PLASTIC SOUP

AN ATLAS OF OCEAN POLLUTION

MICHIEL ROSCAM ABBING

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Island Press gratefully acknowledges major support from The Bobolink Foundation, Caldera Foundation, The Curtis and Edith Munson Foundation, The Forrest C. and Frances H. Lattner Foundation, The JPB Foundation, The Kresge Foundation, The Summit Charitable Foundation, Inc., and many other generous organizations and individuals.

Generous support for the publication of this book was provided by Margot and John Ernst in honor of their granddaughter, Sydney, who champions a future with reduced plastic.

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ISLANDPRESS

Washington | Covelo | London

PLASTIC SOUP

Translation by Tessera Translations
Design by Nico Richter
Infographics by Jan Vork

First published in 2018 by Uitgeverij Lias in the Dutch language. Published in the English language in 2019 by Island Press.

Library of Congress Control Number: 2018963536

All Island Press books are printed on environmentally responsible materials.

Manufactured in the United States of America
10 9 8 7 6 5 4 3 2 1

Because this book was originally published in the Netherlands, the metric system has been used for all measurements. To ensure accuracy, we have left these measurements in their original units. Please consult the chart below for some basic conversions:

28 grams = about 1 ounce
1 kilogram = about 2.2 pounds
1 meter = about 1.10 yards
1 kilometer = about .62 miles
5 milliliters = about 1 teaspoon

For example, the average American produces 85 kilograms of plastic waste each year—that's about 185 pounds.

Keywords: BPA, Beat the Microbead, Great Pacific Garbage Patch, Kamilo Beach, Midway Atoll, PET bottles, Plastic Soup Foundation, plastic pollution, beaches, biodiversity, bioplastics, cosmetics, drinking straws, entanglement, environment, fish, gyres, microbeads, microfibers, microplastic, nanoplastic, nets, oceans, personal care products, plastic bags, plastic footprint, plastic soup, plastiglomerate, recycling, single-use, sustainability, toxins, waste, wildlife

This book is dedicated to children everywhere, in the hope and conviction that they will live in a world in which plastic soup is no longer on the menu.

← *Used bottles sometimes get a second lease on life as bricks for a wall. They turn out to be a cheap building material and are no longer discarded.*

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INTRODUCTION

Plastic dominates our lives. Plastics are synthetic materials derived from petrochemicals. They can be found in all shapes and sizes, ranging from soft and thin to rock-hard and thick. Plastics have become enormously popular over the last seventy years, thanks to their particular properties and extremely low production costs.

We reap the benefits of those features every day. But those same properties turn out to be disastrous for ecosystems. Plastics do not dissolve in water and do not decay. All the plastic that has ever ended up in the environment is still present in some form or other. What plastic does do in the environment, though, is break down into smaller and smaller fragments. These include microplastics, which are mostly so small that they are no longer visible to the naked eye and can easily get into food chains.

United Nations Environment believes plastic litter and microplastics to be one of the biggest environmental problems that the world is facing. The problem has acquired a name, too: *plastic soup*.

The oceans cover 71 percent of the Earth's surface. A misunderstanding persists that there are floating islands of plastic out there—and the few people who sail the seas do sporadically come across floating plastic. However, it's only possible to understand the scope of the problem after investigating what is floating on the surface, drifting around in the water column, and lying on the seabed. It's easy to see at the surface level: every wave that breaks on shore leaves some plastic behind, and beaches all over the world have to be cleaned up constantly. Smaller fragments go unnoticed, however, and can never be removed.

Plastic soup is everywhere. There's no place on Earth nowadays that is genuinely free of plastic: it is in rivers and canals as well as the oceans—in the water, on the land, and even in the air. The accumulation and fragmentation of plastic in the environment means that the benefits of plastic are being overtaken by the drawbacks. More than a thousand animal species are being affected in some way by all that plastic. They are ingesting it, injuring themselves with it or suffocating on it. And all that plastic litter is damaging for humans, too. The truth is difficult to digest—quite literally—and that plastic soup is making us ill. Evidence of damage to health is accumulating.

In a timeframe that is less than the average human lifespan, plastic soup has become a staple on the menu. The rapidly growing global population does not know how to handle the miracle material. The planet is becoming polluted faster than ever, and humankind is going to have to resolve the problem together. If that can't be done, we are going to saddle future generations with an issue that will plague them for centuries.

The first part of this book addresses the causes of plastic soup, whereas the second part is about inspirational initiatives for wiping plastic soup off the map.

In Ancient Greek mythology, Atlas was one of the Titans. For his part in the Titans' rebellion against the leader of the gods, Zeus, he was condemned to bear the heavens on his shoulders as punishment. Books of Maps were later named after him. *Plastic Soup: An Atlas of Ocean Pollution* presents a thematic perspective on the worldwide plastic soup problem and possible solutions. The overall message is crystal clear: combating plastic soup is going to be a titanic struggle.

← *Microplastics from the Rhode River in Maryland, collected in a manta trawl. Pictured at the laboratory of Dr Lance Yonkos, University of Maryland in 2015.*

ON

THE MAP

1

PLASTIC FANTASTIC

← *Plastic sticks from cotton swabs are one of the most common items found on many countries' beaches. Italy has become the first country to ban them.*

The photographer Gregg Segal portrayed a number of Americans lying among newspapers, cans, and lots of plastic, which represented the amount of waste that these people had produced in a single week. His series from 2014 is confrontational; every one of us could have been lying there with just as much rubbish. Over recent decades, nothing has changed more than the composition and quantity of our waste. And there's a reason: plastic.

