FWR NEWSLETTER
...from the Foundation for Water Research
www.fwr.org
Issue 2, May 2017

Welcome to the spring issue of the FWR Newsletter

Defra recently ran a consultation on *Proposals to ban the use of plastic microbeads in cosmetics and personal care products in the UK and call for evidence on other sources of microplastics entering the marine environment*. This followed the inquiry on the environmental impact of microplastics in the marine environment by the Environmental Audit Committee – its report included a number of recommendations for the UK government to address key sources of microplastic pollution. The outcome from Defra's consultation is now awaited.

Our lead article this time gives you a good overview of the subject of microplastic pollution and its implications and I am very grateful to Alice Horton from CEH for her contribution on this.

The landscape of water quality and water pollution post-Brexit is of concern to many environmentalists. Initial thoughts and worries were expressed at a recent seminar *Exploring the Future of Water Management in Post-Brexit Britain*. Get a flavour of the day from our commentary on page 4. And in his *Wastewater Matters* section Steve Bungay takes a look at antimicrobial resistance in sewage treatment works.

For information on events and news highlights please go to our website *www.fwr.org*. You can also contact us via email *(office@fwr.org.uk)* or telephone (01628 891589).

Maxine Forshaw - Editor

THIS ISSUE

MICROPLASTICS: HOW BIG A THREAT?

Microplastics from a beach

Alice Horton
Research Associate, CEH

PLASTIC IS A WONDERFUL THING. It is cheap, strong and hard-wearing, and we use plastics multiple times a day across many applications.

Although nowadays we can't imagine a world without plastic, it is actually only since the 1950s that plastics have become widely manufactured and used for domestic purposes – for example in packaging materials and textiles. Since then, manufacture and use of plastic has seen an enormous increase, from 1.5 million tonnes in 1950 to 322 million tonnes in 2015. This has unfortunately correlated with an increase in the presence of waste plastics in the environment.

The word 'plastic' covers a very wide range of polymer products with different chemical compositions and characteristics. Well-known examples include polyethylene (commonly used in food wrapping and drinks bottles), polypropylene (frequently used in packaging materials), polyvinyl chloride (PVC, routinely used in construction and plumbing applications), polyester and nylon (both used in the textile industry).

Recent technologies allow us to effectively recycle much of our plastic waste, allowing the materials to be reused rather than ending up in landfill. However, not all types of plastic are currently recyclable and this, combined with the sheer volume of plastics we are consuming, means that much of it is disposed of in non-renewable ways: in landfill, down the drains or simply into the environment as litter. It is obvious to anybody who goes for a walk in the park, along the beach or in a town that this

Agricultural plastic mulching

mismanaged plastic waste is everywhere. Ask anybody and they will tell you that this is a problem that has been obvious for years. However, it is not often considered what happens to this litter if not collected – where does it go?

This is where microplastics come in. Microplastics are defined as plastic particles with the largest dimension less than 5mm in size, ranging all the way down to particles of micrometre scale. The definition 'microplastic' also includes different shapes of particle and different polymer types, therefore microplastics represent an assortment of particles originating from a variety of sources. Microplastics are becoming slowly imprinted into the public consciousness with the recent announcement of a government ban on 'microbeads' in face scrubs – these are tiny pieces of plastic put into bathing products for exfoliating purposes. When washed off, they go straight down the drain, passing through water treatment plants due to their small size, and are released directly into rivers with the treated effluent.

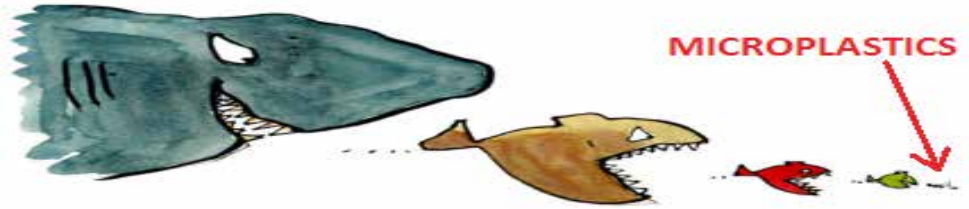
However, this is just one (very small) part of the story. The majority of microplastics are recognised to derive from the breakdown of larger items. This includes the items of litter strewn across the land or plastic coverings used in agriculture, which break into smaller and smaller pieces under environmental stress and UV light, in addition to the natural wear and tear of products such as car tyres. Shedding of fibres from synthetic garments, especially during laundering, is another significant input of microplastic to the environment. These may enter the environment by a variety of routes, either from sewage effluent released to rivers, treated sludge applied to land as fertiliser, or simply as 'urban dust' from household furnishings and general day-to-day use of synthetic garments that can be transported in the air. Due to the enormous variation in the types and applications of these products, microplastics from these sources are very difficult to quantify or regulate. However, environmental surveys worldwide are finding these 'secondary' microplastics in far higher numbers than the 'primary' (ie manufactured as a small particle) microbeads.

