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PLASTIC CHEMISTRY AND POLLUTION

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ABSTRACT: Turtles tangled in fishing nets, whales washed ashore with stomachs full of plastic bags. These are images we, unfortunately, see far too often. But what about the threats you cannot see? Plastic debris is not just a physical threat to marine life, it's a chemical threat too.

Once in the marine environment, plastics can absorb chemical pollutants from surrounding waters and transport them great distances as they move around with ocean currents. When animals eat plastic, these chemical pollutants can leach into their stomachs, causing toxic effects. Many of these chemicals have been banned from production due to concerns about human and environmental health. However, some are so persistent in the environment that they are still found today.

Plastic products also contain chemical additives such as flame retardants, UV stabilisers and colorants which are added to the plastics during manufacturing. In our ocean, these chemical additives can leach into surrounding waters—posing another potential chemical threat to marine life.

In a recently published paper, we estimated the amount of chemicals that enter the ocean within common single-use plastic items and estimated the amount of chemical pollutants that can be removed from the environment via cleanups. We estimate that combined, these seven plastic items contribute more than 87,000 metric tons of plastic debris to our oceans and carry with them 190 metric tons of 20 different chemical additives. If plastic pollution continues to increase, this value could almost double to 370 metric tons of additives by 2025. This might not sound like very much, but these seven items account for only about 1% of the estimated 8 million metric tons of plastic entering the oceans every year!

Furthermore, we estimated how plastic cleanups contribute to chemical cleanup by removing those absorbed chemical pollutants. For this, we compared coastal and open ocean locations using Hong Kong and Hawaii as coastal case studies and the North Pacific and South Atlantic gyres as open ocean case studies. Here, we focused on Polychlorinated biphenyls (PCBs) because they are commonly found in plastic debris, despite having been banned for decades. Thus, if we can prevent plastic from entering the environment and cleanup what is already there, we can also mitigate chemical pollution. This reiterates the value of reducing our plastic footprint and participating in coastal cleanups. Cleanup of plastic pollution goes beyond what the eye can see. Cleanup of plastic pollution is also cleanup of chemical pollution!

KEYWORDS: plastic, chemistry, pollution, environment, PCBs, cleanup, additives

I.INTRODUCTION

Since Bakelite was revealed in 1907 as the first synthetic plastic — it was used as an electrical insulator — this lightweight, strong and mouldable class of materials has helped to make the modern world. Plastics are a staple ingredient in product design and manufacture, and their use, especially as single-use items such as water bottles and food wrappings, is expanding. The total weight of plastics produced per year currently stands at more than 380 million tonnes and is set to top 900 million tones. For comparison, this number stood at around 4.9 billion tonnes in 2015. Used plastics also form a large proportion of the fuel fed into energy-generating waste incinerators, which are a source of carbon emissions. Documentary films such as those narrated by David Attenborough have drawn attention to the environmental hazards posed by waste plastics. Footage of discarded water bottles suffocating marine life has also helped to trigger a public outcry and propelled plastics pollution up global agendas.