DISPOSABLE PLASTIC

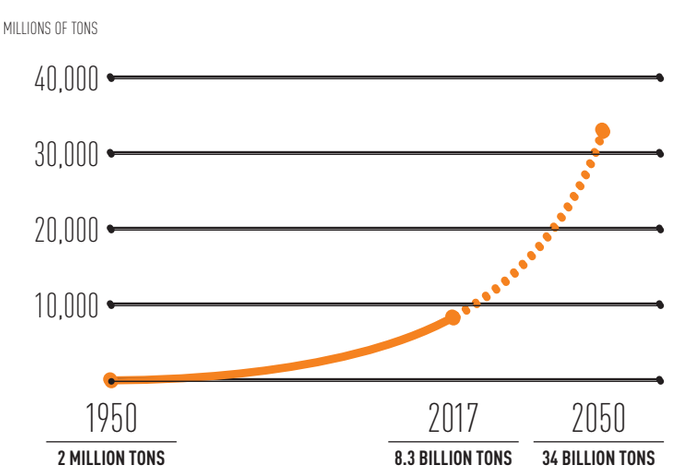
Plastics started their irresistible rise a century ago. Plastic waste is a mirror that reflects the throw-away society that quickly emerged after the Second World War. Increasing numbers of more traditional products were replaced by plastics. Polyethylene, lighter and tougher than traditional glass or earthenware, was introduced into the home and became familiar as 'polythene'. Zinc tubs and basins gave way to lightweight plastic ones in modern shapes and cheerful colors. Nylon stockings and plastic toys became immensely popular. Plastic bags were invented at the end of the 1960s.

We surrounded ourselves with plastic plates, tumblers, cutlery, bottles, and margarine tubs. Never in our history had so many products been available so cheaply. Plastic is the miracle material for mass production. Thanks to low prices, it no longer matters if a plastic product is used only once or if it soon breaks.

The properties of plastics made them absolutely revolutionary—lightweight and easily molded, strong and waterproof. Because plastics hardly react at all with other substances, the applications are endless. Food packed in plastic can be kept for much longer, and goods wrapped in plastic stay well protected during transport. Not only are increasing numbers of products made of plastic, but they are also packaged in it, sometimes in several layers. In the United States, 2.5 million plastic bottles are thrown away every hour. The average American produces the better part of 85 kilograms of plastic waste each year. On average, a plastic bag is used for just twelve minutes.

The use of plastic will increase sharply in the United States, due in part to the use of cheap shale gas as raw material instead of oil. That gas contains a large amount of ethane, which is converted at cracking plants into ethylene, the raw material for polyethylene. The American chemical industry is investing billions of dollars in these new cracking plants, making the production of plastic even cheaper. The plastics industry is continuously on the lookout for new technologies, and more and more are becoming possible.

→ *If global plastic production continues to grow at the current rate, the world will have produced 34 billion tons by 2050.*



→ *How much waste do we produce in a week? Photographer Gregg Segal depicted it hauntingly in 7 Days of Garbage.*


Celeste
RICE KRISPIES TREATS
FLOWERS
HADLEY

BENEFITS FOR THE ENVIRONMENT AND FOOD

At first glance, plastics seemingly have environmental benefits when compared with other materials. The production of one kilogram of plastic results in lower greenhouse gas emissions and less water and energy consumption than one kilogram of paper. It also takes more energy to transport paper since paper is a heavier material. But does that mean that a plastic bag is better for the environment than a paper one? Different materials vary in their environmental effects. The comparisons must carefully weigh all the environmental factors in all stages of the lifecycle of a material. Only then is it possible to determine which material is, on balance, less harmful.

↑ *In supermarkets, plastic helps cut down on food waste. Nowadays even single items like peppers and cucumbers are wrapped in plastic.*

Consumption of energy and water is simple to measure, but the impact of plastic waste on the environment is difficult to quantify. When plastics are said to be environmentally friendly, one factor—plastic soup—is consistently left out of the equation. While paper breaks down naturally, plastic in the environment does not decay, and that has lasting consequences.

Supermarkets are full of individually packaged fruits and vegetables. There's a reason for that: plastic wrap stops them from drying out. The plastic wrap allows products such as peppers, cucumbers, and carrots to be kept longer and be better protected during transport. Because of the longer shelf life, they can be transported greater distances, which is important when there is no local supply—for example, in winter.

Manufacturing plastic wrap takes energy, which adds to greenhouse gas emissions. However, if the shelf life of products was not extended by using plastic wrap, more food would be wasted. And in that case, more food would have to be grown—which takes more energy than does producing the packaging. The result is that more and more products are being individually wrapped in plastic throughout the world, including products that have their own natural rind or peel, such as bananas and oranges. Even organically grown fruits and vegetables often get their own separate packaging. The bulk of those wrappings then appear in consumers' trash cans.

The risk of plastic wrap ending up in the environment is not so high. However, it's about the quantities rather than the likelihood. Even if only a small percentage of the world's plastic packaging for fruits and vegetables ends up littering the environment, that still means hundreds of millions of fragments of plastic wrap and plastic sheeting in our midst. More and more supermarkets have decided to cut back on this packaging, and there are already some who have stopped using it altogether.

