Marine litter – Academic Research Review

EMFF MARINE LITTER RESEARCH PROJECT

Keep Wales Tidy, Marine Conservation Society and Eunomia Consulting have been successful in a partnership bid to Welsh Government to undertake research into Marine Litter in Wales. Thanks to funding through the European Maritime and Fisheries Fund, this research will provide critical knowledge to support the delivery of the Marine Litter Action Plan for Wales and the Marine Strategic Framework Directive.

The Clean Seas Wales Partnership is the multi-stakeholder group which represents Welsh Government and Local Authorities, port and harbour authorities, the fishing industry and private and third sector partners who have come together to take forward the Marine Litter Action Plan (MLAP) for Wales.

Front-page image: *Full-page microscope image of microplastics*

Top of page: Left: *EU Investment logo* Top Right: *Welsh Government Logo* Bottom Right: *Clean Seas Wales Logo*

Bottom of page: Right to left: *Keep Wales Tidy Logo, Eunomia logo, Marine Conservation Society logo*

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Contents

Glossary

COPLAR: Code of Practice for Litter and Refuse
A practical guide to the duties to keep land clear of litter under the Environmental Protection Act 1990 England & Wales

EMFF: European Maritime and Fisheries Fund
The fund for the European Union's maritime and fisheries policies for 2014-2020

EPR: Extended Producer Responsibility
An environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle

GIS: Geographic Information Systems
GIS is a mapping technology that allows the user to create and interact with a variety of maps and data sources

HEI: Higher Education Institution
Universities, colleges, and further education institutions offering and delivering higher education

KS2 and KS3: Key Stage 2 and Key Stage 3
Key Stage 2 refers to 4 years of schooling (years 3-6), while Key Stage 3 refers to the 3 years of schooling (years 7-9)

KWT: Keep Wales Tidy
The charity working across Wales to protect our environment for now and for the future

MCS: Marine Conservation Society
The UK charity working to ensure our seas are healthy, pollution free and protected

MLAP: Marine Litter Action Plan (for Wales)
An action plan which is designed to help tackle marine litter and maintain or achieve Good Environmental Status in our sea waters by 2020 under the EU Marine Strategy Framework Directive

MSFD: Marine Strategy Framework Directive
Legislation aiming to protect more effectively the marine environment across Europe

NGO: Non-Governmental Organisation
A non-profit organisation that works independently of any government

R&D: Research and Development
Activity aimed at discovering solutions to problems or creating new knowledge

UK: United Kingdom
Country consisting of Great Britain (England, Scotland and Wales) and Northern Ireland

UN: United Nations
An international organisation which aims to solve world problems in a peaceful way

UNEP: United Nations Environment Programme
The voice for the environment within the United Nations

WLGA: Welsh Local Government Association
The organisation which represents the interests of Local Government and promotes local democracy in Wales

Introduction

Keep Wales Tidy, Marine Conservation Society and Eunomia Consulting have undertaken this research in on behalf of Welsh Government to explore current activity in the UK and beyond to identify opportunities to replicate and scale up best practice in Wales. Part of this research has sought to capture an overview of Higher Education Institute (HEI) activity in the disciplines most relevant to our understanding of marine litter and the delivery of the Marine litter Action Plan (MLAP) for Wales.

The United Nations defines marine litter as '*any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment*'.[1]

Marine litter poses a growing threat to the aquatic and coastal environment. Up to 12.7m tonnes of plastic enters the world's oceans every year, equivalent to dumping one garbage truck of plastic per minute into the world's oceans.[2] This causes significant problems for wildlife and aquatic ecosystems, but it also has a detrimental effect on our health as millions of tiny plastic particles end up in the fish we eat and even the salt we consume. There is also increasing direct costs to Local Authorities and our shipping industry. Indirectly, it is thought that litter suppresses tourism by between 1-5%.[3] It has been estimated that around 80% of marine debris is from land-based sources and the remaining 20% is from ocean-based sources.[4] There are no oceans where these particles have not been found and there is increasing evidence[5] that the problem extends to rivers and freshwater areas too, making this a truly global crisis with far reaching implications.

By its very nature, litter is an ever changing and movable issue, which presents a challenge to measure and record accurately. This is particularly complex in the marine environment where debris is dependent on tides, currents, weather and resident and visitor populations. Wales' location means that pollution and debris are carried large distances to our shores by the North Atlantic Drift making any identification of source largely impossible.

The awareness of marine litter as a result of the '*Blue Planet II effect*', has served to increase public engagement awareness of the issue significantly in recent years. The problem of marine litter, particularly plastics, has gained considerable media attention and the 'plastic free' aspiration has fuelled unprecedented increase in engagement of schools, communities, individual efforts and even big business.

Policy development in this area at an European level through the EU Strategy for Plastics in the Circular Economy and related measures, although increasingly at national and regional levels, has highlighted the gaps in legislation and infrastructure that is required to reduce our reliance on virgin plastics and the limited value and capacity of secondary markets. It has also highlighted the lack of viable materials that could be developed as plastic alternatives and substantial inconsistencies of consumer messaging and communication. In order to create a new, sustainable waste culture and to curb plastic consumption globally, it is critical to build a robust evidence base and to continue to explore the implications of 'business as usual'.

The crucial role of university research in this area is not limited to one field and a great variety of disciplines, from social sciences to engineering and technology to the natural sciences, all have a role to play in exploring solutions to our current challenges. Various estimates of the scale and impacts of marine litter are considered to be underestimated and new discoveries are announced from research on an almost weekly basis.

This review does not aim to capture all of the activity that is taking place in this arena but to provide an overview of some of the key elements of current research, current institutions and current funding allocations so that we can consider the future needs and priorities in taking forward the MLAP for Wales. Although we have considered evidence internationally, the activity of the Welsh Universities are

highlighted. For the purpose of this review, the areas of research have been confined to published studies from the last 3 years (where applicable) and have focused on:

- Behaviour change to reduce litter and waste or to reduce plastic consumption
- Scale and impacts of marine litter
- Methodologies for measuring (marine litter) and identifying pathways
- Research & Development (R&D) into alternatives to plastics

We have also highlighted some of the work of the UK Water Industry Research (UKWIR) group as an important body, funder and contributor to the area of wastewater treatment, processing and sampling.

Other elements of this project include an analysis of the interventions and data to tackle litter across Wales, a review of current projects and activity and work to explore the options for cohesive messages, which can be used in Wales to promote positive behaviour change.

Every year, the sum of humanity's knowledge increases exponentially. In addition, as we learn more, we also learn there is much we still do not know. Plastic litter in our oceans is one area where we need to learn more, and we need to learn it quickly. [But] the important message is that we already know enough to take action.[6]

Overview

There is a significant level of research activity in the field of marine litter at present. Arguably, this area was already establishing itself as result of various definitive studies on the presence and scale of microplastics from the early 2000's but recent media attention and increased policy activity has put a spotlight on marine litter and, in particular, the abundance of plastics. As a result, research from a variety of disciplines to explore this global crisis has exploded in recent years.

