Sustainable Chemistry

Tackling the Challenge of Packaging Plastic in the Environment

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Plastics in the Ocean: A Systems Failure?

Nearly all of us will have seen the pictures of marine life from seabirds to whales starving due to their stomachs being full of plastic bags or plastic fragments. Or the scenes from 'The Blue Planet' of dolphins playing with plastic bags and of turtles tangled in plastic straps. Or reports of the Pacific and other ocean gyre garbage patches. Responding to public concerns, politicians have called for measures to solve the 'plastic waste problem', and the European Commission has launched a range of initiatives within the European Union starting with the role of plastics in the circular economy and including a range of measures to improve recycling rates and limit the use of so-called single-use plastics (SUPs).

But will this problem by easily solved? Pollution of the environment by plastics (especially plastic packaging) is what we call a social trap—people and organizations and society as a whole do not intend to put plastics into the environment; it is nevertheless happening on a large scale. Many stakeholders are involved in the value chain from feedstock to waste and there are examples of a blame game which can distract from solving the problem. For example, consumers complain that everything is covered in plastic, while retailers claim consumers demand convenience for their on-the-go lifestyle.

Solving this social trap requires a holistic perspective where the motives and actions of the various stakeholders are in some sort of alignment and certainly not opposed to each other. Stakeholders involve significant parts of the chemical industry, product designers, marketing departments, consumers (and their behavior), all the way to the recycling and disposal industries which offer options at end-of-life. We at EASAC[1] decided to take such a holistic approach when we launched a project on packaging plastics and the circular economy, culminating in a report released in March.[2] Let us highlight some of the findings.

Linearity and its Problems

The current value chain for packaging plastics is an example of the 'linear economy'. Fossil fuel feedstocks are refined to produce monomers which are polymerized to produce the basic plastic resin (ethylene to polythene (PE) etc.). The resins can be compounded, using additives and fillers, into the many different types of plastics required for the product concerned. After use the consumer discards the packaging, from whence it may be recycled, incinerated, landfilled or leak into the environment. Our 'systems' approach reveals many conflicts between different parts of this value chain. For example, do designers think much about how to recycle their packaging? Why are refiners investing so heavily on the flawed historical paradigm of perpetual growth when circular economy aims for reducing material flows? Do consumers really mean what they say when they say we should use less plastic (perhaps while carrying a plastic water bottle or consuming their take-away food and drink). Why is recycled material more expensive than virgin plastic, or ruled out on quality grounds? Why have we been 'recycling' by offloading the problem onto other low- and middle-income countries? What can Europe do when most of the plastic waste entering the marine environment enters via from Asia and Africa?

In our review we look at the related technical issues of environmental impact, technical challenges in recycling, how consumers behave, the role of bio-based and degradable plastics, and policy options including extended producer responsibility and deposit return schemes. Some of the system failures addressed in the report are shown, along with some of the headline policy options in Figure 1.

Externalities Ignored

At the start, we find that, whatever policy makers are saying about the need for a circular economy (and its importance in achieving Sustainable Development Goals), the message is not being heard by the players in the old linear economy. They want to keep growing at historical rates despite concerns over planetary boundaries, climate change, resource depletion or other 'green' issues. Companies are spending billions on increasing cracker capacity assuming we will continue to grow our demand for plastics, while societies are banning plastic bags or otherwise trying to reduce the flow. Reducing leakage into the environment is hardly compatible with continuing historical growth rates!