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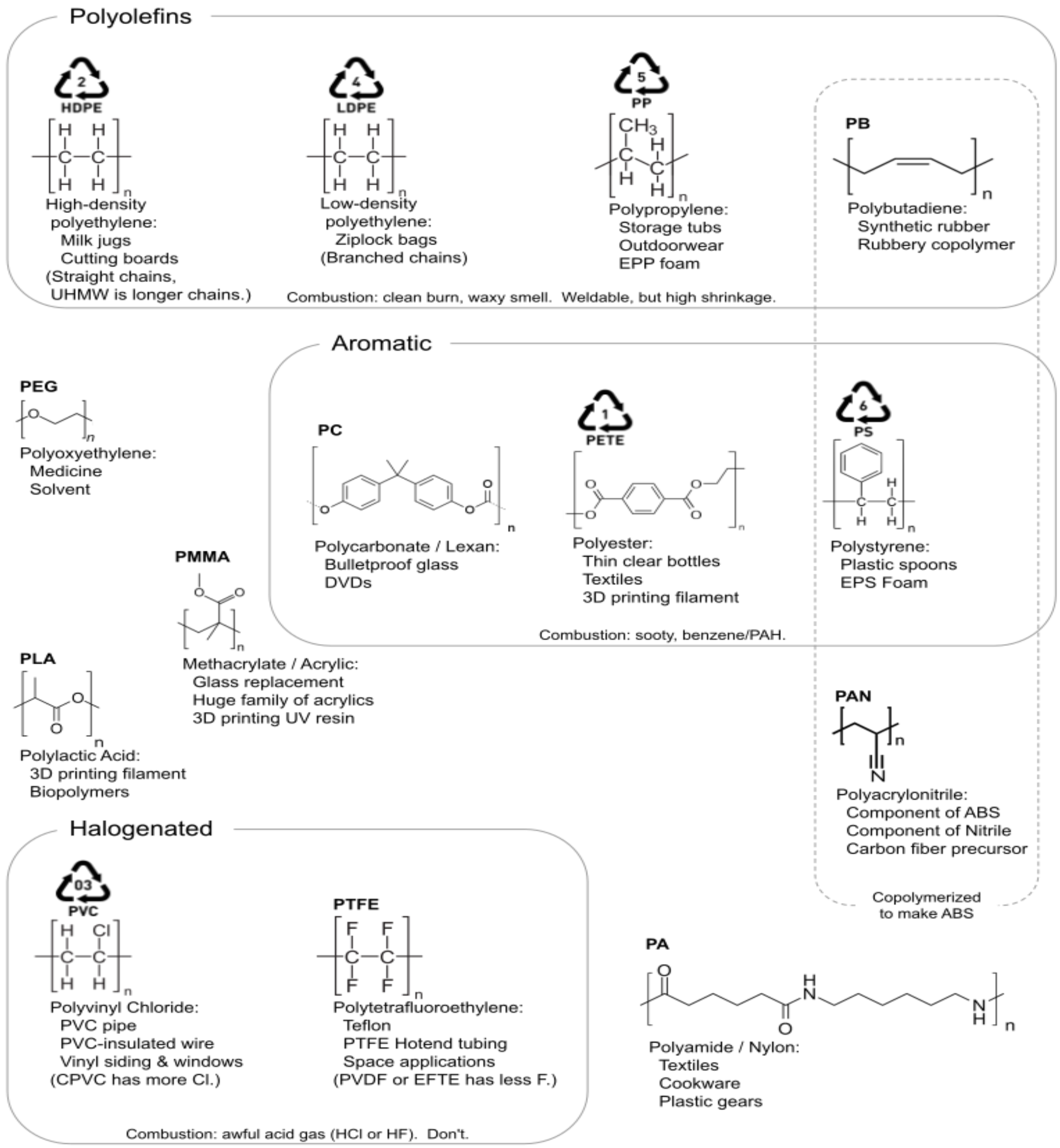

Chemical structures and uses of some common plastics

Although many plastics now carry the recycling symbol, in practice plastics recycling is crude and energy-intensive. Recycled plastics tend to be of lower-quality — they have less strength — than newly manufactured plastics. Increasingly, consumers are being sold products made from biodegradable plastics, derived from plant sources or spiked with oxygen and other chemicals to allow them to be broken down in the environment. However, this is complicating recycling efforts, because biodegradable plastics have a detrimental effect on the quality of recycled plastics, and there is no reliable way for recycling plants to separate these plastics from other forms. How more-sustainable plastics might be created has become one of the biggest and most urgent questions in chemistry today. Researchers from many branches of the field are now working on ways to reduce plastics waste and to improve the chances that it can be recycled. One such effort is reported in this week's issue of Nature. Stefan Mecking and his colleagues at the University of Konstanz in Germany describe a new type of polyethylene — one of the most common types of single-use plastic — that can be recycled by recovering most of the starting materials1 — something that is hard to do with existing materials and recycling technologies.

This new plastic needs to be further tested, and its impacts on existing recycling infrastructure need to be evaluated. It will require a different kind of recycling technology from that available at existing recycling centres. If there's a consensus that it should be used, and if it can be scaled up, it has the potential to accelerate the shift to recycled plastics. It could be a part of the solution to making plastics use less harmful.

But chemistry alone can take us only so far. If the burning of plastics and the accumulation of the materials in oceans and landfill is to be reduced, industry cannot continue to manufacture plastics at the current rate. Companies need to take more responsibility for the full life cycle of their plastic products. And, for this to happen, governments will need to introduce more regulations, and a proposed United Nations plastics treaty needs also to succeed. Plastics are made by combining chains of simple molecular building blocks. It isn't easy to run that process backwards to create materials for reuse — although researchers have made some progress2. The main obstacle to improved plastics recycling is how to break the chemical bonds in a systematic and low-energy way to recover valuable materials that can then be used to make equally high-quality plastics. There are several ways to give plastics an afterlife. These include mechanical recycling — whereby they are chopped up, melted and reused as a lower-quality plastic. Another option is for them to be chemically recycled — by breaking the bonds that hold the long plastics molecules together, creating smaller, useful molecules that can be made into new plastics. The latter approach, possibly the harder of the two, is what Mecking and his colleagues have been working on.