This report is not intended as a comprehensive literature review but seeks to provide an oversight of where current research is to date and, in particular, to identify gaps in HEI activity and potential opportunities for the sector in Wales and beyond.

Many marine litter research collaborations are increasingly interdisciplinary in nature and there are some exceptional examples of this, particularly throughout Europe. We have considered current evidence from social sciences (behaviour change, health and economics), natural sciences (ecology and conservation) and data, technology and engineering (methodology, materials R&D and water treatment and engineering).

The contribution of the Welsh universities to our current understanding is not insignificant. Welsh universities have the highest percentage of 'world leading' research in terms of its impact of any part of the UK, with almost half of it considered to be having a transformational effect on all walks of life beyond academia.[7] Due to increasing competition and relatively close geography, HEI institutions in Wales have each formed unique identities and research expertise. All but a few are in coastal locations, meaning that many offer opportunities to study different aspects of the marine and coastal sciences. (A snapshot of the current research contribution areas and research centres of Cardiff, Bangor and Swansea can be seen on page 6).

European expertise is particularly invested in this field and HEI's across the continent have benefited significantly from EU research funding in many areas, including R&D and STEM subjects (e.g. through Horizon 2020). Many of these collaborations have been facilitated through the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans), of which the UK is a member. The UK is one of the largest recipients of research funding in the EU with Wales accounting for around 2% of that income.[8]

UK networks and HEI collaborations also exist through, for example, the UK Microplastics Network, which represents a number of sectors but is also contributing to common methodologies for academic research. This year, the Plymouth Marine Laboratory and the University of Exeter, both renowned for their work on marine litter and microplastics research announced, 'a renewed, reinvigorated relationship that also reinforces the South West region as a global leader in pioneering marine science'.[9] In Wales, Aberystwyth and Bangor Universities have a strategic alliance for their Catchment and Coastal Research Centre.

This partnership is particularly interested in the role of social sciences and behaviour change in addressing marine litter in Wales. A call for evidence was sent out by Cardiff University and although this is not a comprehensive literature review, it has been recognised here and in other more detailed reviews that this area in particular has been identified as having a need for further study. To varying degrees however, this is increasingly being recognised as policy initiatives advance and governments from around the world seek more robust evidence of impact.

Despite the growth of research in this field, there is still much we do not know about the scale and impact of marine litter and microplastics. In particular, their interaction with the terrestrial environment such as freshwater and soils. Even less is known on the human impacts of ingestion or inhalation.

It is critical to note that studies on marine litter and microplastics, regardless of discipline, vary in quality and consistency and methodologies differ, making comparisons difficult. This is recognised in the academic community and research collaborations such as BASEMAN, which aims to identify common standards for measuring microplastic in European Waters. (See 'Methodologies; Research Snapshot').

Despite the scale of activity, rigorous academic research into marine litter and microplastics in the environment is relatively new and there are still numerous gaps in our understanding of the impacts, transportation, scale and presence. There is enough for us to confirm that the problem is of a significant scale and has wide-reaching effects, although the evidence on the nature and true impact on the environment, human health and wildlife is surprisingly scarce. To coin a phrase; '*There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns — the ones we do not know we don't know.*'

Far from this being a deterrent to action however, these findings conclude the need for further research and further funding to address these knowledge gaps so that we can avoid undue speculation and focus on evidence which will inform effective and sustainable policy in the long term. Although the current availability of funding in this area does not match the scale of the crisis, we know enough to know we need to take rapid and joined up action.

We might imagine picking up a stone in tens of millions of years' time and finding – instead of the shells of former sea creatures – the shapes of cotton buds, coffee spoons, fishing nets, CD cases, water bottles, biros …[10]

Swansea University

Swansea was ranked 26th in the UK for quality of research and 22nd for the impact of their research and is one of the top 30 research-intensive universities in the UK. (REF 2014)
The University has seen a 50% increase in student numbers over the last four years and is the third largest in Wales with over 20,000 students.

Key research areas:
Engineering (Water Processes and Material design)
Marine & Freshwater Systems (biosciences)

Institutes:
Materials Research Centre
Centre for Sustainable Aquatic Research

Current Research Highlights:
ALG-AD - Creating value from waste nutrients by integrating algal and anaerobic digestion technology (Interreg)

Cardiff University

Cardiff University was ranked 5th amongst UK universities in the 2014 Research Excellence Framework (REF) based on quality, and is a member of the Russell Group, a group of 24 leading UK research intensive universities. Cardiff is the largest university in Wales and the eighth largest in the UK with over 30,000 students.

Key research areas:
Behaviour change (Environmental behaviour and policy impact)
Freshwater studies on Microplastics and organisms

Institutes:
Water Institute
Sustainable Places Research Institute

Current Research Highlights:
Cross-context behavioural spill over and sustainable tourism in Wales (ESRC)
Social norms, identity, and habits for better local environmental quality in Wales (ESRC) (KWT)

Cardiff University Campus via: https://www.cardiff.ac.uk/

Bangor University

Bangor University is ranked in the top 40 in the UK in the 2014 Research Excellence Framework (REF) and more than three-quarters of Bangor's research has been recognised as either world leading or internationally excellent. It is the fourth largest university in Wales and has around 12,000 students.

Key research areas:
Behaviour Change (Health, Wellbeing & Sustainability)
Impact on Coastal and marine ecosystems
Bio composites

Institutes:
Biocomposites Centre
Catchment & Coastal Research (Aberystwyth University Alliance)
Centre for Behaviour Change

Current Research Highlights:
Microbial hitchhikers of marine plastics: the survival, persistence & ecology of microbial communities in the Plastisphere (NERC)
High Deflection Temperature BioBased Polymers for Horticulture and Food Service Applications (HDTBioPol) (Innovate UK)

Behaviour change to reduce litter and waste or to reduce plastic consumption

Many of the global challenges we face today are synonymous with a pattern of unsustainable behaviours and consumer choices. Although long realised as a primary objective in the health sector, behaviour change as part of broader public policy (and environmental behaviours in particular) is a relatively new development, signalling a move away from the traditional 'carrot and stick' (reward and punishment) approach. Whilst all policy can be said to be aimed at changing behaviour in one way or another, the result of many traditional policy drivers is that, even if successful, they often lack the power to change the motivation behind the behaviour. For example, a tax may be a deterrent for a specific action but if it is removed, the behaviour would likely revert because the intervention does not address the underlying motive or value.

Behaviour change is a research-based process for addressing knowledge, attitudes and practices, which focuses on the individual as an agent for change. Whilst social scientists argue that it is not actually possible to change people's behaviour, by providing them with an enabling environment and the right messages, people will transform their choices accordingly.

