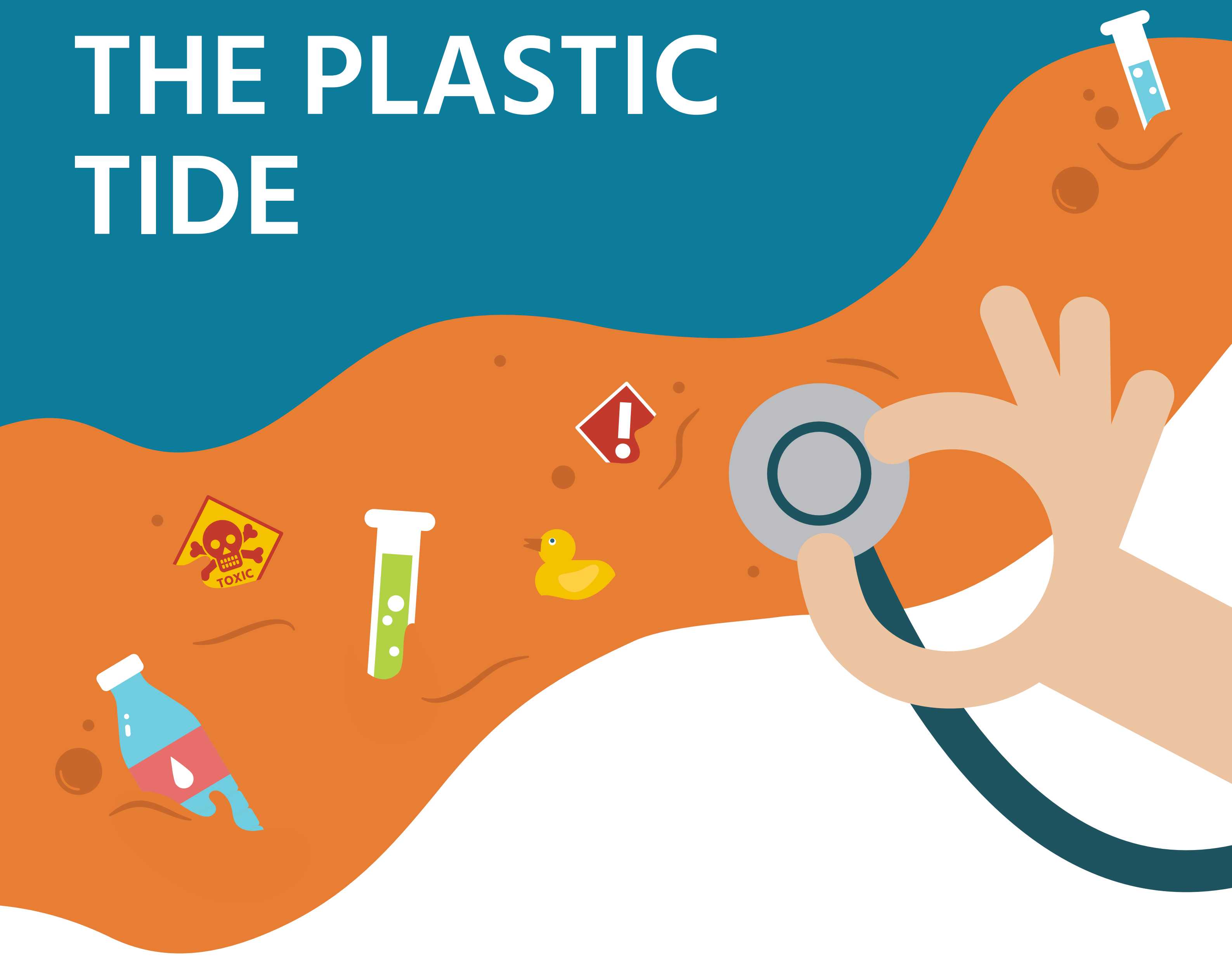
TURNING THE PLASTIC TIDE



THE CHEMICALS IN PLASTIC THAT PUT OUR HEALTH AT RISK

SEPTEMBER 2020

HEAL
HEALTH AND ENVIRONMENT ALLIANCE

Contents

Introduction

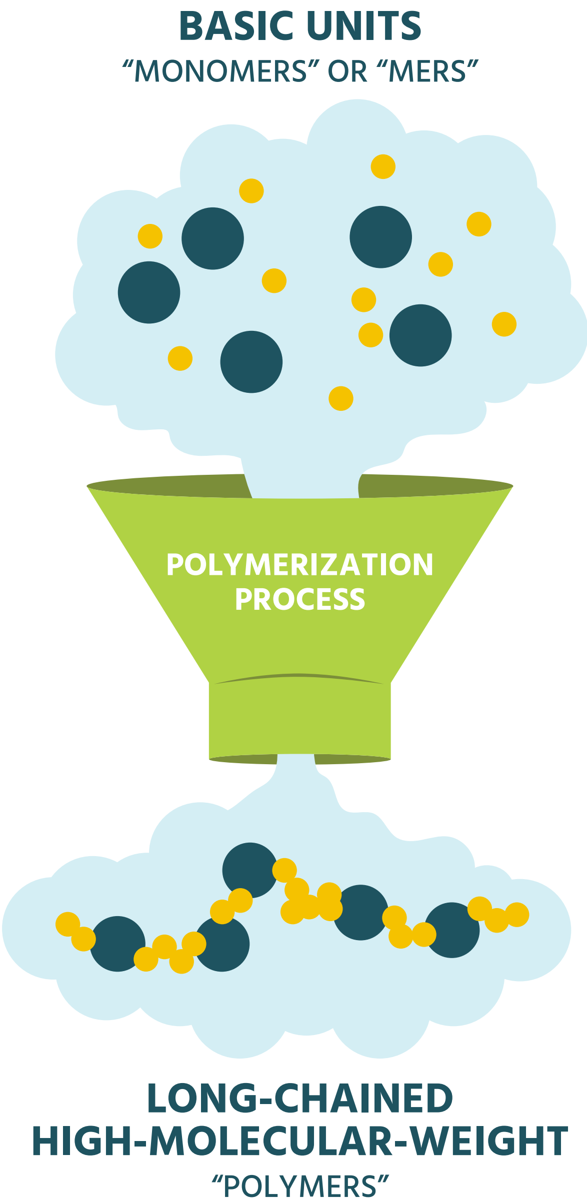
The production and use of plastics are the source of unprecedented pollution of our environment. While the disastrous impact of plastic on the environment has been widely discussed, a less commonly explored perspective on plastic pollution is the link between the synthetic chemicals used in plastics and their effects on our health. Toxic substances are at the root of plastics production and processing, and they represent an essential barrier to the sustainable transition that the world urgently needs [1]. **The problem of plastics *is* the problem of chemical safety.**

While most of us think of plastics only in their final form as consumer products, packaging, or other useful items, all plastics are made of complex mixtures of chemicals. It is the properties of those chemicals—and particularly the "additives", which are typically not bound to the plastic material itself—that cause concerns for health. Many of the largest and most hazardous chemical families—including heavy metals, flame retardants, phthalates, bisphenols, and fluorinated compounds—are directly associated with plastics production. Plastics represent a tremendously diverse set of compounds, from the coatings and resins used in construction and industry, to the synthetic textiles making up our clothes, to the rubber granules recycled from tyres which end up on football fields children play on. We ingest or inhale these substances daily, and many have serious impacts on our health.

This primer expands the focus of the plastics pollution debate to include the molecular-level effects of plastics-associated chemicals on health, and moves away from the materials-orientated discussion of the impacts of plastics on the environment. We highlight the close link between plastics production and toxic chemicals; the health concerns associated with plastics over the entire lifecycle; the grave challenge to the circular economy posed by plastics and plastic additives; the need for a broad definition of plastics that allows to define the full scale of contamination; and the all-pervasive problem of microplastics. We also discuss the urgent need to strengthen EU chemicals regulations in order to reduce the toxic impacts of plastics on health and the environment. Finally we present solutions for policymakers to tackle plastic pollution in a health-protective way.

WHAT ARE PLASTICS?