Furthermore, owing to the heterogeneity of different types of plastic, it is very difficult to determine how a microplastic particle will behave once in the environment. This will depend on many factors including the size of the particle, the density of the polymer (affecting whether it will float or sink in water) and its interactions with other organic or inorganic matter. The large variation between particles means that microplastics can be found throughout the range of environmental compartments including soils, sediments and water.

Due to their ubiquity, microplastics are highly likely to be encountered by organisms across a range of trophic levels. Studies have shown that many organisms will ingest microplastics, from zooplankton and shellfish to fish, sea turtles and even whales. It has also been shown that microplastics can be transported up the food web via trophic transfer.

The potential long-term effects of this ingestion are not yet clear. Laboratory studies have shown a range of detrimental effects to organisms through ingestion of microplastics: these include reduced reproduction, altered mobility and behaviour, reduced immunity, inflammation of tissues and depleted energy reserves. All of these have the potential to cause knock-on implications for communities and eco-

Thermoplastic road marking paint



Transfer to higher tropic levels. Original artwork by Food Chain Clipart, Clipart Kid

systems, with the possibility of long-lasting effects. However, the research so far hasn't identified how these laboratory studies realistically link to likely scenarios involving interactions of organisms with microplastics under actual environmental conditions, which are far more complex than a controlled laboratory test. Additionally, the potential for a microplastic to cause harm will vary depending on the species in question, and the particle it is encountering.

Zooplankton ingesting microplastics. Credit: Matt Cole, University of Exeter/Plymouth Marine Laboratory

A common misconception about plastics is that they are inert, ie although they may cause physical harm, they will not pose a chemical threat. This is not correct as many potentially toxic chemicals are added to plastics as a result of the manufacturing process – these include phthalates for flexibility and polybrominated diphenyl ethers (PBDEs), used as flame retardants. Many of these chemicals, added to plastics to give them their distinctive properties, may cause carcinogenic or endocrine disruptive effects.

An additional chemical issue with microplastics is that of associated organic chemicals. Many chemicals that end up in the environment are classified as 'hydrophobic organic chemicals' or 'persistent organic pollutants' including organophosphate pesticides, polychlorinated biphenyls (PCBs) used as coolants, and PBDE flame retardants. The fact that they are 'hydrophobic' means that they are not soluble in water, a trait also shared with plastics. For this reason, plastics and hydrophobic chemicals are likely to associate in the environment, binding and travelling together. This is especially notable with microplastics (as opposed to larger plastic items) due to their great surface area. It is possible that microplastics can facilitate the uptake of the associated chemicals if ingested by organisms, leading to exposure and bioaccumulation when organisms may not have otherwise been exposed to these chemicals. Alternatively, microplastics may bind these chemicals so strongly that they actually become less bioavailable; there is evidence to support both theories and thus the environmental relevance of this has yet to be determined.

Microplastics can also act as a habitat for algae and bacteria which can adhere to the surface of the particle, forming an organic coating known as a biofilm. There are two issues with this. Firstly, biofilms may make a plastic particle more appealing to an organism (or reduce their ability to distinguish it as a non-food item) leading to a higher likelihood of ingestion. Secondly, the transport of microplastics with a coating of bacteria or algae may ultimately lead to the introduction of invasive species to areas they otherwise wouldn't have reached.