The word *plastic* means malleable, able to be molded. That is a property of this synthetic material when heated, so that it can be pressed into a shape that it retains upon cooling. In the cooled state, the material is sturdy, watertight, non-wearing, unbreakable, and insulating. This means that plastics are ideal replacements for traditional materials. What used to be made of metal, paper, ceramic, cotton, bone, leather, or wood is now more than likely made of plastic. In just a few decades, plastics have displaced many other materials.

→ *You don't have to give a plastic plant water, and it can look good for years. Plastic products are sometimes tricky to distinguish from the products they are replacing.*

BETTER THAN OTHER MATERIALS

There are two classes of plastics, thermoset and thermoplastic, and one of those groups has an additional property: it can be recycled. Thermoset plastics become hard after they have been heated and then remain hard—electrical sockets, sail boats, surfboards, or aircraft, for instance. These products cannot be melted again. Bakelite, one of the first plastics to be invented early in the twentieth century, is thermoset. Thermoplastics soften when they are heated and they can therefore be melted and reshaped time and time again. The applications are numerous and too many to mention, ranging from clothing, polystyrene, tubing, sheeting, and tumblers to bottles and window frames. Because they can be melted down, many of these items can be recycled.

Plastics are replacing traditional materials, but not people's desire for those materials. The original products are mimicked, and it is sometimes nearly impossible to see the difference. Is that a leather sofa, a wool sweater, a glass bottle? Is there grass on the field? Is the parquet floor real wood? Is that a live plant on the window sill? Or are they all made of plastic?

The process of substitution has never stopped. Zinc colanders were replaced fifty years ago by colorful plastic ones, and it will not be long before the steel used in cars and planes will be replaced by lightweight, tough composite materials. Nobody is surprised by such innovations anymore. The plastics industry is continually on the lookout for new applications for, and improvements to, its products, for example by adding chemicals during the production process or by tweaking the molecular structure of the polymers. The costs of development are high, and new types of plastic are continually being patented.

There are thousands of different trademarked names for patented plastics, and each type is slightly different. The development of new plastics is geared toward obtaining desired properties and does not take into consideration whether the material will remain as useful when recycled. The flip side of more advanced plastics, which are in many ways better than the materials they are replacing, is that they may be less useful as recyclable raw material.

MIRACLE MATERIAL FOR MASS PRODUCTION

Never in our history have so many products been available so cheaply. Those products are overwhelmingly made of plastic. Consumers are awash with products that do not last long and that they often don't even really need. Plastic is a *wunderkind*, mass production's miracle material. Shops in lots of countries are full of dirt-cheap knickknacks. As a consumer, you feel more and more as if you'd be shooting yourself in the foot by not snapping up these bargains. We are living in a throw-away society that is ruled by predatory pricing.

← *Growing use of countless mass-produced, cheap plastic items for a wide range of short-lived applications gives rise to enormous quantities of plastic waste.*

The products are bought in bulk in countries where cheap labor means they can be manufactured in vast quantities. The bigger the order, the lower the unit price. Many chain stores are happy with just a small margin: they are not concerned with the profit per item alone, but in how it is magnified when they sell items at a high volume. If lots of those products go through the checkouts, there will always be a profit no matter how low the margin.

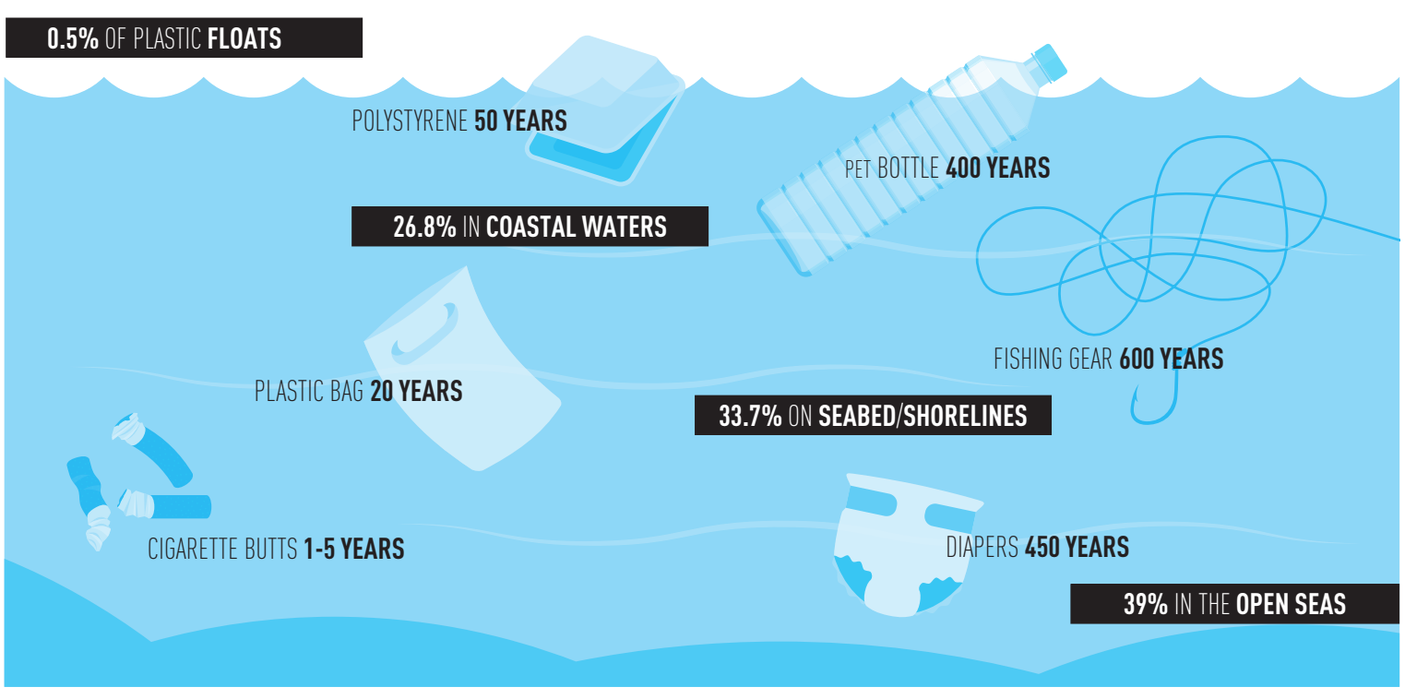
Everything that is made of plastic becomes waste at a certain point. The average useful lifespan of cheap products is short; plastic objects that last many years are outliers. Many of those cheap plastic products are, in fact, deliberately designed so that they will soon be thrown away. The manufacturers rely on this to allow them to sell high quantities.