Economic and investment decisions are also skewed because of the failure to internalise social and environmental costs. One driver of increased investment is to find ways of using cheap shale gas from US shale, but these prices do not include externalities such as methane leakage or the ability to

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Value chain stage	Fossil fuel feedstocks	Bio feedstocks	Packaged goods manufacture and retailer	Consumer	End-of-life
System Failure	Social and environmental costs of fossil fuels ignored	Simplistic image that 'bio'= environmentally friendly	Inadequate attention to end-of-life issues	Single use and on-the-go culture; Weak incentives	Limited and uneconomic recycling
Policy Options	Charging for externalities Plastics tax?	Full Life Cycle Assessment for bio feedstocks	Full cost EPR and eco-modulation	Pricing (deposits/ discounts) and seeing packaging as on loan	More capacity and range of options for recycling
			Deposit Return Schemes		Ban on landfill and export
			Simplify resins and formats		

Figure 1. Some system failures and policy options (EASAC, 2020).

avoid post-closure costs by abandoning wells. Neither is a realistic carbon price yet in place. Such market failures lead to low prices for virgin plastic resins, which in turn encourages higher rates of consumption and creates a cost barrier to replacing virgin with recycled materials. There is thus a reasonable case for a tax to reflect the negative externalities of virgin plastics, although we have to be careful in designing this so as to avoid perverse incentives to switch to materials with greater environmental impacts or energy and material demands.

Incentives to Recycle?

When we think about the design of plastic packaging and its recycling, we find examples where current market incentives actually reward producers for disrupting the recycle system (e.g. opaque PET, composites), and the market signals that incentivize producers to take into account end-of-life recyclability may be weak. Each country has a policy tool to address this in the form of extended producer responsibility (EPR) where fees are charged based on the amounts of plastic used, but these vary greatly between countries and may be insufficient to influence manufacturer and retailer priorities. Our analysis suggests that EPR costs need to be at or above the highest existing charges (e.g. in Austria or Italy's ca. €250 per tonne of packaging material with this average figure adjusted so that fees for easily recyclable plastics are low and those for unrecyclable materials very much higher (termed 'eco-modulation'). Needless to say, since imported goods and products purchased via the internet tend to use more packaging than those bought in a store, these should not be exempt from EPR.

Recovering materials for recycling presents a major challenge which mechanical sorting technology can only partly solve. For valuable materials like polyethylene terephthalate (PET), deposit return schemes (DRS) already deployed in many countries achieve collection rates of over 90% for drinks containers and have a ready market in existing PET recycling capacity. DRS (along with plastic bag charges) is an example of one of the basic rules underlying consumer behaviour—that consumers are highly influenced by prices. We thus not only encourage wider application of DRS schemes within the EU, but also see scope for widening the scope of DRS to other containers and single-use beverage bottles (e.g. HDPE containers, coffee cups). Consumers should be encouraged to these as 'on loan' rather than something to be discarded.

Special Challenges in Recycling Mixed Plastics

At present, outside the recycling of easily separated (e.g. via DRS) waste streams, much packaging waste ends up as mixed plastics which pose huge challenges. Not only are the resins different, but there will be a huge variety of fillers, additives, as well as contamination by contents. Such wastes have thus tended to go to landfill, or incineration (with or without energy recovery). Even though statistics show that an increasing proportion of these plastics are being 'recycled', the public has been rather shocked to find out that much of this 'recycling' consisted of exporting it, without too much attention given to what happened to it. China was the main destination until 2017 but since their ban, there has been a shift to find other countries which will accept the displaced shipments. Since most of these countries had inadequate waste management and recycling infrastructure for their own waste, it is hardly surprising that any recycling has been crude and polluting and much of the waste often abandoned. We concluded that EU countries should tackle their own plastic waste within Europe and not offload this on low- to middle-income countries.