All litter is the result of human behaviour and understanding this behaviour will be key to promoting a more sustainable waste future and less impactful lifestyles. It is equally important from a policy perspective. Recent research has estimated that behavioural-nudging interventions can be more cost-effective than policy tools including incentives.[11]

Although there may be some intuitive policy actions to force behaviour change (such as banning unnecessary single-use plastics), we do not know what actions or lifestyle changes would have the biggest impact in terms of plastic pollution. We can derive some assumptions from current data and research such as litter breakdowns from street cleanliness surveys (Wales) and beach cleans (UK and areas of northern Europe) which demonstrates that the litter found is largely from the general public and largely (unidentified) plastic. Research from 2018 has recently estimated that traffic, infrastructure and buildings are major emitters of primary microplastics.[12] Therefore, as our knowledge of primary sources continues to increase, it is hoped that this knowledge can be more commonly applied to target the most effective behavioural interventions for prevention and reduction.

Behaviours are driven by different factors; such as knowledge, social norms, values, attitudes and perception of impact. Plastic contamination of the food chain, for example, may stimulate change in those who are more inclined to act upon consideration of health risk rather than environmental change. It may also be useful to consider waste behaviours and interventions. In Europe, 62% of all plastic waste is generated by packaging so a behavioural backlash against packaging could be very effective.[13] Waste prevention behaviours range from one-off behaviours, e.g. purchasing reusable cups, to habitual behaviours, e.g. reusing items such as shopping bags.

The sheer complexity of human behaviours and motivations makes it very hard to predict with certainty what the impacts of policy interventions on people's behaviour are going to be.[14]

Importantly, various studies have shown that knowledge alone is typically not sufficient to motivate pro-environmental behaviour by individuals.[15] Behaviour change requires, at a minimum, a motivation to change (motivation) and practical know-how (skills), in addition to knowledge.[16] It is therefore not enough to simply tell people to change, without also giving them the means and the motivation to do so. This point is very relevant for plastics reduction as there is no clear regulation, information or communication about alternatives to plastic although this may change as a result of newly proposed Extended Producer Responsibility (EPR) legislation from the UK government. Individual and community

efforts may be hindered by a lack of rapid action on plastic manufacture and sale, such as the continuing prevalence of single-use plastic packaging in supermarkets as it could lead to a perceived lack of individual capacity to change or to make an impact.

Although it is not a priority within the waste hierarchy, recycling is one of the most studied of waste-related behaviours. Much less is known about drivers for reduction. Some psychological studies have suggested that recycling opportunities may have unintended consequences, in that it may 'license' increased consumption of resources.[17]Research from Cardiff University found that found that reduction behaviours are far less common than recycling, and that they are predicted by both socio-demographic and psychological factors, including education, pro-social values, a green identity and intrinsic motivation.[18]

A study by the University of Bern observed the take up of reusable containers when manipulating the social norm. The results were mixed but found that there was an effect of the observed social modelling: witnessing others using a reusable takeaway box increased the odds of choosing one oneself. This finding demonstrates the importance of getting customers to perform the desired behaviour, to serve as social role models for others.[19]

A prominent view separates decision-making into two types of information processing: automatic, quick and heuristic-driven cognition (Type 1), and conscious, slower, and reasoned cognition (Type 2), where the two types may contrast or conflict with each other. [20] This view is at the centre to 'Traffic Psychology' and the behaviour of drivers. Roadside littering is a particularly complex phenomenon as environmental behaviours and driving behaviour is an especially good example of where these two types of information processing conflict. There are no known published studies, which have addressed the behaviour of littering from cars directly. Keep Wales Tidy and the University of Bath have undertaken a trial aimed at reducing roadside litter by applying type psychology but was deemed unsuccessful. The most common conclusion from research of behaviour change is to combine a variety of different interventions and approaches, tackling a wide range of behavioural determinants, both psychological and situational.

> The uses of plastic posing the highest risks in the future will be those related to high volumes, high emission profiles, and/or intrinsic hazardous properties of the materials. If [marine plastics] pollution is to be reduced, societal understanding and risk perception of the issue, together with motivations and behaviour change principles, need to be considered for lasting change.[21]

Although public perception is not a particularly reliable measure of litter levels, perception studies, which can identify values and responsibilities, are intrinsic to identifying underlying motivations, which can be used for targeting behaviour change. Work on a European scale has been carried out on this though the MARLISCO project which analysed public perceptions of marine litter from 1133 respondents across 16 European countries. People reported high levels of concern about marine litter, and the vast majority (95%) reported seeing litter when visiting the coast. The problem was attributed to product and packaging design and behaviour rather than lack of facilities or accidental loss of items.[22] Although not without its limitations, this study provided a good basis for further analysis of marine litter perceptions and will contribute significantly to future targeting of interventions. The study also identified public perceptions of government, retailers, industry and the media as agencies, which are considered to have the most responsibility and competence for reducing the problem but were less motivated to take action.[23]

Behaviour change has also been an element of recent research into Fishing for Litter schemes, notably from the University of Surrey, UK, which captured a number of recommendations for maximising take up of Litter schemes amongst the fishing community. (Wyles, 2018). Further research into this demographic and surrounding industries is important, particularly as studies have shown that the

general public consider this type of litter as 'lacking in intention' and therefore responsibility (unlike public litter). [24] The development of effective and efficient instruments requires a strong link between the behaviour change driven by the instrument and the harm caused by marine litter.[25] Importantly for policy makers, studies suggest that public perceptions are more likely to increase in positivity only after they have had experience of a particular intervention.[26]

Research of post-implementation policy impacts on behaviour is increasing as more countries adopt interventions to reduce marine litter through voluntary or financial incentives. Most notably in Wales is Cardiff University's longitudinal study on the impacts of the Single-Use Carrier Bag Charge (SUCB) in the UK, which also considered the phenomenon of 'spill-over' behaviours and public attitude to related environmental interventions as a result of the charge.[27] Further research has been undertaken, particularly in the USA and more recently in Australia as to the effectiveness of Deposit Return Schemes, which can easily measure consumer participation in the levels of return rates. For example, a study of South Australia's container deposit scheme undertaken to evaluate its effect on reducing waste lost to beaches and reported a threefold reduction. [28] A clear reduction was also seen in a study of the Gulf of Maine region which gathered beach clean-up data from Canadian provinces and US states with bottle return system in place and were compared to clean up data from US states without. [29]

Environmental taxes (such as tourist taxes) have also been widely studied for their ability to change behaviours and cover the costs of maintaining a high-quality visitor environment and Pay as You Throw (PAYT) Systems for as an incentivisation for waste reduction has also been widely researched in Europe where the system is commonplace.

Research has been devoted to exploring the impact of economic incentives rather than the more complex task of measuring inaction. It is not clear for example, the impact that the expansion of the sharing economy has had on litter reduction and consumer behaviour or, conversely, whether media attention of waste and reuse has contributed to greater participation in sharing and re-use schemes. The ONS is currently attempting to define this area for future research as many surveys have identified a significant increase in take up. One 2018 study from Warwick Business School claims that users of the sharing economy in the UK have grown by 60% in 18 months.[30]

Any proposed solutions to our marine litter crisis will require an understanding of current practices, motivations and behaviours. Although there is an explosion of activity in this field, more robust study is needed from HEI's in the UK in order to truly integrate behaviour change into policymaking and to effectively target communication and interventions.