So what does all this mean for the future? Unfortunately, given that plastics are an 'emerging contaminant' (ie only recently recognised to be an environmental pollutant), we don't yet have enough knowledge to speculate on the long-term effects of microplastic pollution. It is highly likely that this pollution will continue to increase with the ever-growing manufacture and use of plastic products. Unless removed, all the plastic that is currently in the environment will remain for hundreds if not thousands of years to come, not to mention the breakdown of larger plastic items leading to the production of many more microplastics. Evidence shows that microplastics have the potential to cause ecosystem-level effects in a variety of different environments, but more research is needed to investigate the likely real impacts of this widespread pollution in the context of the complex systems and processes that are at play within the environment.

Alice Horton is an Ecotoxicologist at the Centre for Ecology & Hydrology. **Find out more at:** *https://www.ceh.ac.uk/staff/alice-horton*. ❖

(Unless otherwise credited, all images are courtesy of Alice Horton.)

Microplastics extracted from UK river sediment

Improving Water Quality and Tackling Water Pollution: exploring the future of water management in post-Brexit Britain

1 March 2017 Mike Waite and Maxine Forshaw, *FWR*

A NUMBER OF EXCELLENT SPEAKERS FEATURED IN THIS ONE DAY SYMPOSIUM IN LONDON. The chair for the day, Jan Hoffman (University of Bath) remarked in his opening comments that a recent survey in the EU showed 47% of people were worried about water pollution, and in some countries this was as high as 71%. He gave a brief summary of the basic principles behind the various water quality Directives and reminded us that water quality issues transcend national boundaries.

River Test, Hampshire. Credit Alan M Barr/Shutterstock.com

The morning session was particularly interesting, dedicated to looking at the national scene – assessing progress made, identifying gaps and exploring the future of the water policy framework post-Brexit.

Angela Smith MP is chair of the All-Party Parliamentary Water Group. She gave some personal thoughts, as a pro-Remainer, on government thinking post-Brexit. She explained that the Great Repeal Bill will take us out of Europe, Defra taking over the water-related legislation, which will consist of around 1000 new Statutory Instruments. She fears that there could be a weakening of environmental standards during this process if proper parliamentary scrutiny slips. She expressed the view that it's not just about embedding policy into British legislation, but that the government should seek to 'up its game'.

In answer to her rhetorical question of 'What did the EU ever do for us?' she pointed out that EU legislation such as the Bathing Water Directive has led to major improvements in coastal waters, that the Thames Tideway Tunnel has been approved due to breaches of the Urban Wastewater Directive and the subsequent threat of fines from the EU, and that the Catchment Restoration Fund has resulted in many examples of environmental improvements across the country. Although the UK lags behind on some Water Framework Directive (WFD) requirements, we are generally on track but she felt that Brexit could result in a reappraisal of our approach to water with less funding for environmental improvements and catchment restoration. Adequate funding is needed to continue the good progress!

On the positive side, she said that Brexit does provide an opportunity to stand back and think about policy. She praised the Dutch approach to water as they regard it as an essential resource on environmental, social and economic grounds.

From the legal point of view, Scott McCallum (Shepherd & Wedderburn) explained that, in the short term, legislation will stay the same, as Brexit negotiations continue. He also pointed out that many EU laws have international treaties' elements, eg OSPAR, and these treaties remain obligations for the UK. He expects that any attempts to diverge negatively from EU standards would be met with public resistance. There are many pros and cons in the future following Brexit: if we have more stringent standards our goods will be more expensive and therefore we would not be competitive with Europe and other areas of the world such as the USA; on the other hand, we could free ourselves from the 'one out, all out' WFD rule, which may be stifling business.

An in-depth discussion session followed which was sometimes wide-ranging and at other times quite specific! Some thoughts expressed were:

- it's a good opportunity to assess what's working well and not so well … what could be done better?
- time to lobby for improved environmental policies?
- danger of trading off environmental protection against economics.
- The government may want to avoid improvement of environmental standards if it affects being able to trade with other countries, including Europe.
- If the government in the US are going to seriously weaken the USEPA, we may have problems trading economically if we have much higher standards.
- Infraction proceedings from Europe have driven the UK's environmental improvement to some extent. Without this, judicial reviews may have to be taken out to challenge an organisation or government, and this can be very expensive.
- There is good potential for the shellfish industry in the UK and shellfish protection is very important – it's vital to control water quality in shellfish harvesting areas otherwise you'll have a public health problem.
- Could Marine Protection Zones slip post-Brexit?
- Defra's 25 year Environment Plan (draft due soon) will be a useful tool for organising parliamentary responses.