The word "plastic" refers to a huge variety of synthetic chemical substances that can be moulded or shaped into useful forms. The manufacture of plastics starts with small molecules, called "monomers", which are repeated thousands or millions of times and assembled into long strands, called "polymers". Almost all plastics derive from fossil fuels, especially natural gas. As seen in Table 1, a wide variety of monomers—including several with serious health consequences—are used to make common plastics.



Plastics are made of large numbers of "monomers", which are assembled into long chains called "polymers".

Other chemicals, called "additives", are blended in to lend the final product specific desirable characteristics.

You may have noticed the numeric codes found on the bottom of most plastic packaging. These codes indicate the type of plastic used, so that each item can be sorted and processed for appropriate recycling (where possible and available). However, many other types of plastics do not carry a code and are usually not recyclable.

Unfortunately, despite decades of promotion, recycling rates in Europe are still low. In 2016, of the more than 27 million tonnes of plastic waste collected, over 40% was incinerated, while only 30% was recycled, and about the same amount was disposed in landfills [2].

TABLE 1. *Common plastic polymers and their associated monomers. [3] [4] [5]*

		POLYMER	COMMON EXAMPLES	MONOMER	MONOMER HAZARD?
1	PET, PETE	Polyethylene Terephthalate	soft drink bottle, yogurt cup, vegetable tray, shampoo bottle, plastic tea bags, polar fleece textile fabric	Terephthalic acid + ethylene glycol	
		(Polyester)			
2	HDPE	High-Density Polyethylene	drinking water pipes, cutting board, refillable drinking bottle, yogurt drink bottle, trash bag / bin liner, shower gel bottle	Ethylene	
3	PVC	Polyvinyl Chloride	artificial leather, bath tub squirt toys, inflatable bathing ring, tablecloth, drinking water pipes, flooring, cling wrap, pond liner	Vinyl chloride	Carcinogen
4	LDPE	Low-Density Polyethylene	cling wrap, trash bag / bin liner, lemon juice bottle, plastic wrap, freezer bag, hair conditioner bottle	Ethylene	
5	PP	Polypropylene	foldable water container, thermal undergarments, ground water pipes, refillable drinking bottle, yogurt cup, gummy candy packaging	Propylene	
6	PS	Polystyrene	styrofoam cup, yogurt cup, fruit and vegetable tray	Styrene	Probable carcinogen; suspected reproductive toxicant
7	OTHER	Other			
*	PC	Polycarbonate	baby bottles, electronics enclosures, compact discs	Bisphenol A	Endocrine disruptor
				Bisphenol S	Endocrine disruptor
*	PUR	Polyurethane	artificial leather, foam mattress, scouring pad, kids bath sponge, shower slippers	Isocyanate + polyol	Isocycanates: inhalation hazard
*	PTFE	Polytetrafluoroethylene	nonstick baking sheet liner; nonstick cookware; some breathable water-repellent materials like Gore-Tex	Tetrafluoroethylene	Probably carcinogen
		(Teflon)			
		Polyamide	“plastic” tea bags; clothing	(Various)	
		(Nylon)			
*	ABS	Acrylonitrile butadiene styrene	drinking water pipes, electronics enclosures, 3d-printed objects	Acrylonitrile, butadiene, styrene	Acrylonitrile: possible carcincogen; butadiene: known carcinogen; styrene: suspected carcinogen
*	PLA	Polylactide	yogurt cup, coffee cup lid, shampoo bottle, vegetable tray, 3d-printed objects	Lactic acid	
*	NITRILE	Acrylonitrile butadiene rubber	non-latex gloves	Acrylonitrile, butadiene	Acrylonitrile: possible carcincogen; butadiene: known carcinogen

* may be numbered “7 OTHER”, but often not numbered for recycling

TABLE 2. ***Typical plastics comprising common consumer products. [6] [7] [3]***

PRODUCT	TYPICAL PLASTICS
acoustic foam	PUR
artificial leather	PUR, PVC
baby bottles	PC
bath tub squirt toys	PVC
bib	PE
cling wrap	PVC, LDPE
coffee cup lid	PLA
compact disc	PC
crisps packaging	PP+PE layers
cutting board	HDPE
drinking water pipes	PVC, HDPE, ABS
flooring	PVC
foam mattress	PUR
foldable water container	PE, PP
freezer bag	LDPE
fruit tray	PS
furniture foam	PUR
ground water pipes	PP, PVC
gummy candy packaging	PP
hair conditioner bottle	LDPE
handkerchief packaging	PP
inflatable bathing ring	PVC
inflatable pool toys	PVC
kids bath sponge	PUR
lemon juice bottle	LDPE
nonstick baking sheet liner	PTFE
oven bag	PET
place mat	PVC
plastic cup	PS
plastic tea bags	Nylon, PET
polar fleece textile fabric	recycled PET
pond liner	PVC
pool noodles	PE
rain pant	PE
refillable drinking bottle	PP, HDPE
scouring pad	PUR
shampoo bottle	PP, PET, PLA
shower gel bottle	HDPE
shower slippers	PUR
soft drink bottle	PET
styrofoam cup	PS
tablecloth	PVC
thermal undergarments	PP
trash bag / bin liner	LDPE, HDPE
vegetable tray	PS, PET, PLA
water bottle (not reusable)	PET
yogurt cup	PS, PP, PET, PLA
yogurt drink bottle	HDPE

The chemical constituents of plastics go far beyond monomers and polymers. Most plastics also incorporate numerous “additive” chemicals, which have a wide variety of uses. These may be added to increase the strength of a plastic, or to make it more flexible. They may mitigate the destablising effects of sunlight, or prevent plastics from yellowing with age. Many plastics include a large concentration of flame retardants, which are intended to decrease their flammability—but which, produce dangerous toxic by-products when burned. And many additives fulfil several of these functions, which explains that the mixing of plastics is a highly complex field.

SPOTLIGHT ON UNREGULATED POLYMERS

Plastics are largely made up of **polymers**, large chemical molecules consisting of strings of repeating smaller units, known as **monomers**. These polymers are made in great volumes and their purity can vary greatly.

Small amounts of residual monomers and related molecules—in addition to many additives —are often found in the finished products. During and after use, polymers may break down into smaller components or into their constituent monomers, for example, when exposed to water and sunlight.

Yet despite these concerns inherent to their use, polymers are exempted from registration under Europe’s flagship chemical regulation REACH. This means that companies are neither obliged to provide information on health and environmental hazards linked to their exposure, nor to monitor their fate in the environment and the food chain—a loophole that NGOs have repeatedly asked European authorities to close.

CATEGORIES OF ADDITIVES AND TYPICAL EXAMPLES

TABLE 3. ***Categories of additives, with typical examples of each. Because they are usually not chemically bound, additives often migrate out of a plastic product during use or after disposal.*** ***Categories and examples [9] [7] [3] [6]; health impacts and regulatory status from ECHA Substance Information.***

INGREDIENT AND ROLE	ADDITIVE	EXPOSURE POTENTIAL	HEALTH IMPACT	REGULATORY STATUS
MONOMERS **The basis of the plastic polymer**	**BPA:** monomer used in some polycarbonates	Direct consumer exposure to residual monomer in product	SVHC, toxic to reproduction, skin sensitising, endocrine disrupting	Voluntarily pulled from many uses due to public outcry; restricted from some uses in EU
	BPS: substitute for BPA in some polycarbonates	Direct consumer exposure to residual monomer in product	Endocrine disrupting; suspected to be toxic to reproduction	Some restrictions on cosmetics, thermal paper; other regulations being considered
BULK PROPERTY MODIFIERS **Used as filler; adds strength; confers heat resistance; changes electrical properties**	**Phthalates** in PVC	Direct dermal exposure to consumers	BBP, DEHP, DBP, DIBP: toxic to reproduction, endocrine disrupting	Most important four phthalates (DEHP, BBP, DBP, DIBP) now require authorisation for use in EU
STABILIZERS **Protects against heat and light**	**Lead** in PVC	Possible dermal exposure to consumers	Toxic to reproduction; potent neurotoxicant	Lead-added PVC currently allowed in recycling loops; COM re-evaluating
PERFORMANCE ENHANCING ADDITIVES **Flame retardants; dispersing agents**	**Brominated flame retardants:** used in many plastics	Exposure to users via migration, dust, diet Inhalation exposure to firefighters via toxic combustion products	Varied effects and inadequate data. Endocrine disruption, thyroid impacts, neurological development impacts are among the best understood	Several BFR's banned in Europe; some restrictions on others; many novel BFRs in use