At this point in time, it is not clear what the best solution is, but it is clear that human practices and perspectives will need to be integrated with technical and systemic solutions to find effective solutions that reduce plastic and stop them from escaping to the natural environment.[31]

Research Snapshot

K. Wyles (2018) (Under Review) *Fishers as the Stewards of the Sea: An Evaluation of the Fishing for Litter (FFL) Scheme in the UK in terms of Attitudes, Behaviour, Barriers and Opportunities*

MARLISCO - Marine litter in Europe Seas: Social Awareness and CO-Responsibility (2012-2015)

Litter Free Coast and Sea Somerset project aims to protect bathing water quality and reduce beach and marine litter along the Severn Estuary coastline by encouraging local communities to consider their own impacts on water quality and marine litter (based at Cardiff University).

‘The uses of plastic posing the highest risks in the future will be those related to high volumes, high emission profiles, and/or intrinsic hazardous properties of the materials. If [marine plastics] pollution is to be reduced, societal understanding and risk perception of the issue, together with motivations and behaviour change principles, need to be considered for lasting change.’ - *SEPEA Review 2019*

Full-page image of swimming turtle with plastic bag in the background

Scale, Sources and Impacts

Within the field of the natural sciences, there has been a consistent stream of research, which has added to our knowledge of the scale and impacts of marine litter. The majority of research in this field has focused on the environmental impacts, particularly the threat to wildlife. One of the most renowned centres for studying these impacts is the International Marine litter Research Unit at Plymouth University. Their microplastics research, since 2004, has been highlighted as one of UK's 100 best university breakthroughs after demonstrating in a number of key publications, the scale, distribution and accumulation of microplastics in the ocean. Recent research has focused on sources and the impact of tyre particles as primary contributors to micro-pollution, building on the work of publications from NW Europe which have suggested that the relative contribution of tyre wear and tear to the total global amount of plastics ending up in our oceans is estimated to be 5–10% [32] although some studies of atmospheric presence have suggested as high as 42%.[33] Microfibres from clothes is also a more recent area of research in the past 4 years and has estimated that over 700,000 fibres could be released from an average 6 kg wash load of acrylic fabric.[34]

There are gaps in knowledge on the actual sources and entry pathways in quantitative terms and no reliable method exists for tracing and tracking the origin, source, transport or manufacturer of degraded plastics or microplastics found in environmental samples.

There are even more gaps in published knowledge in terms of the source transportation of plastics, particularly microplastics. For example, we know virtually nothing about transport mechanisms and mass flows in and from the atmosphere or soils. In freshwaters, we do not know to what extent peak events such as flooding influence Microplastics transport. Furthermore, there is little known about the scale and impact of plastics in the water column or the role of coastal geo-ecology in transporting or breaking down plastics.[35]

Environment

A number of environmental institutes exist globally which have taken on research into impacts of marine debris and microplastics on a variety of ecosystems from the Arctic to the Red Sea, from microbes to mammals to sea flora and corals. Ingestion of plastics by all levels of the food chain is perhaps the most commonly considered occurrence in the marine environment. We know, for example, that filter feeders, deposit feeders and planktonic suspension organisms have been considered the most susceptible to microplastic ingestion, 'due to the relatively unselective nature of their feeding strategies'.[36] However, there is still a great deal about the impacts on individual species and on ecosystems that we do not know and studies into the impacts in the freshwater and terrestrial environments is in relatively early stages.

Recent freshwater studies have indicated that microplastic concentrations are similar to levels found in the marine environment. Although work by the Association for the Sciences of Limnology and Oceanography (Argentina) has cautioned that; 'the numerous differences between freshwater studies (including studied species and habitats, geographical locations, social and economic contexts, the type of data obtained and also the broad range of purposes), show only fragments of the overall picture of freshwater plastic pollution'.[37] The Association also notes that the bulk of current study focuses on micro and not macro plastics and that there is little existing data and understanding of the impact on the major rivers around the world. Some of our most recent understanding has come out of Cardiff University's Water Institute.

Research shows that microplastic fragments - pieces of plastic debris under five millimetres - are ingested by one in every two insects in the rivers of South Wales (Rivers Taff, Usk and Wye). [38]

The Water Research Institute was launched in 2015 to address the grand challenge of sustainable water management for people and ecosystems in a changing world. Current research from Institute is focusing on the impact of microplastics on freshwater systems, having already discovered their presence in two- thirds of invertebrates and river birds along Welsh rivers. The majority of research funding has been directed to marine investigation so these findings are at an early stage but could mark the beginning of a new phase of study into the scale and impact of plastics in our environment. Currently however, funding in this area is scarce. Waste Water treatment, sources of microfibres and impacts of plastic alternatives are also pending research areas for freshwater analysis.

A global study considering the scale of plastics across all types of environment concluded that; fragments of all sizes are ubiquitous in soils to lakebeds, from remote Antarctic island shores to tropical seabeds.[39] As research in this area expands, we are gaining more knowledge about the scale of plastics in our environment and the impact on terrestrial environments. Microplastics in various soil studies have been detected although our understanding of the impact is limited. Early research has been undertaken in laboratory settings which have demonstrated that soil biota have the ability to transport micro particles[40] but further studies are required to explore the impacts of this and on other organisms as well as crops and soil quality.

Social

Microplastics have been detected in both bottled and tap drinking water[41] and there is sufficient published evidence to say that microplastics occur in both water and foodstuff.[42] Although the quality and consistency of methodologies in these studies do vary. Our knowledge of the occurrence of microplastics in components of the human diet varies across regions and there is a current lack of studies, which have considered the impact of plastic in soil and the potential effect on crop production.

Microplastics have been reported in both indoor and outdoor air (tyre wear is again considered to be a major contributor).[43] Aside from degradation studies, (i.e.; laboratory experiments on the degradation time of different types of material) plastic interactions with the terrestrial environment, in particular the human impact, is not well understood. The extent of plastics in our air is not easily measured, as it is not a part of current technological systems for measuring air quality.

Economic

There have been some studies which have been carried out into the economic impact of marine litter although many of these tend to be broad estimates or hyper-localised. This area of research is growing however, and methodologies are becoming increasingly aligned. Measuring the full economic cost of marine litter is complex due to the wide range of economic, social and environmental impacts, the

ECONOMIC IMPACT OF MARINE LITTER IN THE UK

Fanshawe and Everard (2002) estimate the costs related to marine litter in the UK at USD 35 million (GBP 23.4 million) per year. This figure is obtained by multiplying the most cautious of Hall (2000)'s estimates (USD 9,000 (GBP 6,000) per boat per year) by half of the total UK fishing fleet (i.e. 3,900 boats). The same authors estimate the cost of marine litter to UK aquaculture at USD 475,000 (GBP 316,800) for cage clearance (one hour per month, as estimated by Hall (2000) at USD 121 (GBP 80) per hour, multiplied by 330 farms) and USD 890,000 (GBP 594,000) for fouled propellers and intakes (USD 225 (GBP 150) per incident x 330 boats x 1 incident/month).