According to United Nations Environment Programme, between 22 and 43 percent of all plastic used worldwide ends in landfills. That is a colossal waste of raw materials. Plastics blow or wash away easily, ultimately ending up in the seas. Garbage dumps are one of the major contributors to plastic soup. Consumers think they are benefiting from cheap items, but every purchase harms the environment.

Advanced systems are needed for recycling, just as they are for clean ways of generating electricity by incinerating plastic waste. Dumping is simpler and cheaper than recycling. Exporting plastic waste to countries where the environmental regulations are more lax can often seem attractive, even for countries where the infrastructure for recycling exists. Until recently, China imported a substantial proportion of plastic waste collected worldwide. They used it as raw material for new plastic products or for generating energy. Some of the plastic imported by China was also originally produced there. Chinese imports have been halted, which has moved the export of plastic waste to other countries.

Plastic circulates around the world, in vast quantities.

↓ *It is difficult to determine how long it takes before plastics break up. Plastics in the oceans do not degrade, ending up instead as miniscule particles.*



Worldwide production of plastic has increased sixfold since the 1980s. A key reason is that a lot of plastic is used only briefly. That applies, in particular, to packaging materials for consumer products. Plastic packaging represents about 40 percent of global plastic production. The trend is not to package fewer products in plastic, but actually more. On top of that, the units that are packaged are getting smaller and smaller. Single use, as it is generally known, contributes disproportionately to plastic soup.

DOMINANCE OF 'SINGLE USE'

→ *Single-use plastic items such as bottles are a major source of plastic in the environment. They remain there for hundreds of years.*

You see them hanging in shops in poorer countries: long, colorful strips of pouches or sachets. They are used for packaging and selling tiny quantities of a product—laundry detergent or shampoo or noodles, for instance. Customers only buy one or two of those little bags at a time. It is an inventive solution because people are often too poor to afford larger quantities.

These mini-packages illustrate the relationship between single use and plastic soup. After use, the sachets are often discarded. Sewers and rivers easily carry them off toward the oceans. Because they are intended for small volumes, there are huge numbers of them. And their value for recycling is zero, unlike PET bottles that can still be fished out of the garbage to be traded. So a waste picker will not see this packaging as being worthwhile. The miniature packages consist of several different layers of plastic foil, making recycling the material technically complex. In addition, the areas in which these products are sold typically only rarely have a properly functioning refuse collection infrastructure.

In principle, plastic packaging material has a residual value after use as a raw material. According to one calculation, 95 percent of that value is lost to the global economy, however. That annual value is estimated at $80–$120 billion dollars. A mere 5 percent of the value of the plastic packaging material is reused in the sense that new products are made from it.

A key reason why plastic packaging is rarely reused for new products is that the costs of collecting and sorting it are high. In addition, it is often cheaper for the plastics industry to make new plastic from oil, and the new material is better quality. When world oil prices are low, virgin plastic is extremely cheap. While they wait for oil prices to rise again, recycling companies go bankrupt or have to be kept going with government subsidies. In short, it is no surprise that packaging material ends up on the streets, is incinerated, or is dumped somewhere.

← *Some cosmetics products consist of 10 percent microplastics. That means that the five milliliters you use daily can contain up to 100,000 particles.*

DESIGNED TO BE WASTE

Plastic does not belong in the environment. Everyone can agree on that. Nevertheless, many products are designed to end up as waste. The environmental argument rarely seems to be a deciding factor for manufacturers. For them, it is primarily about cost reduction, profits for shareholders, and going as far as the regulations allow. Manufacturers also like shifting responsibility to consumers, who are expected to conduct themselves appropriately and leave nothing behind in the environment. Plastic is so cheap and so suitable for all kinds of applications that products will continue to be made—unless the regulations are clear—that will further contribute directly to the plastic soup problem.