The afternoon session focused on tackling diffuse water pollution, mainly covering pollution from road runoff and farming.

In his summing up, Jan Hoffman concluded from the presentations and discussions that there would be no overnight change following Brexit, change would be gradual. Concern was expressed that during the transfer of EU regulations into domestic regulations there could be a weakening of the legislation because of the economic implications of having higher environmental standards. Brexit, however, *could* give opportunities for improvements.

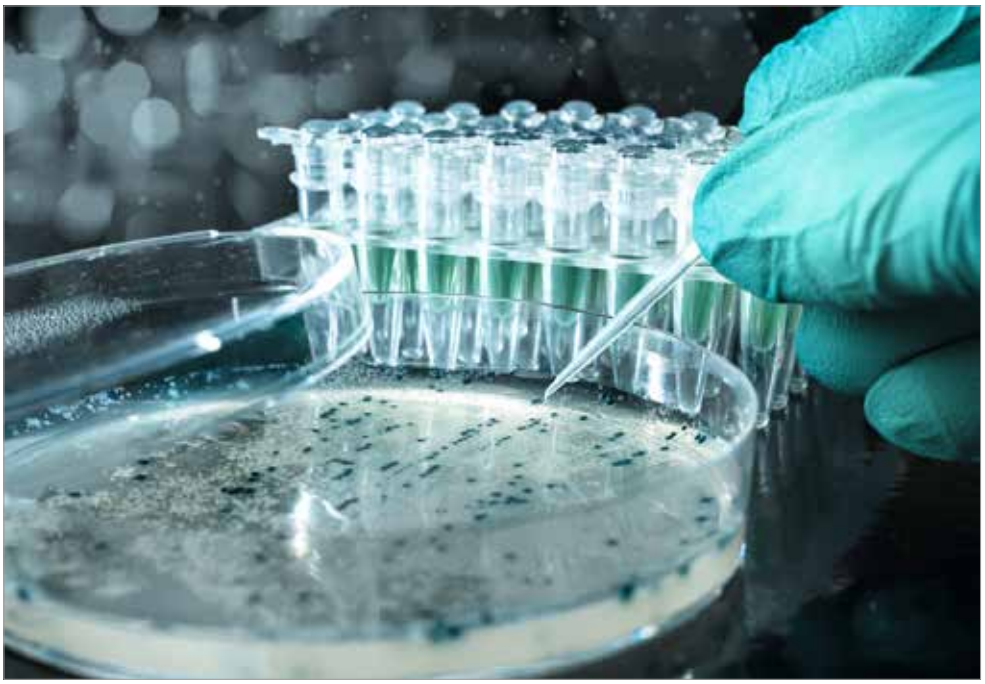
It was interesting to hear how people involved in water quality are perceiving the post-Brexit landscape and this made for a fascinating day. ❖

WASTEWATER MATTERS

Antimicrobial Resistance in Sewage Treatment Works

Steve Bungay, *FWR Wastewater Section Co-ordinator*

ANTIBIOTICS are a class of naturally occurring and synthetic chemical compounds with antimicrobial activity and are widely used in human and veterinary medicine. The increasing incidence of resistance to a wide range of antibiotic agents by a variety of organisms is a major concern facing modern medicine. Clinical infections, disease and death caused by resistant bacteria are increasingly common.



Bacterial colonies. Credit anyaivanova/Shutterstock.com

The World Health Organisation (WHO) defines antimicrobial resistance (AMR) as the ability of a microorganism (such as bacteria, viruses, and some parasites) to stop an antimicrobial (such as antibiotics, antivirals and antimalarials) from working against it. As a result, standard treatments become ineffective, infections persist – and may spread to others.

The dissemination of antibiotic resistance genes (ARGs) carried by antibiotic-resistant bacteria (ARB) and their threats to public health have attracted concerns worldwide in recent years. ARB have been found in soil, sewage, surface water, rural groundwater supplies and municipal drinking water. However, the source and fate of ARGs in the environment is still not fully understood. Since the late 1990s, several classes of antibiotics have been reported in sewage and sewage treatment works (STWs). Some of these antibiotics are incompletely metabolized during therapeutic use and are excreted, unchanged, into sewage. STWs are considered to be among the main anthropogenic sources of ARGs discharged into the environment. Natural antibiotic producers are inherently resistant to the antibiotics they produce. Other bacteria survive by developing or acquiring antibiotic resistance mechanisms. There are two routes for acquired resistance: vertical evolution via mutation and horizontal evolution (horizontal gene transfer) via exchange of genes between similar and different species. Vertical evolution is determined by natural selection whereby spontaneous mutation in the bacterial chromosome bestows resistance to a bacterium and its progeny within the population. Horizontal gene transfer (HGT) generally occurs via three routes: transformation (DNA uptake), conjugation (direct contact transfer of mobile plasmids) or transduction (uptake of naked DNA).