UNEP (2017) 'Marine litter – Socio-Economic Study'

range of sectors impacted by marine litter and the geographic spread of those affected. Some of the impacts are easier to evaluate in economic terms because they are more direct (e.g.: cost of cleansing, clearance and disposal) whilst others are more complex, (e.g.: ecosystem deterioration or reductions in quality of life and coastal resilience).

The absence of economic studies into the impact on ecosystems and provisioning services is perhaps somewhat surprising given the increasing interesting in measuring these systems within academia and government (although arguably, many remain in the environmental field). Valuations of marine ecosystem services, estimated at €16.5 trillion in one study[44] suggest that even fractional deterioration in provision would represent a significant cost.[45] The ecological impacts are particularly important to include in any estimation of economic impact as one study notes; 'given that the introduction of alien invasive species can have a detrimental impact on marine ecosystems and biodiversity and can result in serious economic losses to many marine industries, any estimates, which exclude such ecological impacts, will inevitably fall seriously short of the true cost of the marine litter problem'.[46] For example, the introduction of the carpet sea squirt (Didemnum vexillum) in Holyhead Harbour resulted in an eradication and monitoring program over a decade starting in 2009, which was expected to cost €670,000. This expenditure was economically justified as allowing the species to spread unpredicted and smother organisms and marine habitats would have cost the local mussel fisheries up to €8.6 million alone over 10 years.[47]

Economic impact can be most directly valued by the cost of clearance (quantified by the labour required to remove litter from shores and beaches). In the UK, the cost of removing beach litter to all coastal municipalities is estimated to be in the region of €18–19 million, equating to an average cost per municipality of €146,000.[48] *

An estimate of marine litter costs for the Shetland economy of €1–1.1 million on average per year consisted of actual expenditures and some cases of lost income. This is only a single case study, and the sectors affected on Shetland would be affected to varying degrees in other coastal areas. However, these findings clearly demonstrate that the economic impact of marine litter on coastal communities can be extremely high.[49]

The costs of cleansing are inevitably higher in those areas with higher population density and higher visitor numbers where greater resources are needed. It is important to note that these cleansing figures do not include any volunteer efforts. Mouat et al. (2010) estimated the value of volunteers' time in two annual beach clean operations in the UK. at which a substantial quantity of litter from the UK coastline was collected, to be around €131,000.[50] Although as this estimate includes neither financial assistance nor operational management costs, it is likely to be a substantial underestimate.

Other attempts have been made to quantify the economic costs of marine litter, which have included fishing gear removal, boat and propeller damage, tourism, recreation and other services.

Studies on the impact of litter on tourism have been undertaken in several regions although there is no agreed methodology to determine this as it is so guided by geographical factors and personal choice. There are a significant number of international examples, which have demonstrated that experiences or perceptions of litter at destinations impact visitor choice although more research is needed to assess the extent of the deterrent. According to one evaluation model from the University of London, coastal tourism together with bathing water quality (which are vulnerable to marine litter) show potential costs of up to £16m per year, not including larger economic losses from beach closures or wider ecosystem services (such as the value of wildlife).[51] Swedish research suggests that beach litter alone reduces tourism by between 1 and 5%.[52]

* Despite a recent Local Authority analysis of litter interventions, it is not possible to quantify the costs of litter for Welsh municipalities as very few separate waste and cleansing budgets

Marine litter cannot only directly affect fishing and aquaculture industries but also extends to other maritime sectors. For example, it can become entangled in the propellers of commercial and recreational vessels, causing a direct economic impact and also a potential reduction in maritime safety. Mouat's research again estimated that removing marine litter costs UK ports and harbours on average €2.4 million per year. There is no estimate for the cost of removing marine litter to the UK marina industry as a whole, but data from a small sample indicate that it could be costly, with one marina reporting an annual bill of €39,000.[53] The actual combined figure for the industry may be significantly higher (see page 12).

Research snapshot

Water Research Institute, Cardiff University – Publications & evidence to the Senedd Committee on Microplastics in rivers: http://senedd.assembly.wales/ieListDocuments.aspx?MId=5090

PLASTOX - *Direct and indirect effects of microplastics on marine organisms. Ecotoxicological effects of microplastics* (2016-2018)
PLASTOX is a European JPI oceans project of 14 European partners (Norway, Belgium, Ireland, Portugal Sweden, Italy, France and the Netherlands). The lead is Dr Andy Booth at SINTEF Materials and Chemistry, Trondheim, Norway. The projects primary focus is investigating the ingestion, food web transfer, and ecotoxicological impact of microplastics, together with persistent organic pollutants on key European marine species and ecosystems.

PLAST – *Dealing with environmental risks caused by plastic usage and consumption – An interdisciplinary contribution towards an ecological transformation*. (2016-2019)
This project is led by the University Koblenz-Landau (Germany) and was implemented in 2016 by the *Interdisciplinary Research Group for Environmental Studies (IFG-Umwelt).* In an interdisciplinary approach, the PLAST-project aims to analyse environmental risks due to the direct and indirect use of plastics and to contribute to a limitation of these risks. The sub-project of natural science (SOILPLAST) focuses on soil quality and sustainability analysing opportunities and risks of the use of plastic mulching in agriculture. Communication science (COMMPLAST) aims to identify how these risks are communicated via diverse media and among key actors. And psychological research (PSYCHOPLAST) investigates factors, which promote or impede the ecologically conscientious conduct of consumers.

WEATHER-MIC - *How microplastic weathering changes its transport, fate and toxicity in the marine environment* (2016-2018) - Norway, Sweden, Belgium and Germany.

EPHEMARE - *Ecotoxicological effects of microplastics in marine ecosystems*. (2016-2018). he EPHEMARE consortium incorporates complementary expertise from 14 partner institutes located in Belgium, France, Germany, Ireland, Italy, Norway, Portugal, Spain and Sweden as well as two microplastic experts from the UK.

The Arctic Marine Litter project is designed to work as a catalyst for change by directly engaging stakeholders in the identification of sources and solutions and by providing input for ongoing initiatives on marine litter in the Arctic. Wageningan University & Research, Netherlands.

While most people are perhaps not too keen on engaging in waste management, the lure of the sea is strong, and many communities are very active in protecting marine life and cleaning beaches. This enthusiasm has the potential to change land-based processes. – *Sabine Pahl, Plymouth University (2017)*

Full-page image of fishing boat

Methodologies for measuring (marine litter) and identifying Pathways

Today, published observations and measurements of plastic debris in all of these reservoirs (coastlines, sea surface, seafloor, and biota) as well as the water column, sediments and sea ice are numerous and global, yet the most commonly used sampling strategies remain much the same as they were in the 1970s, with relatively little standardisation across studies.[54] This means that studies are hard to compare and careful consideration is needed of the sampling methods in each dataset.