One of the types of waste most commonly found on coastlines consists of short plastic sticks. They were once cotton swabs. Many people take the simplest option and flush them down the toilet. The sticks aren't always caught by the grills during wastewater treatment, so they end up in the surface water and finally in the sea. In September 2016, a total count was taken during a major cleanup of beaches in Britain. An average of 24 of these sticks were found per hundred meters of beach. In that country, plastic cotton-swab sticks were the sixth most common type of waste found on the beaches.

Manufacturers do not make the sticks from biodegradable paper or cardboard because plastic ones are cheaper, and there is no law prohibiting it. The plastic cotton swab is an example of a product that manufacturers know will only be used once. So, there is a good chance it will end up in the environment.

One instance where consumers can hardly be deemed responsible for pollution is the microplastics in personal care products. There can be tens of thousands of these tiny beads in every bottle. The microbeads disappear with the wastewater down the drain and some of them end up in the sea. They are also added to some cleaning products and detergents.

Manufacturers only appear willing to modify existing products when pressure is exerted on them and there is a threat of damage to their public image. One way this was achieved was through a worldwide campaign called *Beat the Microbead*. Most multinational companies have now voluntarily replaced the abrasive plastic particles and consumers think that this problem has been resolved. There can, however, still be microplastics in cosmetics, where they have a different function. Clear legislation and regulations are the only way that consumers can be certain there are no microplastics in personal care products.

When regulation falls short, competition drives manufacturers to add the cheapest raw material—plastic—and consumers become polluters without realizing it.

↓ *Following the* Switch the Stick *campaign by City to Sea, British retailers promised to make their own-label cotton swab products from paper.*

2

FLOATING PLASTIC

BOTTLES WITH A MESSAGE

→ *Some plastics are heavier than water and sink immediately. Other types are lighter and stay afloat. Still others remain suspended in the water for a time.*

There are five major rotating ocean currents, known as *gyres*. These are gigantic whirlpools in which floating waste is slowly but surely drawn to the center of the oceans. The idea that the concentrations of plastic there have virtually formed islands is a persistent myth. Even in the centers of the gyres, you see surprisingly little floating plastic—just a big piece every now and again. But if you sieve the water with a fine-meshed dragnet, you will find lots of tiny pieces of plastic. And nobody sees what is floating around in the water beneath the surface or what has sunk.

Some plastics are heavier than water and sink immediately. This is, for instance, the case for PET (polyethylene terephthalate), the material that some drink bottles are made from. If one of these bottles ends up in the water, it sinks straight to the bottom. But with the top on and full of air, a PET bottle can easily get to the middle of a gyre. Anyone who sees a bottle floating there, so incredibly far from the inhabited world, will realise that something is seriously wrong. This happened to Charles Moore, a marine captain who was sailing from Hawaii to California in 1997 and occasionally saw floating pieces of plastic in the middle of the Pacific Ocean. He was shocked, investigated the issue, and put the problem on the international agenda. He also came up with the term *plastic soup* for plastic that is floating on or in the water.

Other types of plastic are lighter than water and therefore stay afloat. Over time, as they are broken up into smaller and smaller pieces and are made heavier by algae that attach to them, these plastics finally sink as well. Because of this, as you get further from the coast, you come across less floating plastic.

