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Briefing Note – summary of Briefing Paper No 5 July 2020

Enabling a greener plastic future through molecular science

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Headlines

Issues

- Plastic is a low-cost, versatile, high-performance material.
- Plastic production is expected to double in 20 years and almost quadruple by 2050, by which time the plastic industry will account for 20% of the world's total oil consumption.
- Many plastic products are difficult and/or expensive to recycle because of the substances used in their manufacture. Waste management and infrastructure are often insufficient, so plastics leak into the environment.
- Discarded packaging plastics for fast-moving consumer goods are hazardous to wildlife and contaminate the food chain.
- Packaging plastics for food are potentially a substantial hazard to public health.

Solutions

- This needs a multi-pronged, medium-term strategy that implements the right incentives for each stage of the innovation cycle:
  - make plastic products less toxic, more reusable and more recyclable through novel material combinations, processing methods and overall design,
  - develop new technologies to recover polymers and monomers from used plastics and improve recyclability,
  - gain a wider understanding of the health impacts from plastic products on humans and the environment,
  - build new policies, better commercial and civic practices, and increased public awareness of resource efficiency.

What is plastic and why is it hard to recycle?

Plastics are materials made by joining a large number of small molecules, called monomers, together into a polymer. The more complex the make-up of the polymer, the harder it is to break it down to its original building blocks, so high-quality recycling is difficult to achieve.

Additives may be added to change the thermomechanical or physical properties of a plastic, e.g. plasticisers, flame retardants, UV stabilizers, dyes. Some additives, e.g. bisphenol A (BPA) and certain phthalates, may have adverse effects on human health and the environment. If they are incorporated into recycled plastics, this may prohibit their re-use in food packaging or consumer goods. The same is true for contaminants and legacy materials which have been phased out of plastic production but may still exist in older plastic products.

Why is plastic so widely used?

Plastic is low cost, versatile, durable, and has high strength-to-weight ratio. Plastic production has increased exponentially over the past half-century, reaching 381 million tonnes per annum in 2015. In the EU, the plastics sector employs 1.5 million people and generated a turnover of €360 billion in 2018. Packaging is the largest application of plastics in Europe, representing approximately 40% by weight of total market demand. Plastics production is expected to double in the next 20 years and almost quadruple by 2050.

How is plastic currently disposed of?

As of 2015, approximately 6,300 million tonnes of plastic waste had been generated, of which approximately 9% had been recycled, 12% incinerated, and 79% accumulated in landfills or the natural environment. This is because most packaging plastics are designed to be used only once.

Globally, approximately 32% of the 80 million tonnes of plastic packaging used every year escapes collection or is dumped illegally.

In Europe, only 32.5% of plastic packaging is recycled, while 24.9% ends up in landfill. An additional 42.6% is incinerated with partial energy recovery. These capital-intensive infrastructure and services are only available in high-income countries. In lower-income countries, consumers resort to open-burning of waste, or disposal in unmanaged dumps.

Effects of plastic in the environment

Plastic pollution can range from relatively large pieces, termed macroplastic, to small pieces in the micro (between 100 nm and 5 mm) and nano (less than 100 nm) scales. Plastic creates physical hazards (e.g. discarded fishing nets entangling marine animals) and ingestion can lead to starvation and death caused by blockage or damage to the gut. Further prominent effects of plastic pollution include blockage or entanglement of propellers, gears or air intakes in ships. Plastic particles may reduce the flow of oxygen within soils and sediments affecting functions and health of plants and soil microorganisms.

Effects of plastic on human health

- Humans can ingest plastics through consumption of invertebrates and crustaceans, or through bottled and tap water. More than 90% of ingested microplastics are likely to be removed by excretion, but the possible migration and deposition of microplastics into the body, and their effects over time, are not fully understood.
- Microplastics can be inhaled from the atmosphere, and can induce or exacerbate immune responses.
- The incineration of mixed plastics releases harmful pollutants such as sulphur dioxide, oxides of nitrogen as well as dioxins and furans, which need adequate pollution controls.

Current plastic recycling

Mechanical recycling is currently the main route for plastic recycling. Plastic is sorted, shredded, melted, and extruded into recovered pellets. Problems with this method include:

- It cannot be applied to sort Multi-Layered Plastic (like crisp packets) or black plastics.
- It often causes deterioration of the material, e.g. discolouration, loss of strength, contamination, so recycled plastics are usually downcycled/cascaded to lower-grade applications such as garden furniture and traffic cones.
- Sorting single-use plastic packaging collected from postconsumer and some business-to-business streams is costly, time- and transport-intensive, so recycled material is often expensive compared to centralised virgin resin production.

Rethinking mechanical recycling

- Integrate recyclability and sustainability into the product design phase, e.g. brands should use water-based inks, separate sleeves, stuck-on labels or easily separable layers rather than direct printing on packaging. See the Recyclability by Design guidelines by RECOUP, APR Design Guide.
- Develop compatibilizers or fibrous reinforcements, which allow the combining of otherwise un-mixable plastics to create a blended product.
- Develop novel reagents to separate layered plastics like MLP.

Chemical recycling

Chemical recycling is the decomposition of plastics to their monomers, or other valuable low molecular weight fragments. These can be used to produce the original polymer or other valuable petrochemicals, either by de-polymerisation (usually dissolving into a solvent, e.g. ionic liquids, using a catalyst, e.g. PET, nylon-6, PLA, or pyrolysis/thermal cracking, using a catalyst and/or high temperatures (300–500°C) in the absence of oxygen.

Relative use of recycled and virgin plastic

Demand for recycled plastics today accounts for only around 6–8% of plastics demand in Europe. In recent years, the EU plastic recycling sector has suffered from low commodity prices for virgin resins and lower quality products. Investments in new plastic recycling facilities and methodologies have been hampered by the low projected profits. The low quality of recovered plastics is improving as closed-loop recycling technology (mostly through chemical recycling pathways) becomes established. The advertised recycled content in plastic products is becoming a marketable tool, for example for corporate social responsibility purposes.

New strategies for plastics manufacturing

- Biodegradable polymers, for example PLA, PBS and PHB, are used for short-term usage products such as packaging materials, foils, and utilities in the agricultural sector. It is difficult to design materials that are both degradable and high-performance. Biodegradable polymers are mainly derived from renewable sources (e.g. starch and cellulose) and can be degraded by enzymes or by reacting with water. Biodegradable polymers usually end up in landfill, where they may not degrade as planned, leading to the formation of potentially harmful substances.
- Smart polymers contain chemically responsive switches that can be tripped at end-of-life to trigger degradation, or to enable either reprocessing or chemical recycling. In theory, such approaches could be used for thermoset polymers which are currently hard to recycle because they do not melt or dissolve.
- Hybrid materials combine a crosslinked polymer structure. The crosslinking is via hydrogen bonds or ionic interactions, and can be triggered to reverse. This is called a Covalent Adaptable Network.

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