our built environment, and often provides a more sustainable outcome to our water management issues than traditional hard-engineered solutions, contributing to the protection and enhancement of nature and natural processes by consciously integrating these into spatial planning and development, improving our quality of life and providing environmental benefits.

GI can be used for removing or reducing the concentration of aquatic pollutants or for managing water flows.

Conference Aims

This conference will bring together those who wish to review current research and technologies directed towards the use of green infrastructure for pollution abatement. The talks and Q&A sessions will explore the removal of priority pollutants using biological wetland/sustainable urban drainage, sustainable drainage systems, and other nature-based solutions.

This meeting is aimed at

- Water policy developers and urban planners
- Regulators, planners, and policymakers
- Water treatment engineers, industrialists, quality managers, and analysts
- Freshwater biologists
- Groundwater specialists
- Agriculture and aquaculture sectors
- Public health workers and pharmaceutical industrialists
- Academic water policy and water science researchers
- Third sector organisations involved in water and public health
- Local authority and municipal representatives
- Businesses wishing to address the UN Sustainable Development Goals - particularly SGD6
- National and regional government water policy
- Companies providing scientific services to the water sector

Registration: https://www.eventbrite.co.uk/e/green-infrastructure-and-the-chemical-sciences-tickets-82282879307

Registration includes:

- Attendance at the sessions
- Refreshments throughout the meeting
- Lunch

Disposable attitude: Electronics in the environment

This one-day meeting, incorporating the 2020 ECG Distinguished Guest Lecture, will explore the environmental implications and defences, material scarcity and modern attitude associated with electronics manufacture and disposal.

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

When: Tuesday 24th March 2020, 12:00-17:15

Ms Janet Gunter (Restart Project)

Ms Gunter is an American/British activist and anthropologist who has lived and worked in Brazil, East Timor, Portugal and Mozambique. Now from Brixton, south London, she is one of the founders of the Restart Project, a London-based charity established to combat the “throwaway consumerist model of electronics” that has established in the 21st century.

Ms Gunter will speak on the disposable attitude associated with modern electronics and alternatives to recycling.

Mr. Andrew Bloodworth (British Geological Survey)

Mr Bloodworth is a Chartered Geologist and Mineralogist who has contributed significantly to planning and communication for mineral extraction and recovery. His experience includes extensive research into the impact of mining on the developing world, public perception of minerals extraction, and regulatory issues involved with minerals extraction and waste disposal. His current work sees his involvement in the Critical Minerals project, investigating scarce materials without substitutes, used in the manufacture of new and green technologies.

Mr Bloodworth will speak on the state of security and scarcity of the supply of minerals used for the manufacture of electronics.

Speaker TBC

Our third speaker will deliver a talk on material recovery and recycling, associated with electronics.

2020 Distinguished Guest Lecturer: Mr Steve Cottle (Edwards EMS Ltd)

Mr Cottle is a Senior Applications Manager at Edwards Vacuum. During his 25-year tenure at Edwards, he has worked in multiple technical roles leading advanced development of customer specific solutions for Exhaust Management. He is an industry recognised expert in exhaust management and knowledgeable in all technical aspects of exhaust management. He holds a BSc in Chemistry from Bristol University.

Mr Cottle will speak on the management and pollution of exhaust gases associated with the manufacture of electronics.

Registration

To register, visit the RSC events pages and search for **“Disposable Attitude: Electronics in the Environment”.**

Early Bird Members: £35 (free to join as an RSC member)

Early Bird Non-members: £50

Members: £50 (free to join as an RSC member)

Non-members: £65

EARLY BIRD is available before **1st February 2020**