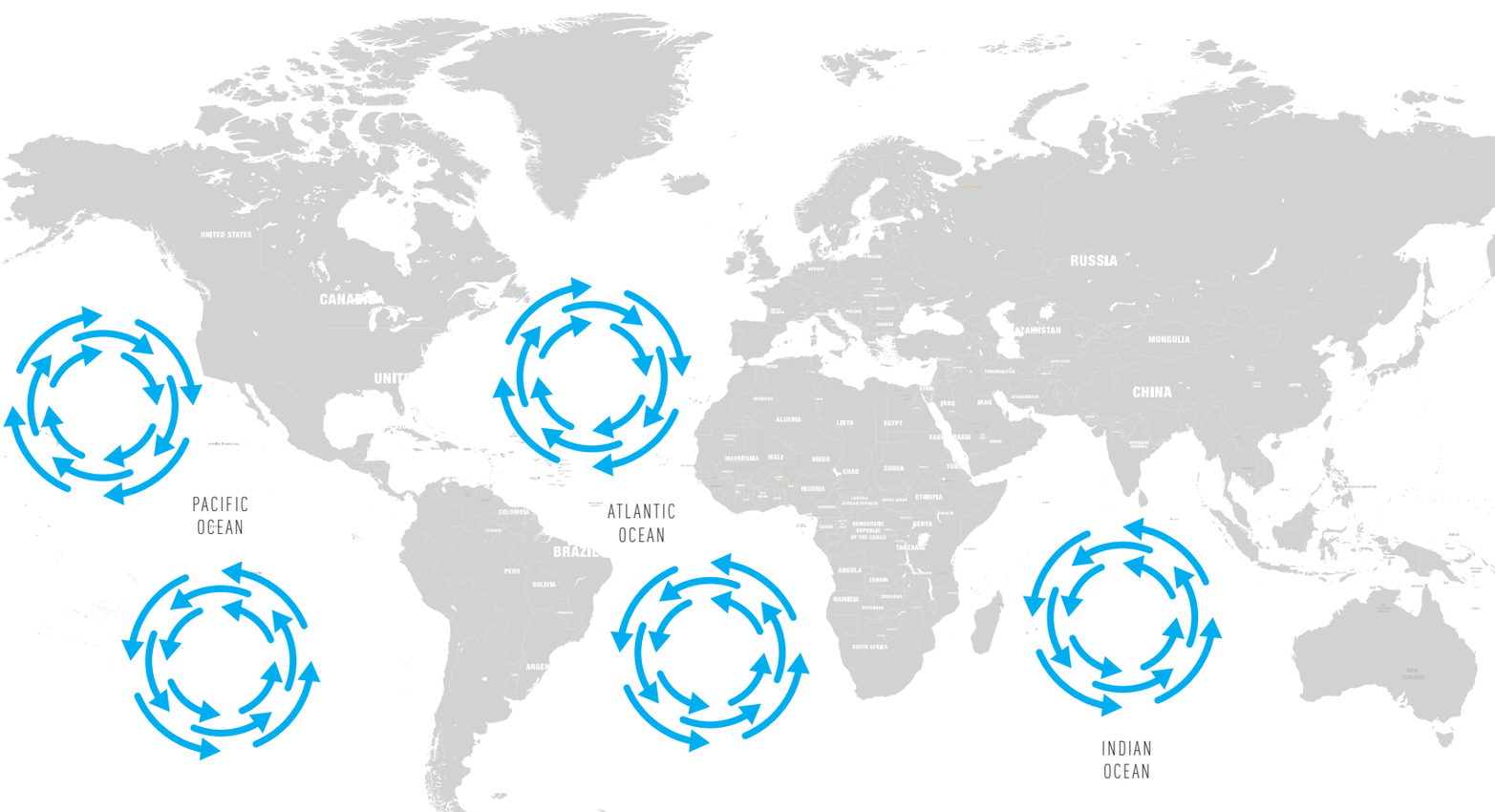
PET sinks, but bottle tops don't. They are made of a different kind of plastic (HDPE) and they are lighter than water. That is why lots more bottle tops than plastic bottles are found on beaches. The bottle that went with it is lying on the seafloor somewhere. There are even places where underwater garbage dumps appear: the currents bring the bottles together, where they then remain for eternity.

Billions of PET bottles are used worldwide every year. After they are used, the bottles are just waste. People are highly dependent on bottled water, particularly in areas where water is not accessible or is of poor quality. The labels often praise the contents as being natural, sparkling, and fresh—a message that is completely at odds with the plastic bottle as waste.

← *Being caught in fishing nets is one of the biggest threats to marine turtles. Dragged through the water and unable to breathe, they die.*

↑ *Drastic reduction of plastic use and sound waste prevention and management systems are essential to keeping plastics out of the oceans.*

→ *Waste accumulates in the center of the five gyres. It is, however, a persistent myth that large, floating islands of plastic are created.*


RUSSIA
CHINA
MONGOLIA
PACIFIC
OCEAN
ATLANTIC
OCEAN
INDIAN
OCEAN

A beach paradise with white sand and palm trees in the Pacific Ocean—this idyllic image is etched into the mind's eye for many people, but is no longer the reality anywhere. White, sandy beaches are now multi-colored because of the plastic that has washed up on them. Remote beaches, which are rarely or never cleaned up, particularly look as if a dump truck of household waste has just lost its load at the high-tide line. There is no longer a single beach in the world where you will not find plastic, although its composition can vary a great deal locally. Large pieces of plastic can, in principle, still be cleaned up, but smaller ones cannot. The very smallest pieces cannot be distinguished from sand grains. Plastic soup is more tangible on the beach than anywhere else.

PLASTIC BEACH

Kamilo Beach, at the southernmost tip of the Hawaiian archipelago, was once a holy place for the original inhabitants. Because of the combination of currents and strong onshore winds, extreme amounts of plastic wash up there. Literally every wave leaves plastic behind, even though Hawaii is in the middle of the Pacific. The plastic that remains on the beach may have been carried along on ocean currents for years. Sunlight and wave motion have crumbled much of the plastic into small pieces and particles. Kamilo Beach is now known as Plastic Beach and plastics have been deposited there in a layer that is tens of centimeters thick in places.

Analysing all this beach trash tells us a lot. The bulk of it, certainly in terms of weight, comes from shipping and fishing. We're talking nets, ropes, buoys, and fish boxes. Pieces that have been broken up further can, however, no longer be assigned to a specific source.

In many places, it is customary to release balloons on festive occasions. Those balloons and plastic ribbons will then end up on the beaches. How many plastic bottles do you find lying on the beach? It turns out that whether or not there is a deposit on beverage packaging makes quite a difference. On the beaches in Australian states where no deposit was introduced, no less than three times as many beverage packaging items were found.

Beach cleanups have become a familiar activity around the world. Removing plastic from beaches is particularly useful and provides substantial educational value as a group activity. There is, however, one big problem. How long will all those volunteers keep it up, going to clean up the beach over and over, if that same beach is full of plastic again in no time? Cleanups are needed, but without effective measures to rein in the plastic soup problem, tidying the beaches is fighting a losing battle.