CURING AIDS AND BLOWING AGENTS **Expansion of foams; thermosets; curing aids**	**Pentane:** used as blowing agent in foams	Exposure to workers; possible residual exposure to consumers	Inhalation hazard; high aquatic toxicity	Occupational standards for workers in place
COLOURS AND PIGMENTS **Add and brighten colors**	**Cadmium**: used to add shine and weight to cheap jewelry	Children's exposure via mouthing/ chewing/swallowing	Carcinogenic; suspected reproductive toxicant	Commonly found in very cheap jewelry
COATINGS AND SEALANTS **Water resistance; oil and stain resistance; seal against bacteria as well as taste and odor**	**PFAS:** used for water- and stain resistance	Direct exposure via food contact materials;also contaminated drinking water	Numerous and varied: reproductive toxicity, cholesterol/lipid disregulation, endocrine disruption	Two PFAS (of approx 4,700) have been banned in Europe and internationally; further EU regulations in discussion about possible regulation of the whole class
	BPA: used as a sealant in food contact materials	Direct consumer ingestion	(see above)	Varied regulation by member state, strongest in France; EU-wide limits on migration from food contact materials
ADHESIVES AND RESINS	**Acrylates:** used as adhesive in nail polish	Very high exposure to salon workers	Skin and eye sensitizer	Occupational limits on exposure in EU
INCINERATION BYPRODUCTS **May be created when burned**	**Chlorinated dioxins and furans:** produced by burning chlorinated plastics (e.g. PVC)	Worldwide migration and exposure via diet	Potent carcinogen and endocrine disruptor	Continuous monitoring and emission reduction, including emissions regulations on incinerators

SPOTLIGHT ON **MICROPLASTICS**

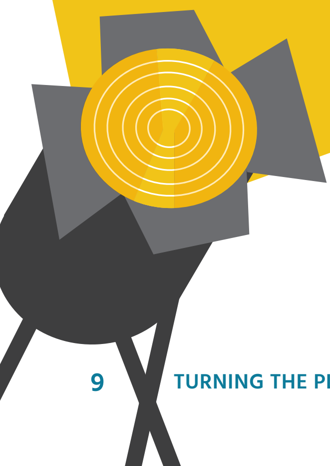
Human exposure to microplastics is manifold, including via the air we breathe, the food we eat, or the products we use. Many consumer products now incorporate **“microplastics”**, tiny particles ranging in size from a few millimetres down to microscopic “nanoplastics” the size of bacteria. Microplastics are often added deliberately to both plastic and non-plastic products, like the small plastic fragments that enhance the function of exfoliating scrubs and toothpastes, or the plastic “microbeads” used to make sunscreen spread more evenly.

In addition, microplastics form when plastic materials break down in the environment [10] [11]. Moreover, because they accumulate in animals such as fish and aquatic invertebrates, they directly enter our food chain, posing a potential danger to human health.

Microplastics now constitute **“a major potential threat to global aquatic ecosystems”** [11] at an almost unimaginable scale.

- A study by researchers at the University of Newcastle, Australia, suggested that people may be ingesting **5 grams of microplastics each week—about the amount of plastic in a credit card** [12].
- In 2013, scientists estimated that already more than **five trillion plastics particles** float in our oceans, most of them microplastics [13].
- Scientists at Ghent University, Belgium recently found that the average European shellfish consumer ingests **6,400 microplastics per year** [14].
- A 2018 investigation of **bottled drinking water**, testing more than 250 samples from nine countries, found that **90% were contaminated by plastics**—primarily polypropylene (54%), nylon (16%) and polyethylene or PET (6%) [15]. These results prompted the World Health Organization (WHO) to initiate a review of the risks of microplastics in drinking water [16]. Following this first review, the WHO highlighted the need for more research on the health effects of microplastics and has called for a “crackdown on plastic pollution” [17].

The Dutch organisation ZonMw recently launched a series of 15 research projects to study the potential impacts on human health [18]. Meanwhile, in January 2019, the European Chemicals Agency (ECHA) proposed a restriction on intentionally added microplastics, which it hopes will prevent the release of 500,000 tonnes of microplastics over the next 20 years [19].



SPOTLIGHT ON **OUR HISTORICAL PLASTIC BURDEN**

A recent attempt to summarize the production and use of all plastics in the last 70 years has estimated that [20]:

- Virgin plastics production from 1950 to 2015 reached **8.3 billion metric tonnes**—roughly the mass of a medium-sized comet.
- **Only 30%** of all plastics ever produced is still in use.
- As of 2015, of more than **6 billion tonnes** of plastics waste produced, **79%** ended up in landfills or our environment; **12%** was incinerated; and only **9%** was recycled.
- Plastics in landfills outlive human lives by far—it takes **400 to 1,000 years** for plastic to degrade.
- By 2050, **12 billion metric tonnes** of plastics are expected to end up in landfills or the natural environment.

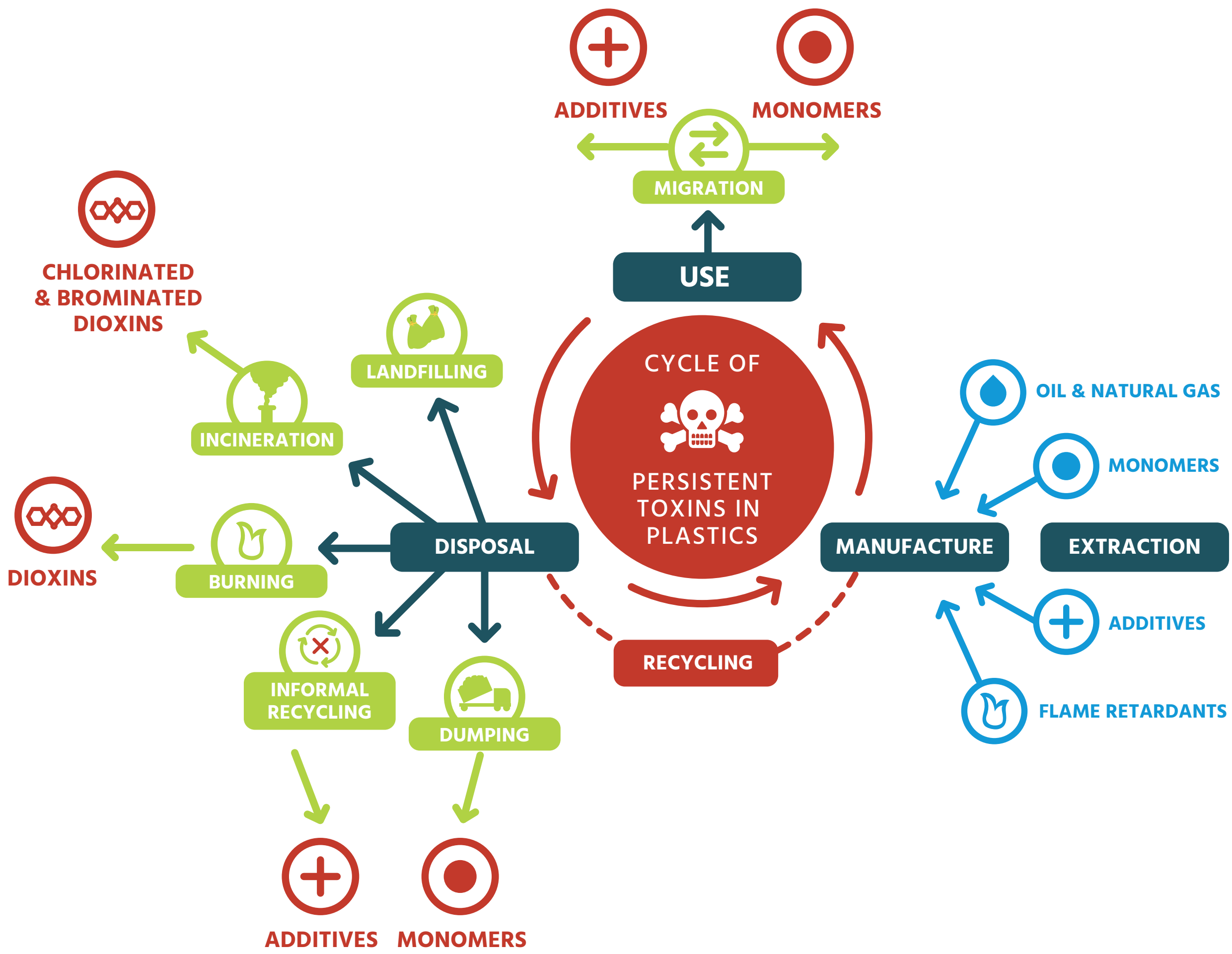
HEALTH IMPACTS OF THE PLASTICS LIFE CYCLE

We often hear about the tremendous environmental damage done by plastic pollution: rivers choked with plastic waste, or whales washing ashore after ingesting tens of kilos of plastic bags.