Furthermore, plastic marine debris has been reported in sizes ranging from microns to meters. Although widely used, the terms microplastic and macroplastic have no generally agreed-upon definition. Microplastics are most commonly defined as particles smaller than 5 mm, but they have also been defined as particles smaller than 1 mm and have been functionally defined (at the lower limit) as particles retained by plankton nets or sieves with variable mesh sizes.[55]

Potentially even more ambiguous is the term 'macroplastic', often this term is used to simply refer to debris bigger than microplastics and / or those visual to the naked eye. Although several studies of microplastics in water and sediment have reported particle size information, the lack of consistency and completeness in size characterization (i.e. equivalent spherical diameter and shape factor) and in concentration measure (i.e. number or mass), as well as other methodological problems, prevents direct comparison of results. [56] Other complexities of measuring include material and environmental considerations such as weather and UV degradation and erosion and the various types and sizes of materials entering the destination at source.

For macroplastic, a wide variety of survey protocols are reported in varying levels of detail, often-omitting even minimum detection size; thus, it is extremely challenging to compare data sets reporting abundance quantities for visible floating debris. To demonstrate the variety of sampling found in studies, the box below shows a just a few of the methodologies, which have been used broadly across international studies to measure macroplastics:

- Beach surveys from water's edge to splash zone
- Varying width transects to find the optimum (recommended transects have increased from 5m in the 1990's to 100m presently).
- Transect line quadrats, randomly dispersed
- Offshore and riverine water columns
- Strand line counts
- Number of plastic bin bags/trucks, by Local Authorities or volunteers.
- OSPAR (2009) and Ocean Conservancy (2016) surveys
- Aerial surveys using drones

Source: Williams, A.T, (2019)

Location bias may also be affecting our understanding of the complete picture. In a critical review of 104 studies of stranded intertidal debris, it was found that site selection strongly favours beaches (95% of studies, mostly performed on sandy beaches) over other coastal habitats, and that widely variable sampling methodologies with respect to site selection, types and sizes of measured debris, reported units (counts or mass), and spatial and temporal replication render data sets too disparate to allow for rigorous global-scale assessments.[57]

There have been efforts by the academic community to come together in recent years to attempt to standardise these methodologies and there are a number of current collaborations, which are working specifically on this issue. A workshop aimed at bringing together UK and European experts to discuss

THE INTERNATIONAL MARINE LITTER RESEARCH UNIT, UNIVERSITY OF PLYMOUTH

The work of Plymouth University in the past decade has put the institution at the forefront of research in the area of marine litter. Renowned for its research on microplastics since 2004, a great deal of our current understanding about the scale and impacts of Marine litter has come out of the IMLR and their impressive range of international collaborations.

The mission of the International Marine litter Research Unit is to further our understanding of the impacts of litter on the environment and society, and to identify the solutions and the pathways necessary to achieve them.

The core team at the Institute is multidisciplinary, expertise includes Marine Science, GeoChemistry and Psychology. Their wide range of publicised research can be found here.

Current Activity includes:

- Current and Future Effects of Microplastics on Marine Shelf Ecosystems (MINIMISE)
- Quantifying the influence of waste water treatment on the release of microplastics to the environment

these issues in depth was organised by the National Environment Research Council (NERC) and the Royal Society of Chemistry Water Forum in 2018. One common agreement was that, for microplastics at least, the issue may be too complex to agree a standard methodology although sampling methods could be replicated in comparable environments, most notably wastewater studies. The outcomes of the workshop can be accessed in their report here.

Research snapshot

UNEP Marine Litter Assessment in the Mediterranean (2016)

UNEP/IOC - Guidelines on Survey and Monitoring of Marine Litter

JRC European Commission - Guidance on Monitoring of Marine Litter in European Seas

JRC European Commission – Guidance for MSFD GES Riverine monitoring: Options & Recommendations

RIVERSEA - *Land-based sources of marine litter and microplastics. Evaluation and modelling transport in rivers and estuaries, and implementation of strategies for prevention and reduction at source.* (2018-2020) Lead- Nova University, Lisbon.

BASEMAN - *Defining the baselines and standards for microplastics analyses in European waters. Validation and harmonisation of analytical methods* (2016 – 2019)

BASEMAN is a European collaborative under the JPI Oceans Programme. It aims to explore validation and harmonization of analytical methods in the Identification and quantification of microplastics. The project is being led by the Alfred Wegener Institute in Germany. Their current publications can be found here.

Research & Development into alternatives to plastics

In 2019, news of eight new projects to be funded through the Plastics Research Innovation Fund in the UK were announced (listed below). Overall, these projects represent a collaborative effort to design out plastic waste, evolve the circular economy and rethink resources and recycling. A Plastic Waste Innovation Hub will also be created to join up efforts and collaboration. The £8million fund from the UK government demonstrates the political weight of this particular area of R&D and is an increasingly important issue for government with increasing pressure to address the plastic issue and to identify alternatives. The announcement followed the news of a £60 million allocation through the Industrial Strategy Challenge Fund, which will research more sustainable packaging, in particular the exploration for new forms of packaging and plastic made from farming, food and industrial waste.

A recent review led by Swansea University found that a great deal of innovation has been developed in the past 2 years. Although many may not be currently commercially viable, the study suggests that many are sound.[58]

Current innovation and research includes; the use of enzymes and bacteria to break down plastic waste, products made from crop sources (such as rice and wheat), edible water pouches made from seaweed, repurposing and upcycling of plastics into high end products using 3D printing and the exploration of bioplastics to name a few.

These innovations are complementary to our prevention and reduction efforts and although a great deal of products exist, solutions to overcoming the complexities for establishing alternatives on a global or even nationwide scale are still to be found. Furthermore, for future sustainability and the avoidance of potential unintended consequences, new innovations will also require lifestyle impact analyses even for natural and renewable products.

Perhaps equal to the research being undertaken in the world of bioplastics are the number of cautionary articles and publications warning against them. For example; According to a report on the environmental impact of bioplastics published by the government in 2010,[59] it takes 1.7 square metres of arable land to grow each kg of PLA (polylactic acid), one of the main bioplastics, which can be used as a substitute for many types of food packaging. Europe consumes almost 60 million tonnes of plastic a year. If all this packaging were instead grown in fields, it would take up 40,000 square miles — nearly a tenth of all arable land currently under cultivation in Europe.[60]

> Everyone agrees something must be done. From banning plastic straws to rebooting recycling systems to harnessing plastic-munching bacteria, there is no shortage of touted solutions. It is less clear what would work best. But fixing the plastic waste crisis is going to take some seriously joined-up thinking. If we make the wrong decisions now, we risk making the problem worse.[61]

Research Snapshot

Projects funded through the Plastics Research Innovation Fund (2019-2021) are:

Exeter Multidisciplinary Plastics Research hub: ExeMPLaR - University of Exeter
Multidisciplinary Plastics Research Hub - "ExeMPlaR" led by the University of Exeter to provide the first stage in a comprehensive, systematic and coordinated approach to the formation of a novel and creative circular economies, using regional demonstrators in the SW of England to test a number of key building blocks.