→ *Beaches can be so polluted with washed-up, discarded plastic that the sand beneath is barely visible.*

In 2014, to celebrate the anniversary of the fall of the Berlin Wall, a single string of almost eight thousand balloons with lights was released. Together, these balloons and lights symbolized the former border. They disappeared slowly from view; the majority of them were later found again in the area, but one balloon reached Riga, eight hundred kilometers to the east. Releasing balloons en masse is nowadays extremely popular in the Western world, particularly on occasions such as birthdays, weddings, or grand openings. The biggest release of balloons ever, in Cleveland, Ohio in 1996, saw over one and a half million balloons go up into the air together.

RELEASING BALLOONS

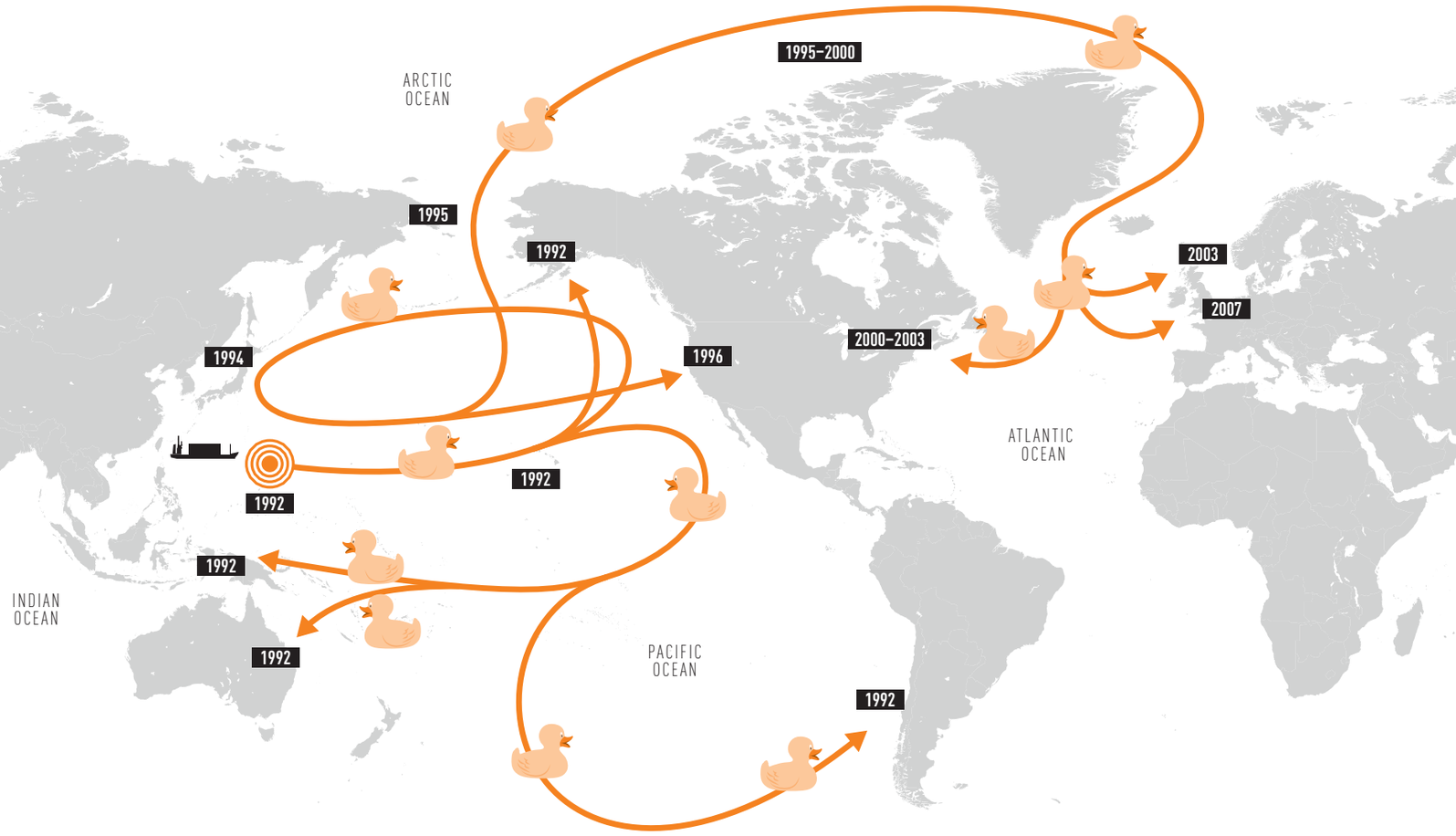
↑ *Releasing balloons looks very festive. But what goes up as a balloon, comes down again as waste.*

Seeing colorful, helium-filled balloons dancing in the air and carried away by the wind is a pleasing spectacle. However, each and every one of them comes down again, contributing to litter, in general, and plastic soup, in particular. Many of them land in the sea. The remains of balloons and plastic ribbons are among the items most commonly found on beaches. Plastic valves and stoppers turn up all over the place, too.

Latex party balloons are harmful to animals as well. The rubber breaks down slowly in water, and there is a risk that animals will eat them. A Dutch researcher, Jan Andries van Franeker, discovered that one out of every fifty northern fulmars had recognizable remnants of balloons in its stomach. In some cases, the pieces of balloon were so large that they obstructed the seabirds' gastro-intestinal tracts. In cases such as these, the birds undoubtedly perished of hunger. Turtles mistake balloons in the water for jellyfish, and birds risk getting their feet caught in ribbons.