But when we think about the problems of plastics, it is important to consider not just the problems of plastic materials, but also the problems of the myriad substances used in across the whole life cycle of plastics production and use.

At each of these stages, humans are exposed to toxic chemicals: by inhalation, by ingestion, or by direct contact with the skin. Microplastics are also being released at all these stages—even during normal use, as through the laundering of synthetic textiles, and the rolling of tyres on the road. The combined effects of these exposures for our health are unknown. However, the health effects of those individual chemicals—such bisphenol A, phthalates such as DEHP, etc—are well documented.

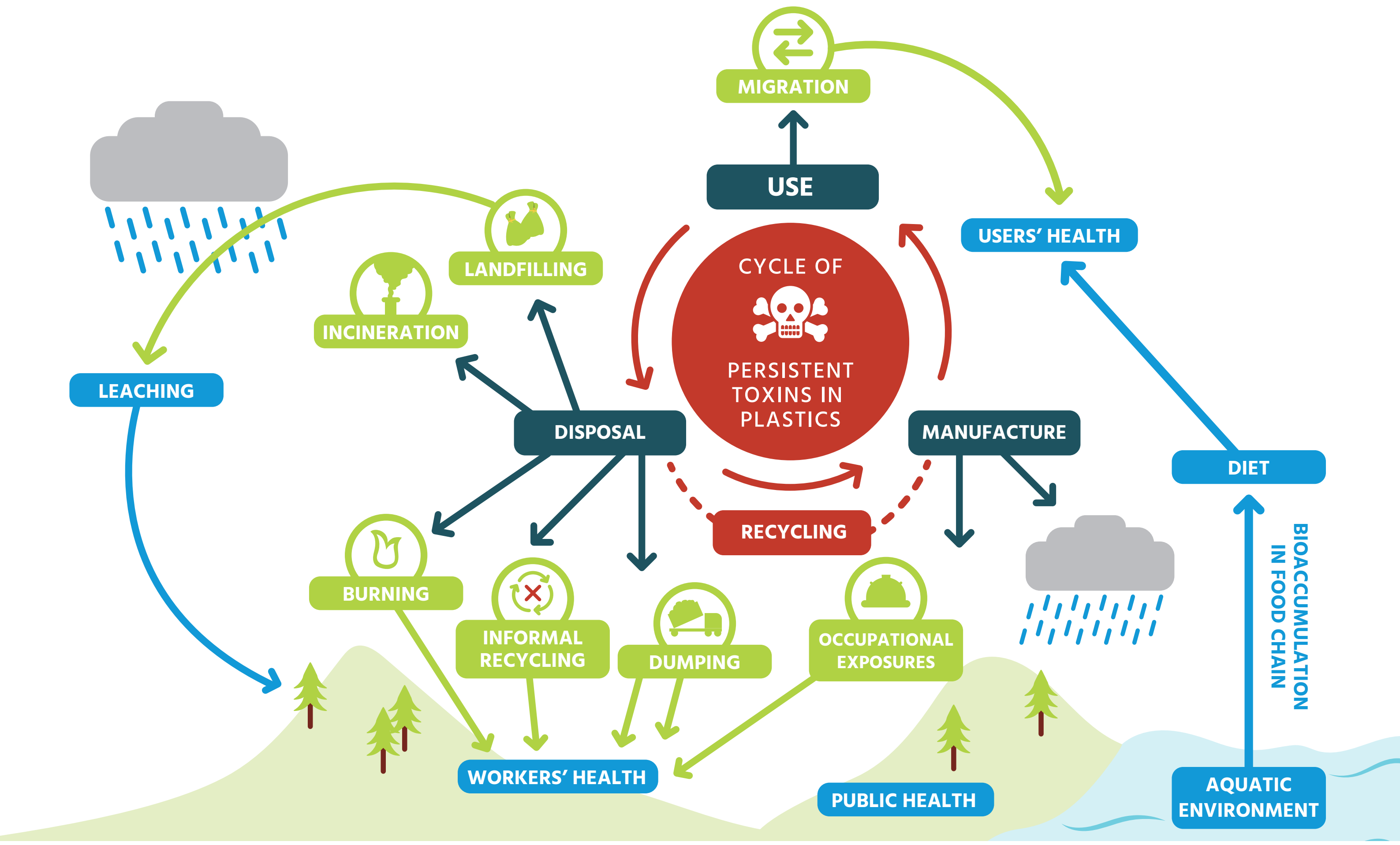
TYPICAL CHEMICAL LIFECYCLE OF PLASTICS



There are many ways by which people can be exposed to toxicants from plastics:

- **Workers in plastics manufacturing** are often exposed to high concentrations of monomers- many of which are carcinogenic - as well as additives.
- **Workers outside of the plastics industry** also come into contact with large amounts of plastics and additives—from grocers using plastic packaging, to nail salon employees and cashiers handling receipt paper.
- **Users of plastic products** can be exposed when plastic chemicals—especially additives—migrate from the plastic into the surrounding environment. For example,
  - **Additives or monomers can migrate from food packaging into the food products; for example, bisphenols from polycarbonate water bottles, or styrene from microwaved Styrofoam;**
  - **Phthalates used in toys or baby products may be ingested directly;**
  - **Additives that migrate from products can end up on the skin, especially hands, where they may be absorbed or ingested.**
- Whether or not they are using plastic products, **people in their everyday lives** can also be exposed once these substances enter the environment. For example,
  - **Flame retardant additives are added to office furniture in especially high amounts, and migrate into the office air and dust, from where they can be breathed in or ingested.**
  - **Persistent toxics that enter the environment can bioaccumulate through the food chain, leading to exposure via contaminated food. For example, diet is the largest contributor to the burden of fluorinated "forever chemicals" (PFAS) for most people.**
- Finally, it is important to note the very high exposures that can be incurred when plastics are sent to low- or middle-income countries for reuse, recycling, or disposal. In many cases, this work will be performed by "informal" workers, working on their own or with their families, without adequate knowledge of hazards or protection. Improper disposal, recycling, or burning will also expose workers' families and communities to toxics in the plastics.

HUMAN AND ENVIRONMENTAL HEALTH IMPACTS OF THE PLASTICS LIFECYCLE



BPA

POTENTIAL HEALTH IMPACTS:

Breast cancer, infertility, early puberty, diabetes and obesity, and neurological disorders in children.