This team is one of several around the world that have been trying to find such a way to recycle polyethylene. Using a renewable source, Mecking and his colleagues made a robust polyethylene-like material that contains chemical groups that can be more easily split than those in conventional plastics, allowing the material to be deconstructed at the recycling stage. The scientists were able to recover almost all of the starting material through the recycling process, and, from it, remake the polyethylene-like material.

This work comes on the heels of that of another team, which reported similar findings in October. Susannah Scott at the University of California, Santa Barbara, and her colleagues used a catalyst to help break polyethylene into smaller molecules that could be used as starting blocks to make different types of polymer3.

This is clever chemistry and vital research. The approach must now be investigated for different types of plastic and at larger scales. But, as long as plastics use continues to rise, recycling alone will not reduce plastics pollution. Industry is well aware of this, and is engaging — although not nearly as much as it needs to — with the question of how to reduce its output. One-fifth of companies that make or use plastic packaging have committed to a pledge called the New Plastics Economy Global Commitment, created by the Ellen MacArthur Foundation and the UN Environment Programme. Signatories promise to increase plastics recycling as part of a broader commitment to circular-economy principles, which aim to achieve continuous use of resources and eliminate waste. But, according to the latest report, progress is uneven — particularly when it comes to reducing single-use packaging and adopting fully reusable packaging.

Clearly, companies need to be nudged, or pressed harder to act. If they were required to take responsibility for the whole life cycle of their plastic products, they would be less inclined to use materials that are difficult to reuse or recycle. To that end, a proposed global treaty, which is being described as the equivalent of the Paris climate agreement for plastics pollution, needs to succeed. In the past, treaties aiming to tackle climate change and biodiversity loss have been opposed, and even weakened, by some in industry and by governments with interests in fossil fuels. History cannot repeat itself; the planet does not have time.

Chemists gave plastics to the world more than a century ago. But these extraordinarily useful materials are now a serious source of environmental distress. Thankfully, chemists in both academia and industry are determined to find an environmentally benign way of unpicking plastics. Companies and governments must now step up and take responsibility for their part in the accumulation of waste plastics. Action cannot come too soon.

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II.DISCUSSION

Is plastic toxic? How much pollutants does plastic contain, and how likely is it that disease-causing pathogens attach themselves to it? These are urgent questions that have not yet been answered, but there are indications that plastic is a viable transporter of toxic additives and pathogens in the environment. There are three main processes through which this happens. The first is that pollutants present in the environment attach themselves to plastic, much like iron to a magnet. Then, there are the chemicals that are added to plastics during production, to give them the desired properties, and these can leak out of the plastic. What happens to those plastic pollutants and chemicals when animals eat plastic? Finally, plastic can carry and spread pathogens in the environment. Pollutants are present in the environment. When plastics end up in the environment, they can bind with these pollutants, including persistent organic toxins such as PCBs (Polychlorinated biphenyls) and dioxins, both of which are not only very resistant to degradation but can also accumulate in animal fats and tissues. Heavy metals such as mercury also attach themselves to plastics. Here, however, the role of plastic seems minor as the main source of these toxins in the bodies of animals in their normal food. Children seem to be more vulnerable than animals in terms of their contact with plastic pollutants and toxins. For years, there have been warnings that there are persistent organic toxins in toys made from recycled plastic – for example, toys that are made from recycled electronic waste have been found to contain brominated flame retardants. These flame retardants can affect, among other things, the nervous system and hormone balance. Microscopically small hydrophobic organisms thrive on floating plastic in the environment. They live on even the smallest pieces of plastic, in close company with hundreds of other types of organisms. Since plastic can persist for an extremely long time in the environment and can cover large distances when carried by currents, it is a means of transporting bacteria. The layer of microscopic life on or around plastic is called the plastisphere. Among the bacteria found here are Vibrio species, some of which can cause disease after contact with humans and animals. There is even a strain of Vibrio that can cause cholera. In areas of the world with a lot of waste plastic and poor sanitation, this can have dire consequences.