If we are to clean up our act, we need first to ensure that the reformed EPR systems do lead to manufacturers designing their packaging for recyclability as much as performance. There is also scope for simplifying the recycling stage if the number of different polymers used for specific applications were to be reduced. For instance, limiting the main resins used in large volume applications to transparent PET (which generally lacks additives) and PE (which often contains only antioxidants) would increase recyclability greatly and potentially increase the amount of waste that can be recycled economically. Nevertheless, a more diverse range of options will also be needed if the energy and materials contained in the majority of waste is to be recovered. Various processes are at the dem-

onstration stage and we advocate that a diverse range of options should be developed to offer recycling or treatment options for all plastic packaging. These could follow a four-stage hierarchy:

1. The optimum would be for **closed loop recycling** where the waste can be recycled to the same product—already possible for recycling PET bottles to PET bottles.
2. The next would be **open-loop recycling** where recycled material is reused in other plastic goods (e.g. in plastic limber, flower pots etc.) where quality requirements are less.
3. For wastes which cannot be recycled as plastics, there may still be options through chemical treatment or pyrolysis to extract chemicals or fuels—we could see that as **'molecule recycling'.** Achieving a net environmental benefit (energy and resource saving) as well as economic viability remain challenges but demonstration plants are operating[3]).
4. As a final option, incineration of any remaining unrecyclable plastic waste may be the 'least worst' option but only with **energy recovery**.

Back to the Environment

Of course, the ultimate target for reforming the packaging plastics value chain is to limit and preferably stop leakage into the environment, especially the marine environment. Here the EU is only responsible for a small percentage of inputs into the oceans with the vast majority coming from rivers in Africa and Asia. Of course, we should do better in our own waters and are applying new measures to reduce use of SUPs, reduce losses from fishing and aquaculture etc., but there is also a role for international aid agencies (World Bank etc.) to support waste management infrastructure in high leakage countries.

Much debate has also taken place recently over 'microplastics'—particles less than 5 mm. These are derived from breakdown from 'macroplastics' but also from deliberate addition to consumer goods and other sources (transport losses, tyre wear, ship blasting etc.). Clearly deliberately adding microplastics to consumer goods can be easily avoided, but microplastics are now found almost everywhere- in the deep ocean, in Polar seas and snows, they can be detected in drinking water and contaminate food. Any risks from this ubiquitous and persistent exposure is very difficult to assess by evidence-based risk analysis, and debate within society on how far to apply the precautionary principle may well be necessary.

The 'Bio' Word

Finally, we looked at bio-based plastics and issues of biodegradability. Despite the ways in which the term is sometimes used in advertising, the term 'bio' does not automatically equate to reduced environmental impact for several reasons; bio-based plastics require feedstocks that can compete with land for food and drive land use change, and assessing overall greenhouse gas emissions can be difficult. Where companies position their 'bio' products as environmentally friendly, we thus suggest such claims should be based on life cycle assessments and not on simplistic assumptions that 'bio' means lower environmental impact. While we applaud the work that has been carried out on biodegradability and encourage further research, we believe that faster and more reproducible rates of degradability are needed before they can offer a solution to the problem of often-littered single-use plastics.

Some Progress?

The Commission has a comprehensive strategy addressing many of the points we make. Another recent development has been the launch of a European Plastics Pact (March, 2020) which displays many basic principles and objectives similar to those we have identified. Leaders in the industry appear to accept that the linear economy for packaging plastics should move towards a circular model. By working together and building on these trends, we can hopefully achieve the target of enjoying the many benefits of plastics in packaging without the current extensive negative side-effects.

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[1] The European Academies Science Advisory Council is a consortium of all 28 of Europe's science academies that analyses issues emerging from science and which are on the European policy agenda.
[2] EASAC, 2020. Packaging plastics in the circular economy. Policy Report 39. https://easac.eu/fileadmin/PDF s/reports statements/Plastics/EASAC Plastics complete Web PDF.pdf.
[3] For example, Recycling Technologies plant at Perth, Scotland with expansion planned to the Netherlands. https://recyclingtechnologies.co.uk/2020/04/first-site-in-europe-will-be-located-in-the-netherlands/.

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Tackling the Challenge of Packaging Plastic in the Environment

How to solve a problem like Man-made plastics? In this Science Voices article, Dr. Michael Norton, Programme Director of the European Academies Science Advisory Council (EASAC) summarizes a recent report on the challenges and progresses concerning plastics in the environment.

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