SPOTLIGHT ON **IMPORTANT SUBSTANCES IN THE PLASTICS WORLD**

BISPHENOLS: You have probably seen water bottles or food packaging bearing the label "BPA Free". BPA, or bisphenol A, is only the best known of a very large group of substances used in a wide range of applications. For example, BPA and other bisphenols are used as the constituent monomer for some polycarbonate plastics; as a sealant in cans and dental fillings; as a coating in aluminium water bottles; and as an ink developer in thermal receipt papers. Of all the bisphenols, only BPA—a known reproductive toxicant and an endocrine disruptor—has been partially restricted at European level (it is banned in baby bottles and restricted in thermal paper and toys for children up to three years old). Scientists have linked exposure to BPA to a number of health conditions including **breast cancer, infertility, early puberty, epidemics such as diabetes and obesity, and neurological disorders in children.**

Unfortunately, as concerns about BPA have grown, the chemical has increasingly been replaced by other bisphenols—including BPS, BPF, BPAF, and BPZ [22]. Many of these alternative bisphenols, which are closely related to BPA, also appear to have similar toxicity [23]. In 2017, the Swedish Chemical Agency identified some 37 bisphenols as potential endocrine disruptors [24]. Instead of continuing to regulate these substances one by one, we need a precautionary approach that regulates bisphenols as an entire group.

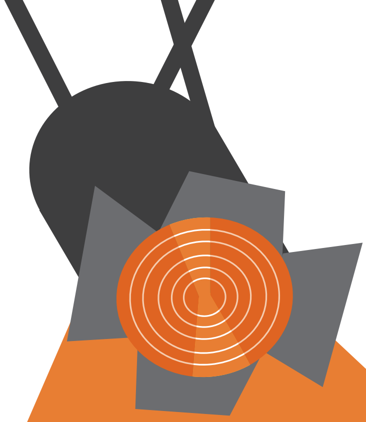
PHTHALATES are synthetic compounds that are used as additives in a myriad of consumer products because their properties add flexibility and other desirable characteristics. Phthalates are commonly added to polyvinyl chloride (PVC), and are used in the manufacturing of packaging, textiles, flooring, and numerous cosmetics. Until just a few years ago, phthalates were used in very high concentrations to make children's toys soft and squishy, to make IV bags more pliable, to make artificial nails more flexible and less likely to crack, and as a solvent in cosmetics. A 2015 study of children's products by the Danish government found that 9 out of 41 products tested contained **over 20% phthalates** by weight [25]. Three years later, an enforcement project undertaken by the European Chemicals Agency (ECHA) found that every fifth second-hand toy contained restricted phthalates [26].

In recent years, scientists have linked exposure to the most common phthalates with a range of health impacts, including reproductive disorders, overweight, insulin resistance, asthma, and attention deficit hyperactivity disorder. Four of the most common phthalates [27] were among the first substances to be regulated at the European level under the authorisation process, and, with limited exceptions, can no longer be used in the EU. In the last few years, five more phthalates [28] have been regulated by the same process for their reproductive toxicity [4]. But even these examples only serve to demonstrate that we must act more quickly to regulate entire groups of these compounds, rather than tackling them one at a time.

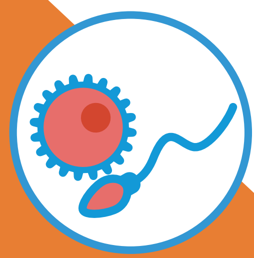
PHTHALATES

POTENTIAL HEALTH IMPACTS:

Reproductive disorders, over-weight, insulin resistance, asthma, and attention deficit hyperactivity disorders



SPOTLIGHT ON **ENDOCRINE DISRUPTION**



Perhaps the most important health effect of the many chemicals associated with plastics is endocrine disruption. Much of the activity of our bodies is controlled by hormones: small molecules produced by many organs and glands (the "endocrine system") and used to signal changes to other parts of the body. **Patterns of growth, sexual development, metabolism, and other key parts of life are all controlled by our hormones.**

Unfortunately, many of the common monomers and additives in common plastics have structures that are similar to hormones, and can sometimes trick the body, upsetting these critical processes. **BPA, for example, mimics oestrogen, an important hormone related to women's sexual development and function. Similarly, some phthalates disrupt male sex hormones, leading to lower sperm counts or genital malformations.**

Because the body uses only minuscule amounts of hormones to signal major changes—for example, the onset of puberty—even a very small concentration of an endocrine disruptor can have large impacts on the body. And, as we have discussed earlier, it is no surprise that "alternative" substances with similar structures can also have similar endocrine disrupting effects. This is the case with bisphenol S (BPS), a very common "alternative" for BPA, which we now know to have similar endocrine toxicity [23].

ENDOCRINE DISRUPTORS

POTENTIAL HEALTH IMPACTS:

reproductive disorders, development dysfunction, behavioural disorders, thyroid disorders, low birth weight, diabetes, obesity, asthma, breast and prostate cancers

SPOTLIGHT ON **TWO WIDE CLASSES OF TOXIC ADDITIVES**

FLAME RETARDANTS are added to many products in order to meet flammability standards, since they can slow the growth of fire when used at very high concentrations. However, there is a solid body of evidence that many flame retardants can be toxic to human health, whereas their actual impact on fire safety is hotly contested. Some of the most toxic flame retardants include the class of organohalogen substances, such as the polybrominated diphenyl ethers (PBDEs), which were widely used in furniture, electronics, and many other products before being banned in the 2000s. Organohalogen substances can now be found in the blood of virtually all humans [29].

Today, flame retardants are used in a very wide array of applications and products; for instance in furniture, vehicles of all kinds (from cars to aircrafts), in many plastics (including children's products like cribs and car seats), in home insulation materials, and in virtually all consumer electronics. Strong evidence has linked some widely used flame retardants to a number of health conditions, including **lowered IQ and hyperactivity in children, cancer, hormone disruption, and decreased fertility** [30] [31]**.**

Several of the most important flame retardants (such as PBDE, decaBDE, and HBCDD) have now been banned worldwide under the international Stockholm Convention on Persistent Organic Pollutants. Unfortunately, this has resulted in their substitution with newer and less well studied flame retardants—including brominated, chlorinated and organophosphate substances such as tris(1,3-dichloro-2-propyl) phosphate (TDCPP), tris(2-chloroethyl)phosphate (TCEP), and triphenylphosphate (TPP), each of which are suspected of harmful effects on health [32] alternative flame retardants are increasingly being used to meet some flammability standards; however it is often unclear which chemicals are being used and how frequently. In an attempt to address this data gap, researchers in the US collected and analyzed 102 samples of polyurethane foam from residential couches purchased from 1985 to 2010. Overall, they detected chemical flame retardants in 85% of the couches analysed. In samples purchased prior to 2005 (n = 41). Worse yet, many newer flame retardants remain unidentified, their identities protected as trade secrets [33]. Few of these replacement flame retardants are currently regulated at the EU level.

FLAME RETARDANTS

POTENTIAL HEALTH IMPACTS: *Lowered IQ and hyperactivity in children, cancer, hormone disruption, and decreased fertility*

POLYFLUORINATED AND PERFLUORINATED COMPOUNDS (PFAS)

POTENTIAL HEALTH IMPACTS:

kidney and testicular cancer, elevated cholesterol, decreased fertility, low birth weight, thyroid problems and decreased immune response to vaccines in children

POLYFLUORINATED AND PERFLUORINATED COMPOUNDS — usually referred to as PFAS — consist of a group of more than 4,700 chemical substances used for their oil-, stick- or stain-repellent properties in the manufacturing of a large array of products and applications [34]. The first commercially important PFAS compound, Teflon, became famous through its widespread use in cookware. Similar compounds are now used in an endless array of products—in greaseproof food packaging like pizza boxes and microwave popcorn bags; in stain-resistant textiles including carpets; in water-repellent outdoor apparel; and in firefighting foams [34].

PFAS are extremely stable, and last indefinitely in the environment without breaking down. They are carried very long distances by water and wind, and today they can be found in the blood of almost everyone in the world. Some scientists have suggested the high concentrations of PFAS found among the Inuit in northern Canada and Greenland may be responsible for the high levels of breast cancer in those populations. Additionally, scientists have linked the most infamous substance of the family to date—PFOA—to numerous health effects, including **kidney and testicular cancer, elevated cholesterol, decreased fertility, low birth weight, thyroid problems and decreased immune response to vaccines in children** [35] [36] .

PFOA and its analogue PFOS have recently been banned under the Stockholm Convention, leading to an explosion of very similar substances used as replacements. Manufacturers have responded with the “GenX” technology, a suite of substances which are polyfluorinated and structurally similar to the banned compounds. The most important of these, HPFO-DA, was recently listed as substance of very high concern at the European level [37] and has already been found to contaminate water in communities in Italy, the Netherlands, and the United States [38]. This once again demonstrates the critical importance of regulating these compounds as a group, rather than trying to address them one by one.