HGT is believed to be the major route for widespread global dissemination of antibiotic resistance and is responsible for transfers of plasmids carrying antibiotic resistance genes in 60–90% of gram-negative bacteria. Biological sewage treatment processes such as activated sludge and trickling filters create favourable conditions for development of antimicrobial resistance genes where they have the potential to be transferred from host bacteria to pathogens via HGT under sub-inhibitory concentrations.

Antibiotics can enter STWs from various routes. One potential route involves antimicrobials and their pharmacologically active metabolites that are excreted from patients following a clinical treatment regime. Another route comes from improper disposal of unused or expired antimicrobials via discharge to a local sewer system by individuals or institutions. These inputs to STWs are accompanied by high concentrations of antimicrobial resistant and susceptible bacteria. Hence, there can be selective pressure and sufficient antimicrobial resistance genes to facilitate amplification of the ARB population in the STW liquid effluent and biosolids.

STWs concentrate bacteria in conditions designed to encourage proliferation and activity, and bacterial diversity is very high. However, STWs significantly reduce viable concentrations of faecal bacteria such as coliforms and enterococci. Biological treatment of sewage can lead to a 200-fold reduction in the number of *E. coli*. Even so, relatively high numbers of bacteria remain in the treated effluent discharged from STWs, contributing to the dissemination of resistant bacteria in the environment. The resistant bacteria will also be present in sludge, so dissemination will also occur when biosolids are recycled to agriculture.

Antibiotic resistance acquisition and/or proliferation may conceivably occur in sewage regardless of the presence of small concentrations of antibiotic drugs. So, although STWs are clearly responsible for disseminating antibiotic resistant bacteria in the environment, antimicrobial resistance is not a new phenomenon and is present in most environments. AMR

has been a common occurrence long before the clinical use of antibiotics. AMR has been detected in environments not exposed to antibiotics. However, most bacteria isolated prior to the antibiotic drug era were sensitive to antibiotics and many contained plasmids free of resistant genes. It is thought that the widespread evidence of AMR, and the subsequent increase in antibiotic resistance is related to the use (and therefore presence) of antibiotic drugs. Consistent with this, it seems reasonable to assume that the presence of antibiotics in sewage may also contribute to the evident rise in resistant bacteria isolated from municipal STWs.

WHO promotes infection prevention and control through clean water and sanitation. Antimicrobial resistance is occurring across the globe, compromising our ability to treat infectious diseases, as well as undermining many other advances in health and medicine. Improving sanitation worldwide will reduce avoidable infections, but in turn could increase the proliferation of AMR, since a key factor for the acquisition and proliferation of antibiotic resistance amongst bacteria appears to be the co-occurrence of high concentrations of faecal bacteria and sub-lethal antibiotic levels; and thus the presence of low concentrations of antibiotics in STWs may serve as a selective pressure for the proliferation of resistant organisms.

Further investigations are required concerning the effects of antibiotic resistant strains released from STWs on the natural ecosystem and on humans. ❖

This article together with full references can be accessed here:
http://www.fwr.org/MayNews2017.pdf

LAST MONTH CIWEM organised a seminar between the Water and Sewerage Companies (WaSCs) and the commercial organic waste sector to discuss the future of organic waste management.

This was the third event following on from CIWEM's initial response to Ofwat's *Water 2020* consultation, where Ofwat are proposing the deregulation of the sludge market. The first seminar event was aimed at the water sector, including Defra, Ofwat, and the EA, with the second seminar involving additional representation from the commercial sector.