Rethinking Resources and Recycling: RE3 - The University of Manchester
RE3 aims to create a number of stakeholder led projects to; reduce the need for plastic by addressing demand, improve the materials used to deliver better performance and clean degradation, demonstrate new methods for recycling soft and mixed plastics/non-plastic films and removal of micro plastics from

source; and create smart circular economies that allow users to take ownership of and reduce plastic waste.

Designing-out Plastic Waste - University College London

Evolving a circular plastics economy - University of Hull
This project aims to identify the gaps and leaks in a plastics circular economy, and explore and develop new pathways to an enhanced circularity in plastics use by facilitating the co-design and execution of specific innovations across an interdisciplinary range of academics, stakeholders and consumers, from the full plastic value chain.

UKRI Circular Economy Approaches to Eliminate Plastic Waste - University of Cambridge
This programme will establish the 'Cambridge Centre for Circular Economy Approaches to Plastic Waste' with the aim of forming a globally-recognised think-tank. Specific programme work includes; new materials to packaging films, methods for biological processing, technology for converting plastic waste, means for generating electricity and hydrogen fuel from plastic waste, production of high value plastic filaments for plastic waste for use in 3D printing, understanding of plastics material flows, technologies for late-stage marking and coding for tracking of different types of plastics, new understanding of how consumers and the public deal with plastic waste, and new business models for industry to support increased recycling and a reduction in plastic waste.

Advancing Creative Circular Economies for Plastics via Technological-Social Transitions (ACCEPT Transitions) - Queen's University of Belfast
ACCEPT Transitions will look at the opportunities to realise a sustainable and resilient plastics circular economy within a 'socio-technological transitions' approach that integrates innovation and creative design thinking across technological, policy, consumer behaviour and supply chain management domains.

Plastics: Redefining Single-Use - University of Sheffield (Grantham Centre for Sustainable Futures)
Four cross-disciplinary teams will address the circular plastic economy from a technological perspective to understand how societal behaviour adapts to increased environmental understanding, regulatory nudges, intervention, and new product development.

Holistic integration of technology, design and policy for a greener plastic future - Imperial College London
Research programme which aims to tackle the challenges associated with plastic waste along two general thrusts: (1) resource preservation; and (2) waste prevention.

‘Litter lies in at the end of a process that involves production, consumption and disposal – a chain in which the consumer (and potential litter) is the weakest link, with the least power’ *(MacGregor, S, University of Manchester, 2017)*

Full-page image of Welsh coast

Wastewater & UK Water Industry Research

Microplastics are directly entering sewer systems from domestic sources, and here mainly consist of synthetic textile fibres, cosmetic microbeads and disintegrated parts of larger consumer products that are flushed down the toilet.[62] Wastewater treatment plants (WWTPs) are considered an important entry point for microplastics to the aquatic environment. Despite this, a review carried out in 2018 on 103 marine litter studies identified that none of them included any marine litter waste management.[63] Like the complexities of other environments, identification methods and sampling standardisation is yet to be developed for wastewater, so qualities of studies vary considerably and are difficult to compare from region to region.

Sewer systems transport microplastics into WWTPs, which are highly efficient barriers preventing microplastics from entering aquatic ecosystems. They are designed to remove particulate matter but the latest studies demonstrate that WWTPs retain 87–99% of the microplastics load.[64] The removal efficiency will depend on the specific treatment technology, and the differences in removal efficiencies between various technologies are still understudied.[65] Research is still in its early stages as to the impact of the use of sewage sludge for fertiliser and non-domestic effluent sources such as plastic pellets and construction work. Industrial effluents are often treated separately but their contribution to the overall concentration of microplastics in wastewaters has not been yet investigated.[66] The potentially significant contribution to plastics and debris entering aquatic environments via sewage water storm overflows also requires further research.

There is increasing evidence on the presence and scale of microfibres from clothing and the washing process. Although the occurrence of microplastics were investigated only in limited regions, secondary microplastics and synthetic fibres originated from garments have been found to be a major source of microplastics in Sewage Treatment Plants.[67] It is estimated that the most advanced wastewater treatment plants with tertiary treatment may be able to capture 80-90% of microfibers, but the cost of applying such treatment infrastructure to less advanced plants has not yet been calculated, and it is not completely clear whether the majority of particles are captured by the final filters or earlier treatment phases such as sedimentation.[68]

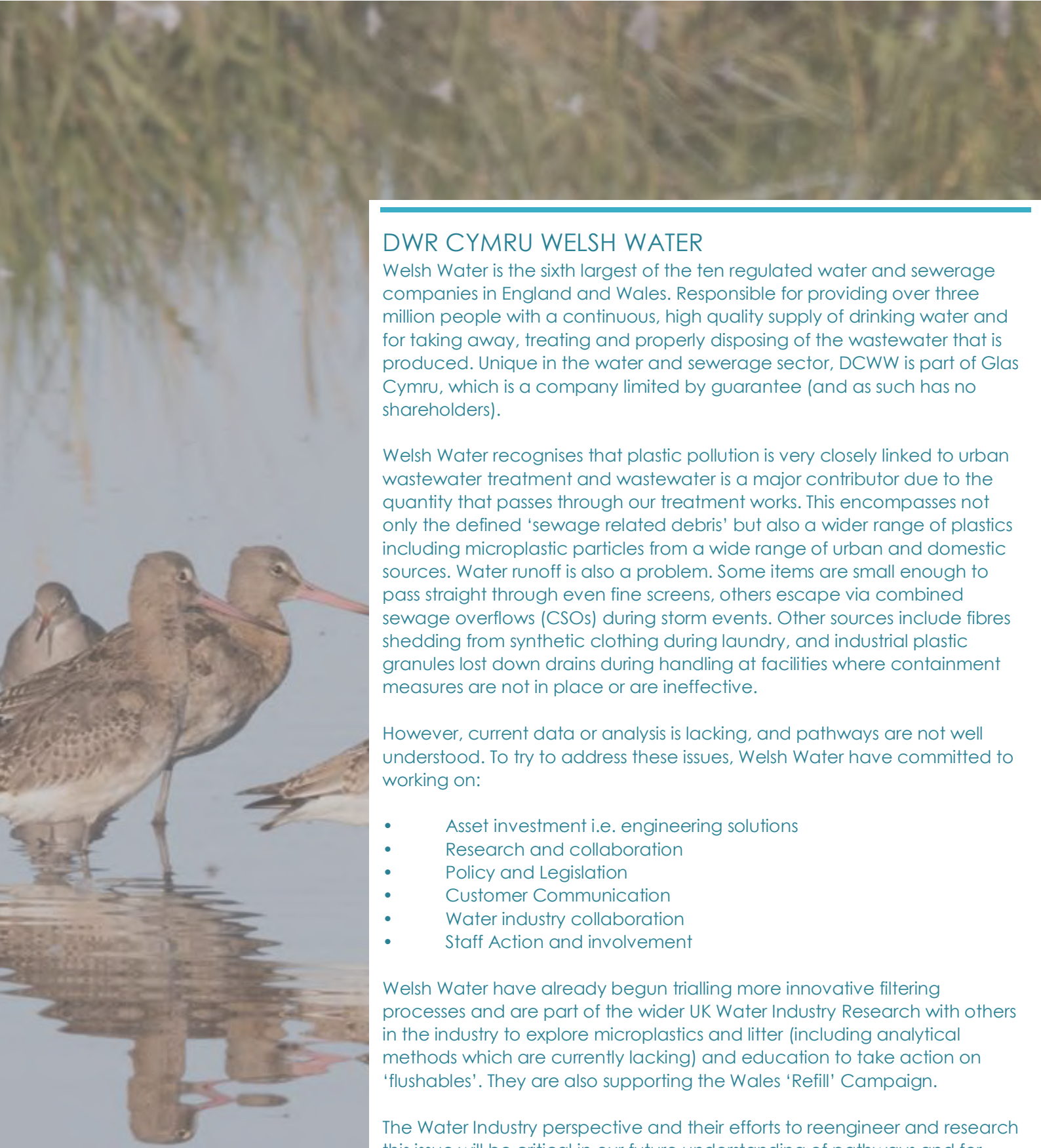
UKWIR was set up by the UK water industry in 1993 to provide a framework for the procurement of a common research programme for UK water operators on 'one voice' issues. UKWIR's members comprise of19 water and sewerage undertakers in England, Wales, Scotland, Northern Ireland, the Republic of Ireland and Irish Water.[69] In 2018 UKWIR added the impact and scale of microplastics on to its research programme and the current project: Sink to River - River to Tap - A review of Potential Risks from Nano-particles and Microplastics project is required to give a clearer understanding to the water industry of any presence or risks arising from nanoparticles and microplastics. Its scope will cover raw water abstraction, through to water treatment and supply and then from wastewater collection and treatment through to the wastewater discharge.