PLASTICS AND THE CIRCULAR ECONOMY

In spite of decades of work, and despite gigantic companies' advertising campaigns promoting their recycling efforts, less than a third of plastic waste in the EU is recycled today. **Of more than six billion tonnes of plastic produced worldwide since 1950, only about 9% has been recycled.** These patterns will need to change drastically if Europe is to meet its circular economy commitments.

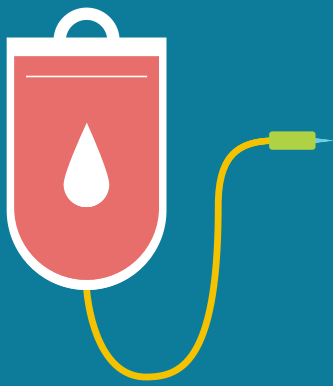
Yet recycling poses significant risks: when plastics include hazardous monomers or additives, or when the plastic polymers break down into hazardous components, the recycled materials will be contaminated. Allowing toxic substances into the recycling loops only ensures that they will continue to pollute future products and supply chains. Moreover, the EU maintains different standards for virgin and recycled materials, allowing higher levels of contamination in recycled products. This is unacceptable. Recycling must promote clean manufacturing loops, rather than being used as a smokescreen to prolong the release of toxics in the environment and our bodies. Toxics in plastics threaten to undermine Europe's hoped-for circular economy.

Recent testing of consumer items made from recycled plastics reveal the extent of our exposure to toxics—and our lack of detailed information about many of them.

- A 2019 research project [7] tested widely used consumer items such as food packages and care products. **74% of these products contained chemicals displaying some level of toxicity** and although they detected over 1,400 chemicals, they were able to identify less than 20% of them. Notably, "bioplastics" made of polylactic acid (PLA) were observed to be of similar toxicity levels to traditional plastics like PVC and PUR.
- A 2018 report showed that **25% of children's toys, hair accessories and kitchen utensils** purchased in 19 European countries had elevated levels of bromine, indicating likely presence of brominated flame retardants. Further analysis of the samples revealed that 46% of these would fail to meet the EU Regulation on persistent organic pollutants (POPs) if the product was composed of new plastic rather than recycled plastic [39].
- An investigation into the presence of toxic chemicals in carpets produced and sold by Europe's largest manufacturers revealed the presence of **suspected carcinogens, endocrine disruptors, and reproductive toxicants** [41]. Most interestingly, the results highlighted the double standards in regulations between primary and recycled contents. For instance, DEHP, a well-known phthalate banned in the EU since 2015, is allowed in recycled PVC and was found in the samples.

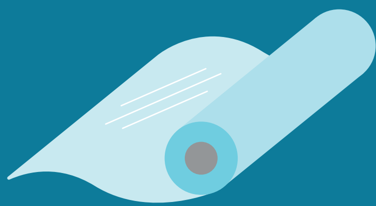
SPOTLIGHT ON **PVC: AN ESPECIALLY PROBLEMATIC PLASTIC**

The familiar plastic called PVC, or **"polyvinyl chloride"**, is a perfect example of the many hazards that may be found in plastic materials. Also called simply "vinyl", it is used in products ranging from house siding to drinking water pipes, pool toys to synthetic leather clothing.



PVC is a polymer made up of the monomer "vinyl chloride". Vinyl chloride monomer is a potent carcinogen, primarily affecting workers in the factories where PVC is manufactured. At the other end of its life cycle, the incineration of PVC creates the extremely potent **carcinogens** called **dioxins and furans**. These dangerous by-products are much more common when plastics are burned at low temperatures—a very common method of waste disposal through much of the world. Dioxins and furans persist indefinitely in the environment, and are carried great distances by air and sea. Today, people and wildlife in even the most remote Arctic regions—thousands of miles from the nearest incinerator—carry dangerous levels of dioxins produced by the burning of PVC.

But these problems are only the beginning of the hazards of PVC. **Over 70% of additives used on the global plastics market are used in PVC.** For example, to add stability to the polymers, **lead** has often been added to the plastic. Lead, a potent **neurotoxin**, is not bound to the plastic material, and can easily migrate out. Holiday lights sold in California bear a warning to the user to wash their hands after setting up the lights, since the PVC-coated wires contain significant amounts of lead. Although the use of lead stabilizer in PVC has now been banned in Europe, industry continues to argue for the right to recycle lead-contaminated PVC, a practice which would ensure the contamination of recycling loops far into the future.



Finally, PVC itself is a very hard plastic. When softness and flexibility is desired, this can be achieved by adding large amounts of phthalates—a class of chemicals that includes many endocrine disrupters. For example, blood bags and other IV bags are often made of PVC, with phthalates added to make them flexible and supple—resulting in huge doses of endocrine disrupting phthalates for patients with extensive IV treatment, like dialysis patients or babies in neonatal intensive care. The most hazardous and widely used phthalates have now been restricted in Europe—but many more phthalates remain on the market.

TURNING THE TIDE

Industry and regulators have usually treated the problem of toxic substances on a case-by-case basis. Once a chemical has been identified as a reproductive toxicant, a neurotoxicant, or a carcinogen—usually after decades of study, while the chemical continues to be used in products—the preferred solution is to simply replace it with another chemical.

This replacement is usually a closely related molecule: similar in structure, and probably similar in toxicity, but conveniently unstudied and unregulated. For example, a common "alternative" to BPA (bisphenol A) has been BPS (bisphenol S), which now appears to have similar toxicity—and after BPS, there are numerous other bisphenols, to BPZ and beyond, which could be used instead [22]. Often, the new chemical is a trade secret, preventing independent scientists from testing it for safety. And so, the research and regulatory cycle must start again.

This piecemeal approach has led to our current state, where hundreds of types of plastics are made, containing any of tens of thousands of different additives. Consumers are often told to choose better, safer, or more environmentally sustainably products. But this is unfair advice: even when a manufacturer advertises a safer chemistry (such as the mentioned "BPA Free" label), the consumer has no way to know what chemicals are in a product. Most are unstudied, and many are secret, the consumer is in a hopeless position.

For the consumer, the simplest answer is to avoid plastics, choosing natural materials whenever possible. Plastics are so pervasive in our lives that we sometimes forget that there are alternatives, and we often do not notice when plastics replace earlier non-plastic materials. For example:

Tea bags: Although traditionally made of paper, manufacturers are increasingly turning towards plastics or blends of plastic and paper. In an article dramatically entitled, “Plastic Teabags Release Billions of Microparticles and Nanoparticles Into Tea”, researchers demonstrated that steeping a single plastic teabag released billion micro- and nano-plastics into a cup of tea [42] .

Exfoliating lotions and scrubs have often contained on finely ground natural materials like oats, apricot or almond shells, sugar or salt, but in recent years, many manufacturers have replaced these with microplastics and plastic microbeads. These nonbiodegradable particles, which also contain complex mixtures of chemical additives, enter the food web when ingested by aquatic invertebrates or other organisms. In a study in Wales in 2019, researchers found microplastics in invertebrates at all study sites [11].

Reusable water bottles: As manufacturers stopped using BPA-based polycarbonates, some turned instead to polycarbonates based on BPS—now known to have a similar oestrogen-disrupting action [23]. Other manufacturers made bottles from metal. Since aluminium imparts a taste to the water, reusable aluminium bottles are always lined with a sealant, which is often a BPA-based epoxy. In fact, one study showed that aluminium bottles leached BPA into water at rates that could exceed the leaching from BPA-containing polycarbonate bottles [43]. A better option may be steel. While some steel bottles are lined, many are not.