The aim of the final seminar was to share views across the sectors and determine whether or not changes to environmental regulation are a critical enabler for developing the bioresources recycling market. The session explored whether both utilities and organic waste companies believe there is a way to consolidate legislation that would create a step forward for the whole industry and the environment. The event was well attended with representation from the water companies, commercial AD (anaerobic digestion) operators (including Agrivert, Biffa, Digit Resource Management, 4R Recycling, Marches Biogas, Veolia), plus ADBA (Anaerobic Digestion & Bioresources Association), CIWM (Chartered Institution of Wastes Management), Aqua Enviro, Grieve Strategic, Imperial College, the World Biogas Association, and WRAP (Waste & Resources Action Programme).

Although there was a very wide range of opinions regarding the effect of the proposed deregulation of the water company sludge market, there was a general consensus that environmental regulation was key to the success of deregulation. Currently, WaSCs still operate under the Sludge (Use in Agriculture) Regulations and the recently introduced Biosolids Assurance Scheme (BAS), whilst the commercial AD sector operates under the Publicly Available Specification (PAS) 110 (ie the specification for digestate). For free trade between the two sectors, there has to be some form of harmonisation between the BAS and PAS certification schemes. Simply extending Environmental Permitting across the municipal sector will not offer any economic benefit to WaSCs customers. The cost and time required for WaSCs to operate under the Environmental Permitting Regulations would be prohibitive, and would negate any economic benefit that Ofwat are seeking in proposing deregulation of the sludge market.

The seminar established the need for a cross-sector group to try and continue to shape this debate with the EA and Defra, and share outcomes with the industry; otherwise there is a risk that both WaSCs and commercial AD operators will simply carry on as before, with no economic or environmental benefit being realised. **Steve Bungay**, *FWR.* ❖

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A World Without Boundaries

THE 18TH INTERNATIONAL WATER ASSOCIATION UK YOUNG WATER PROFESSIONALS CONFERENCE was held this year from 10–12 April at the University of Bath. The event was sponsored by Black & Veatch, Wessex Water, University of Bath, Royal Society of Chemistry, Water Aid and FWR.

Credit: YWP2017

Visit to Avonmouth STW. Credit: Neil Tytler

The conference attracted the largest ever number of delegates attending a UK YWP event, with over 200 people coming from as far away as Israel, Malaysia, Taiwan, China and New Zealand. The event focussed on breaking down the boundaries of communication by delivering tools for cross-field engagement and career development for water professionals. This was achieved not only with plenary presentations but also with interactive workshops and round-table discussions. The plenary sessions were supported by the Young Water Professional attendees and by 'flash' presentations from each of the 40 delegates who were presenting posters on their research work.

Social events included an evening at the Victoria Art Gallery, plus a gala dinner on the second day, held in the Guildhall and followed by a cèilidh in which everyone seemed to engage very enthusiastically! **Neil Tytler**, *FWR* ❖

Investimento e Inovação em Saneamento – São Paulo

Steve Bungay,
FWR Wastewater Section Co-ordinator

FOLLOWING ON FROM THE 1ST UK-BRAZIL WORKSHOP ON SUSTAINABLE WASTEWATER TREATMENT (see our November 2016 newsletter), in March a delegation from both countries took part in an international meeting to discuss **investment and innovation in sanitation**. This involved a number of presentations, panel discussions, and technology showcases, with myself and Pete Vale from FWR's Wastewater Innovation Forum being actively involved throughout the two days.

Pete Vale, Severn Trent Water/ FWR Wastewater Innovation Forum

I gave three presentations, giving an overview of the UK water market, describing the UK regulatory framework for water, and finally, detailing sludge and biosolids utilization in the UK. Pete talked about the adoption of technology for wastewater treatment by Severn Trent Water, showcasing a number of their research projects; he was also involved in one of the panel sessions discussing investment in wastewater infrastructure.

The sessions included:

- Overview of the water sector
- Attracting investments in sanitation projects
- Regulatory aspects of the sector
- Challenges and experience in sanitation infrastructure
- The Prosperity Fund. This forms part of the UK's Official Development Assistance, contributing to poverty reduction and complementing the Department for International Development's work in poorer countries.
- Structuring and modelling large infrastructure projects
- Innovation and improvements in the provision of sanitation services
- Building long-term partnerships between Brazil and the UK.

Steve Bungay, Helix ECL/FWR

A summary of the privatisation of the water industry in the UK was given and detailed how, since 1989, privatisation, with the appropriate regulation, has been a success story, delivering cleaner rivers, better drinking water quality, and better value to customers.