The overall aim of the proposed research is to develop a knowledge base that facilitates improved understanding of complexities involved in the microplastics quantification, characterisation and toxicity potential assessment and then explore the effectiveness of available treatments.

Research snapshot

UK Water Industry Research group

As well as the Water Research Institute in Cardiff mentioned in other sectors, the Water Innovation and Research Centre (WIRC) at Bath University has extensive research collaborations in progress in this area and Plymouth university have a current (2018 – 2022) NERC funded project on 'Quantifying the influence of waste water treatment on the release of microplastics to the environment'.



DWR CYMRU WELSH WATER

Welsh Water is the sixth largest of the ten regulated water and sewerage companies in England and Wales. Responsible for providing over three million people with a continuous, high quality supply of drinking water and for taking away, treating and properly disposing of the wastewater that is produced. Unique in the water and sewerage sector, DCWW is part of Glas Cymru, which is a company limited by guarantee (and as such has no shareholders).

Welsh Water recognises that plastic pollution is very closely linked to urban wastewater treatment and wastewater is a major contributor due to the quantity that passes through our treatment works. This encompasses not only the defined 'sewage related debris' but also a wider range of plastics including microplastic particles from a wide range of urban and domestic sources. Water runoff is also a problem. Some items are small enough to pass straight through even fine screens, others escape via combined sewage overflows (CSOs) during storm events. Other sources include fibres shedding from synthetic clothing during laundry, and industrial plastic granules lost down drains during handling at facilities where containment measures are not in place or are ineffective.

However, current data or analysis is lacking, and pathways are not well understood. To try to address these issues, Welsh Water have committed to working on:

- Asset investment i.e. engineering solutions
- Research and collaboration
- Policy and Legislation
- Customer Communication
- Water industry collaboration
- Staff Action and involvement

Welsh Water have already begun trialling more innovative filtering processes and are part of the wider UK Water Industry Research with others in the industry to explore microplastics and litter (including analytical methods which are currently lacking) and education to take action on 'flushables'. They are also supporting the Wales 'Refill' Campaign.

The Water Industry perspective and their efforts to reengineer and research this issue will be critical in our future understanding of pathways and for future innovation.

Full page image of wading birds

Further Resources

Key Organisations and Institutes

National Oceanography Centre: https://noc.ac.UK/

The National Oceanography Centre is one of six centres supported by the Natural Environmental Research Council (NERC), and funded to work on national capability programmes. NOC has two sites in the UK in Southampton University and Liverpool University respectively. NOC work collaboratively with over 30 other UK marine institutions through the NOC Association, are supported by the NOC Stakeholder Advisory Board and engage through the Marine Facilities Advisory Board. NOC represents the UK internationally, leading the UK delegation of the Intergovernmental Oceanographic Commission of UNESCO, through our membership of the European Marine Board, and through partnerships with other research institutions and organisations worldwide.

NERC Centre for Ecology & Hydrology: https://www.environmental-research.ox.ac.UK/partners/centre-for-ecology-hydrology/

Based in Oxford, the NERC Centre for Ecology & Hydrology is publicly owned and governed by NERC (National Environment Research Council). Their remit is to perform integrated research in terrestrial and freshwater ecosystems and their interaction with the atmosphere.

International Marine Research Unit, Plymouth: https://www.plymouth.ac.UK/research/marine-litter

The International Marine Litter Research Unit at Plymouth University is at the forefront of research into marine litter and microplastics. It has a number of collaborative, international and multi-disciplinary areas of research.

The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans): http://jpi-oceans.eu/about

The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) is established in 2011 as an intergovernmental platform, open to all EU Member States and Associated Countries who invest in marine and maritime research. JPI Oceans covers all European sea basins and provides a long-term integrated approach to marine and maritime research and technology development in Europe. The UK is currently one of a number of EU countries who are members of the initiative.

Society for environmental toxicology (Europe): https://helsinki.setac.org/

The society of Environmental Toxicology and Chemistry (SETAC) is a not-for profit, global professional society established in 1979 to provide a forum for individuals and institutions engaged in education, research and development, ecological risk assessment and life-cycle assessment, chemical manufacture and distribution, management and regulation of natural resources, and the study, analysis, and solution of environmental problems. SETAC Europe is one of five geographic units of the global SETAC organisation.

Ocean Plastic Solutions – Imperial College, London: https://www.imperial.ac.uk/ocean-plastic-solutions

The Imperial College Ocean Plastic Solutions Network strategically combines engineering and environmental science capabilities from all faculties to develop multi-disciplinary transformative research to prevent plastic pollution. The network's aim is to reduce the flow of plastic that becomes residual waste before it leaks to the environment and the ocean. Recent publications can be viewed here.

Evidence Reviews (2016-2019)

Science Advice for Policy by European Academies (SAPEA) Evidence Review on micro and nano-plastics (2019) *A scientific perspective on microplastics in nature and society*

Annual Review of Marine Science: Plastics in the Marine Environment (2017)
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GESAMP Sources, fate and effects of microplastics in the marine environment:
(Part 1): http://www.gesamp.org/publications/reports-and-studies-no-90
(Part 2): http://www.gesamp.org/publications/microplastics-in-the-marine-environment-part-2

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