Plastic or paper bags? In the endless debate over paper or plastic carrier bags, industry usually highlights the lower energy and greenhouse gas costs of plastic bag manufacturing [44]. However, they neglect to discuss the hundreds of billions of plastic bags that end up in the global environment, causing endless harm for aquatic life during the hundreds of years necessary for decomposition. Degradation of plastics happens through complex processes requiring specific conditions of water, light, and air, and produces myriad chemicals along the way depending upon the polymers involved [45]. In fact, plastics in the ocean are unlikely to decay back to simple component molecules during any reasonable timescale. And although “biodegradable” bags are becoming more common, these often degrade only under controlled conditions, and not in the general environment [45].

Moreover, given the weakness of chemicals regulations in Europe and around the world, simply avoiding plastic materials may not be enough. Plastics additives are now commonly added to many non-plastic materials, including cardboard pizza boxes (coated with PFAS), aluminium soda cans (coated with BPA), and cosmetics (phthalates in hairspray, nail polish, and fragrances) [46].

STRONGER REGULATIONS FOR EUROPE-WIDE SOLUTIONS AND BETTER HEALTH

The solution to the problems of plastics cannot be placed on the backs of consumers. Effective protection of health and environment will require stronger, more efficient and protective EU-wide regulations on chemicals and articles in which they are used [47].

PROTECT AND BE CONSISTENT

- No substance of very high concern (SVHC) should ever make its way into consumer products or food.
- It is high time to crack down on plastics additives.
- Rather than treating substances one by one, we must start regulating substances in groups. The reality of our exposure to mixtures, which is particularly relevant when addressing plastics, must be taken into account in chemicals assessments and regulations.
- Regulations on recycled materials should be the same as for virgin materials.

ANTICIPATE AND COMMUNICATE

- Implement essential EU principles such as the precautionary principle in cases of scientific uncertainties and the polluter-pays principle. Do not let substances that are not proven safe enter the market.
- Avoid contaminating the future: do not allow recycling of plastics with hazardous additives and components.
- Safe substitution must be anticipated and put more focus on in regulatory processes in order to avoid regrettable replacements, when a substance or group of substance are being restricted.
- Ensure full transparency on chemical content throughout the supply chain and towards consumers.

Conclusion

According to the plastics industry, the world's plastic production reached **350 million tonnes** in 2017 [2]. Current projections estimate that this number will **double over the next 20 years** [48]. The production of ethylene and propylene alone, the two main precursors used for the production of plastic, will increase by 33-36 percent—approximately 100 million tonnes—by 2025 [49]. Taken all together and considering the many unknowns of the long-term impacts of our continued exposure to toxics in and through plastics, these trends raise serious concerns.

Current regulations do not protect us adequately, because they do not encompass all the relevant aspects of plastics, are not based on precaution, and overlook numerous harmful chemicals used in the manufacturing of virgin and recycled plastics. We need a new regulatory approach if we are to promote a truly non-toxic circular economy and prevent diseases in the future.

Our food packaging, children's toys, phones, and medical devices are too important to trust unknown and impure polymers and unstudied additives. Since so many monomers and additives are hazardous—and so many others are trade secrets—the only answer is that we must reduce our use of plastics.

Taking on the challenge of plastics pollution will require to address the throwaway culture that creates the current demand for and use of plastics, as well as the lax regulations that allow the widespread use of toxic substances in them. Plastics pollution is inextricably linked with chemical regulation and safety, with human and environmental health, and with the future circular economy.

References

[1] HEAL, "How can Europe lead the way to a non-toxic environment?," 2018. https://www.env-health.org/wp-content/uploads/2018/06/HEALs-vision-for-a-non-toxic-environment-strategy-EN.pdf (accessed Jun. 23, 2020).

[2] PlasticsEurope, "Plastic: The Facts 2018," 2018. https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf (accessed Jun. 23, 2020).

[3] D. Lithner, Å. Larsson, and G. Dave, "Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition," Science of The Total Environment, vol. 409, no. 18, pp. 3309–3324, Aug. 2011, doi: 10.1016/j.scitotenv.2011.04.038.

[4] ECHA, "Substance Information portal." https://echa.europa.eu/substance-information/.

[5] "List of Classifications – IARC Monographs on the Identification of Carcinogenic Hazards to Humans." https://monographs.iarc.fr/list-of-classifications/ (accessed Jul. 01, 2020).

[6] D. Lithner, J. Damberg, G. Dave, and Å. Larsson, "Leachates from plastic consumer products – Screening for toxicity with Daphnia magna," Chemosphere, vol. 74, no. 9, pp. 1195–1200, Mar. 2009, doi: 10.1016/j.chemosphere.2008.11.022.

[7] L. Zimmermann, G. Dierkes, T. A. Ternes, C. Völker, and M. Wagner, "Benchmarking the in Vitro Toxicity and Chemical Composition of Plastic Consumer Products," Environ. Sci. Technol., vol. 53, no. 19, pp. 11467–11477, Oct. 2019, doi: 10.1021/acs.est.9b02293.

[8] K. J. Groh et al., "Overview of known plastic packaging-associated chemicals and their hazards," Science of The Total Environment, vol. 651, pp. 3253–3268, Feb. 2019, doi: 10.1016/j.scitotenv.2018.10.015.

[9] J. Murphy, Additives for Plastics Handbook (2nd ed). Elsevier, 2001.

[10] Plastic Soup Foundation, "FAQ: Microplastics and Microbeads in Cosmetics," Beat the Microbead. https://www.beatthemicrobead.org/faq/ (accessed Jun. 23, 2020).

[11] F. M. Windsor, R. M. Tilley, C. R. Tyler, and S. J. Ormerod, "Microplastic ingestion by riverine macroinvertebrates," Science of The Total Environment, vol. 646, pp. 68–74, Jan. 2019, doi: 10.1016/j.scitotenv.2018.07.271.

[12] WWF, "Assessing Plastic Ingestion from Nature to People." 2019, [Online]. Available: https://wwwwwfse.cdn.triggerfish.cloud/uploads/2019/06/dalberg-advocacy-analysis_for-web.pdf.

[13] M. Eriksen et al., "Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea," PLOS ONE, vol. 9, no. 12, p. e111913, Dec. 2014, doi: 10.1371/journal.pone.0111913.

[14] L. Van Cauwenberghe and C. R. Janssen, "Microplastics in bivalves cultured for human consumption," Environ. Pollut., vol. 193, pp. 65–70, Oct. 2014, doi: 10.1016/j.envpol.2014.06.010.

[15] S. A. Mason, V. G. Welch, and J. Neratko, "Synthetic Polymer Contamination in Bottled Water," Front Chem, vol. 6, Sep. 2018, doi: 10.3389/fchem.2018.00407.

[16] G. Readfearn, "WHO launches health review after microplastics found in 90% of bottled water," The Guardian, Mar. 15, 2018.

[17] "WHO calls for more research into microplastics and a crackdown on plastic pollution." https://www.who.int/news-room/detail/22-08-2019-who-calls-for-more-research-into-microplastics-and-a-crackdown-on-plastic-pollution (accessed Jun. 23, 2020).

[18] Plastic Soup Foundation, "Start of scientific research into the health risks of microplastics," Plastic Health Coalition, Mar. 22, 2019. https://www.plastichealthcoalition.org/press/start-of-scientific-research-into-the-health-risks-of-microplastics-does-plastic-make-us-sick/ (accessed Jun. 23, 2020).

[19] "Microplastics - ECHA." https://echa.europa.eu/hot-topics/microplastics (accessed Jun. 23, 2020).

[20] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," Sci. Adv., vol. 3, no. 7, p. e1700782, Jul. 2017, doi: 10.1126/sciadv.1700782.

[21] "Chemicals in plastic products - ECHA." https://chemicalsinourlife.echa.europa.eu/chemicals-in-plastic-products (accessed Jun. 29, 2020).

[22] CHEM Trust, "From BPA to BPZ: a toxic soup?" Mar. 2018, [Online]. Available: https://www.chemtrust.org/wp-content/uploads/chemtrust-toxicsoup-mar-18.pdf.

[23] J. R. Rochester and A. L. Bolden, "Bisphenol S and F: A Systematic Review and Comparison of the Hormonal Activity of Bisphenol A Substitutes," Environmental Health Perspectives, vol. 123, no. 7, pp. 643–650, Jul. 2015, doi: 10.1289/ehp.1408989.