The final session consisted of a panel discussion about building long-term partnerships, with the event being closed by NneNne Iwuji-Eme (Prosperity Consul at British Consulate São Paulo). ❖

The UK delegates included Greg Hands MP (British Minister for Trade and Investment), Steve Bungay (Helix ECL and FWR), Simon Robinson (Mott MacDonald), Sam Hoexter (UK Export Finance), Pete Vale (Severn Trent Water and FWR), Chris Hughes (Amec Foster Wheeler), Keith Hilson (i20 Water), and Phil Chandler (Ionex SG).

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An update on the activities of the FWR

IN THE NEWSLETTER THIS TIME WE HAVE A MAJOR ARTICLE ON MICROPLASTICS – now a subject of great environmental interest and one which needs to be carefully monitored. Further *Reviews of Current Knowledge* are planned this year, one of which will cover microplastics.

On the wastewater side, our Wastewater Innovation Forum is being revamped to encourage more participation, particularly from the new generation of water engineers. We are continuing to update our website, especially in the catchment partnership area, and we were pleased to learn that we have secured a further grant from Defra for 2017/18 for our catchment partnership work.

FWR will attend two popular public festivals before the end of July – the Crick Boat Show and the New Forest & Hampshire County Show. These are always enjoyable occasions and give us further opportunities to meet and talk with the public.

So, as usual, a busy few months ahead for us. As always, a big thank you to all who contribute to the newsletter and I wish all our readers a happy summer.

Caryll Stephen *Chief Executive of the Foundation for Water Research*

Wastewater Innovation Forum Spring Meeting

Steve Bungay, FWR Wastewater Section Co-ordinator

This year the Wastewater Innovation Forum are focussing on four key areas of research: microplastics, the Chemical Investigations Programme, antimicrobial resistance (AMR), and unflushables. These are emerging challenges to the integrated management of wastewater systems and water quality. Urban drainage and anaerobic wastewater treatment technologies are other areas of interest to the forum. As well as these areas of key interest, the forum is always looking to showcase innovative technologies. In keeping with this, there was a presentation on microplastics from Alice Horton of CEH, and an introduction to an innovative Dewaterability Estimation Test (DET) from Prof. Apostolos Antonacopoulos and Dr Blake Prime of the University of Salford.

Alice works in the ecotoxicology group at CEH. Her presentation ***The Abundance and Sources of Microplastics in Freshwater Environments*** gave an overview of the work she has done to date, including her study on microplastics within Thames Basin sediments and ongoing studies looking at the effects of microplastics on organisms. Her research focuses on microplastics (plastic particles <5mm in size) which are now recognised as an 'emerging contaminant'.

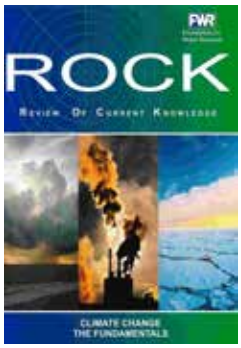
Apostolos and Blake's presentation ***Dewaterability Estimation Test (DET) for Sewage Sludge Monitoring*** introduced a new DET technique that addresses the shortfalls of the traditional CST (Capillary Suction Time) test, with potential to become the preferred choice for the water and sludge industry. Both presentations are available on the FWR website at *http://www.fwr.org/wransom1.html* together with an archive of presentations from past meetings.

The Forum now has a twitter account: *@F4WaterResearch*, so you can keep up to date with our activities.

The next meeting is 14 June 2017, at CIWEM's HQ.

FWR Publication

Copies of this report are available from the Foundation for £15 each, less 20% for FWR members.



Climate Change: The Fundamentals

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The subjects of climate and climate change are huge and embrace many scientific disciplines. There is an enormous amount of literature on the topic from scientists around the globe. This Review of Current Knowledge sifts through some of the important fundamental issues and deals solely with the scientific evidence.

It is based mainly on the work of the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988. Over the past few decades the Panel has provided policymakers with the most authoritative, objective scientific and technical assessments on climate change.

Topics covered include:

- The nature of climate change
- Historic changes in climate
- Recent changes in climate
- Causes of recent changes
- Potential effects of current trends in climate change
- Climate stabilisation.

A bibliography is provided for those wishing to explore the subject further.

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Publication Nº : FWR-NEWS 27-0

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