III.RESULTS

From bottled water alone, the US throws away enough plastic bottles in one week to encircle our planet 5 times! That's just 5% of the global population. Globally, we use 160,000 plastic bags every second! These plastics when thrown in landfills or elsewhere, find their way into our oceans – killing the marine mammals that mistake them for food. This is just the tip of the plastic garbage issue that's alarming environmentalists these days.What makes plastic so harmful to humans, animal and plant life and our environment is that they're non-biodegradable. It only starts degrading in 700 years. This means that all the plastic that has ever been produced has not degraded yet. Even when it degrades, it doesn't turn into some other form that gets absorbed by nature. It photo-degrades, which means it only breaks down into smaller toxic bits of itself. It's forever there. Pollution from plastic affects the air, land and oceans. Plastic materials are everywhere. We use plastic bags, straws and plastic bottles for such a short time and then we dispose of it. Yet, they remain forever - toxic till the end.
When plastic is produced, it's made from toxic materials such as benzene and vinyl hydrochloride. It is destined to be toxic from birth to forever. These chemicals are known to cause cancer, and the manufacturing byproducts contaminate our air and soil. The type of plastic that is the major source of dioxin is PVC. Phthalates are another toxic chemical added to plastics to make them softer and more pliable. It is known to affect our fertility, disrupt our endocrine glands, birth defects and other health problems. The problem with phthalate is that they are not chemically bound to the products, so they're easily evaporated into the air. That new "plastic" smell is the smell of phthalates off-gassing. Don't sniff it! How many marine mammals and birds have died in our oceans because of plastic? When the plastic from our landfills and from shipping lines carrying plastic components get into our ocean, animals and birds mistake it for food and ingest it… and die from it. There is no place on Earth that plastic hasn't reached.

To envision the magnitude of our water pollution from plastic, you need to see the Great Pacific Garbage Patch. It's totally unbelievable! An ocean gyre in the middle of has trapped garbage composed mostly of plastic and it's now as big Europe, India and Mexico. It's a floating garbage island! Fish and shellfish get contaminated and we eat them. Large marine mammals die, disrupting our marine ecosystem. Every living thing in our ocean is affected. You enjoy seafood don't you? We all do. That's why it's a great concern. We'd like to say ban plastics! Recycling it is not solving anything. We just turn it into one toxic form to another. But until we find a new material to replace it, the best thing to do is to cut down on the use of plastics. Carry your own bags when shopping. Recycle all your plastics. Keep it away from the landfill and away from the ocean.It may seem like a small effort but it's not. Together, we can drastically lower our plastic wastes. When there's less demand for plastic, there will be a decrease in production too. This is your power as a consumer! You can lessen the demand.We have created a world littered with plastics in 60 years. With all our technology and with our increasing awareness, we can still turn it around and prevent our children from inheriting a plastic Earth.

IV.CONCLUSIONS

Plastics have transformed everyday life; usage is increasing and annual production is likely to exceed 300 million tonnes by 2010. In this concluding paper to the Theme Issue on Plastics, the Environment and Human Health, we synthesize current understanding of the benefits and concerns surrounding the use of plastics and look to future priorities, challenges and opportunities. It is evident that plastics bring many societal benefits and offer future technological and medical advances. However, concerns about usage and disposal are diverse and include accumulation of waste in landfills and in natural habitats, physical problems for wildlife resulting from ingestion or entanglement in plastic, the leaching of chemicals from plastic products and the potential for plastics to transfer chemicals to wildlife and humans. However, perhaps the most important overriding concern, which is implicit throughout this volume, is that our current usage is not sustainable. Around 4 per cent of world oil production is used as a feedstock to make plastics and a similar amount is used as energy in the process. Yet over a third of current production is used to make items of packaging, which are then rapidly discarded. Given our declining reserves of fossil fuels, and finite capacity for disposal of waste to landfill, this linear use of hydrocarbons, via packaging and other short-lived applications of plastic, is simply not sustainable. There are solutions, including material reduction, design for end-of-life recyclability, increased recycling capacity, development of bio-based feedstocks, strategies to reduce littering, the application of green chemistry life-cycle analyses and revised risk assessment approaches. Such measures will be most effective through the combined actions of the public, industry, scientists and policymakers. There is some urgency, as the quantity of plastics produced in the first 10 years of the current century is likely to approach the quantity produced in the entire century that preceded.

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