[24] KEMI, "Rapport 5/17 – Bisfenoler - en kartläggning och analys," p. 177, 2017.

[25] The Danish Environmental Protection Agency, "Survey and health assessment of phthalates in toys and other products for children." 2015, [Online]. Available: shttps://www2.mst.dk/Udgiv/publications/2015/06/978-87-93352-44-5.pdf.

[26] "Inspectors find phthalates in toys and asbestos in second-hand products - All news - ECHA," 2018. https://echa.europa.eu/-/inspectors-find-phthalates-in-toys-and-asbestos-in-second-hand-products (accessed Jul. 01, 2020).

[27] Benzyl butyl phthalate (BBP), bis(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP).

[28] bis(2-methoxyethyl) phthalate, dihexyl phthalate, diisopentyl phthalate, dipentyl phthalate, n-pentyl-isopentylphthalate.

[29] H. Bjermo et al., "Serum levels of brominated flame retardants (BFRs: PBDE, HBCD) and influence of dietary factors in a population-based study on Swedish adults," Chemosphere, vol. 167, pp. 485–491, Jan. 2017, doi: 10.1016/j.chemosphere.2016.10.008.

[30] "Flame retardants | HBM4EU - science and policy for a healthy future." https://www.hbm4eu.eu/the-substances/flame-retardants/ (accessed Jun. 23, 2020).

[31] "Flame Retardants," Green Science Policy Institute, Oct. 14, 2013. https://greensciencepolicy.org/topics/flame-retardants/ (accessed Jun. 29, 2020).

[32] H. M. Stapleton et al., "Novel and high volume use flame retardants in US couches reflective of the 2005 PentaBDE phase out," Environ. Sci. Technol., vol. 46, no. 24, pp. 13432–13439, Dec. 2012, doi: 10.1021/es303471d.

[33] For example, the common flame retardant known as Firemaster 550 was a trade secret until its four components were identified by chemical analysis by Stapleton in 2008. This type of secrecy greatly hinders the ability of independent scientists to study the health effects of these chemicals.

[34] TEDX, "PFAS Resources," TEDX - The Endocrine Disruption Exchange. https://endocrinedisruption.org/interactive-tools/pfas-test (accessed Jun. 23, 2020).

[35] "Per-/polyfluorinated compounds | HBM4EU - science and policy for a healthy future." https://www.hbm4eu.eu/the-substances/per-polyfluorinated-compounds/ (accessed Jun. 23, 2020).

[36] European Environment Agency, "Emerging chemical risks in Europe — 'PFAS.'" https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe (accessed Jun. 29, 2020).

[37] "MSC unanimously agrees that HFPO-DA is a substance of very high concern - All news - ECHA," 2019. https://echa.europa.eu/fr/-/msc-unanimously-agrees-that-hfpo-da-is-a-substance-of-very-high-concern (accessed Jul. 01, 2020).

[38] S.H. Brandsma et al., "PFOA substitute GenX detected in the environment near a fluoropolymer manufacturing plant in the Netherlands", Chemosphere, volume 220, April 2019, pp.493-500, https://doi.org/10.1016/j.chemosphere.2018.12.135; Chemistry & Engineering News, "What's GenX still doing in the water downstream of a Chemours plant?," 2018, https://cen.acs.org/articles/96/i7/whats-genx-still-doing-in-the-water-downstream-of-a-chemours-plant.html ; The Intercept, "Chemours is using the U.S. as an unregulated dump for Europe's toxic GenX waster", 2019, https://theintercept.com/2019/02/01/chemours-genx-north-carolina-netherlands/

[39] Arnika, IPEN, HEAL, "Toxic Loophole: Recycling Hazardous Waste into New Products," 2018. https://www.env-health.org/wp-content/uploads/2018/10/Toxic_Loophole-Arnika_IPEN_HEAL-2018-brochure_en-6.pdf (accessed Jun. 23, 2020).

[40] Arnika, IPEN, HEAL, BUND, "Toxic Soup: Dioxins in Plastic Toys," 2018. https://www.env-health.org/wp-content/uploads/2018/11/Toxic_Soup_brochure_en_web04-1.pdf (accessed Jun. 23, 2020).

[41] Changing Markets Foundation, "Testing for Toxics: How chemicals in European carpets are harming health and hindering circular economy," 2018. https://www.env-health.org/wp-content/uploads/2018/10/changing-markets-digital-EN.pdf (accessed Jun. 23, 2020).

[42] L. M. Hernandez, E. G. Xu, H. C. E. Larsson, R. Tahara, V. B. Maisuria, and N. Tufenkji, "Plastic Teabags Release Billions of Microparticles and Nanoparticles into Tea," Environ. Sci. Technol., vol. 53, no. 21, pp. 12300–12310, Nov. 2019, doi: 10.1021/acs.est.9b02540.

[43] J. E. Cooper, E. L. Kendig, and S. M. Belcher, "Assessment of bisphenol A released from reusable plastic, aluminium and stainless steel water bottles," Chemosphere, vol. 85, no. 6, pp. 943–947, Oct. 2011, doi: 10.1016/j.chemosphere.2011.06.060.

[44] "Lifecycle of a Plastic Product." https://plastics.americanchemistry.com/Lifecycle-of-a-Plastic-Product/ (accessed Jun. 23, 2020).

[45] J. N. Hahladakis, C. A. Velis, R. Weber, E. Iacovidou, and P. Purnell, "An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling," Journal of Hazardous Materials, vol. 344, pp. 179–199, Feb. 2018, doi: 10.1016/j.jhazmat.2017.10.014.

[46] Center for Food Safety and Applied Nutrition, "Phthalates," FDA, Mar. 2020, Accessed: Jun. 23, 2020. [Online]. Available: https://www.fda.gov/cosmetics/cosmetic-ingredients/phthalates.

[47] Health and Environment Alliance (HEAL), "Comments on the EU Commission roadmap on a chemical strategy for sustainability", 10 June 2020 https://www.env-health.org/wp-content/uploads/2020/06/090166e5d0342750-2.pdf

[48] World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics," 2016. http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf (accessed Jun. 23, 2020).

[49] CIEL, "Fueling Plastics: How Fracked Gas, Cheap Oil, and Unburnable Coal are Driving the Plastics Boom," 2017. https://www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-How-Fracked-Gas-Cheap-Oil-and-Unburnable-Coal-are-Driving-the-Plastics-Boom.pdf (accessed Jun. 23, 2020).

ACKNOWLEDGEMENTS:

Lead authors (writing and research): Natacha Cingotti, Senior Policy Officer Health and Chemicals, Health and Environment Alliance (HEAL), and Rye Howard, environmental public health scientist

Responsible editor: Génon K. Jensen, Executive Director, Health and Environment Alliance (HEAL)

Editing team: Ivonne Leenen, Communications Officer, Health and Environment Alliance (HEAL); Elke Zander, Communications and Media Coordinator, Health and Environment Alliance (HEAL)

Design: Noble Studio

FUNDING ACKNOWLEDGMENTS:

HEAL gratefully acknowledges the financial support of the European Union (EU), the Global Greengrants Fund, and the Kristian Gerhard Jebsen Foundation for the production of this publication. The responsibility for the content lies with the authors and the views expressed in this publication do not necessarily reflect the views of the EU institutions and funders. The funders are not responsible for any use that may be made of the information contained in this publication.

The Health and Environment Alliance (HEAL) is the leading not-for-profit organisation addressing how the environment affects human health in the European Union (EU) and beyond. HEAL works to shape laws and policies that promote planetary and human health and protect those most affected by pollution, and raise awareness on the benefits of environmental action for health.

HEAL's over 80 member organisations include international, European, national and local groups of health professionals, not-for-profit health insurers, patients, citizens, women, youth, and environmental experts representing over 200 million people across the 53 countries of the WHO European Region.

As an alliance, HEAL brings independent and expert evidence from the health community to EU and global decision-making processes to inspire disease prevention and to promote a toxic-free, low-carbon, fair and healthy future. HEAL's EU Transparency Register Number: 00723343929-96

HEAL
HEALTH AND ENVIRONMENT ALLIANCE