Although the protests against this easily avoidable form of pollution are getting more vociferous, the silence in Germany was deafening. Remembering the reunification was too important a collective and emotional event. There are other cases, for instance, where releasing a balloon symbolizes letting go, such as during a remembrance of a deceased family member. And who would dare to protest against a children's party on the grounds that the balloons released could cause severe suffering to animals?

The habit of letting balloons up into the air, en masse or a few at a time, shows that plastic soup and animal suffering are still an abstract concept for most people. People are simply not bothered by what happens to a balloon once it has disappeared from sight. It is often an easy choice when the expected entertainment is weighed against an unspecified risk of animal suffering.



↑ *After a container full of rubber ducks fell overboard in 1992, the ducks ended up bobbing about on the waves for years.*

← *To symbolize plastic pollution, the Dutch artist Florentijn Hofman blew up a yellow bathtub duck, familiar throughout the world, to a monstrous scale.*

On January 10, 1992, there was a severe storm in the middle of the Pacific Ocean. A freighter lost a container. That container was full of fist-sized plastic animals for the bathtub: a total of 28,800 yellow ducks, red beavers, blue turtles and green frogs. These toys, which we will call *rubber ducks* for the sake of simplicity, embarked upon a lengthy voyage with an unknown destination. Every now and then, a few of them would wash up on a beach somewhere. The ones that were found turned out to be incredibly valuable for oceanographers studying the ocean currents. As a result, the yellow rubber duck has become one of the symbols of plastic soup.

RUBBER DUCKS

As a result of Earth's rotation and the prevailing winds, the oceans are continuously in motion. In 1992, the rubber ducks were shipwrecked in the North Pacific Gyre, one of the ocean's large rotating marine currents. Some of them continued to float around in huge circles, but the majority ended up in other currents, including the Subpolar Gyre. Ten months went by before the first ducks washed up on land, in the area around a coastal town called Sitka on the Gulf of Alaska. Rubber ducks were subsequently found on that coast every three years. In those three years, the ducks circumnavigated the Subpolar Gyre, a trip of some seven thousand miles at an average speed of eleven kilometers a day.

To the north of Alaska, a number of the ducks got trapped in the polar ice, which transported them toward Greenland where they were then released and began exploring the Atlantic. A toy duck washed up in Maine in July 2003, for instance, and a frog made landfall on the northwest coast of Scotland in August that year. However, two-thirds of all the rubber ducks took a completely different direction after 1992. A lot of them washed up in Indonesia and Australia; others crossed the southern Pacific and were retrieved from the coast of South America.

Washed-up toy ducks often have bite marks from animals and have been damaged by the action of waves against rocky coasts. Exposure to sunlight means that the majority of them will ultimately break up into fragments somewhere in the middle of the sea. On coasts throughout the world, innumerable fragments will wash up that are no longer recognizable as parts of the rubber ducks that were shipwrecked in 1992.

These toys have yielded a great deal of scientific knowledge. The same does not apply for other containers with plastic objects that have gone overboard. In January 2017, thousands of plastic 'surprise eggs' washed up on one of the German Wadden Islands, Langeoog, and after separate accidents, the beaches of Cornwall in England were innundated with thousands of pink plastic bottles and Lego toys.

GHOST NETS

Ghost nets float around endlessly, killing and wounding marine animals. They do what they were made to do: catch fish. Animals are injured, die of hunger, or suffocate. They become easy prey for other animals, in turn. Life teems around discarded nets, which increases the likelihood of new victims.

These ghost nets catch fish and get tangled with each other, clumping together with floating ropes, buoys, and other waste. On top of that, nets catch on coral easily. The forces of waves and currents can then rip reefs apart. Nets also catch in ships' propellers, causing a hazard to shipping.

↓ *On the German archipelago of Heligoland, gannets are regularly victims of entanglement because they use dolly ropes to build their nests on the rock.*

→ *Abandoned fishing nets not only harm the marine environment but also pose a hazard to ships because they get tangled in boat propellers.*

Nets made of plastic have been used throughout the world since the 1960s. They are cheaper than traditional nets made of rope. They last longer, weigh less, and are much stronger. The fact that they float better is another advantage. Nets come in all shapes and sizes, often designed to catch a specific type of fish. There are dragnets used in trawler fishing that span thousands of square meters. Line fishing uses long cables with hooks on lines that are kilometers in length.

Three tons of ghost netting wash up annually on every kilometer of the North Australian coast, where six of the seven known species of marine turtles live. Turtles search out floating objects to hide under, making sorties from that safe spot to look for food. They have not yet adapted and do not know that they could get their flippers caught in the nets. Three-quarters of all corpses trapped in ghost nets that wash up are marine turtles.

Small pieces of net can also cause substantial damage. Bottom fishing in northern Europe uses polythene fibers—orange, blue, or black threads called 'dolly rope' that protect dragnets against wear and tear. Dolly rope is the type of waste most commonly found on northern European beaches. The Dutch bottom fishing industry alone purchases forty thousand kilograms of the material annually.

Birds use the colorful threads as nesting material. Virtually all the nests of gannets that breed on the rocks of Heligoland in the North Sea contain them. Birds that are unlucky get caught and hung up in it, dangling in place until the fibers rot away.

Fortunately, many ghost nets are cleared up. This is often done by recreational divers who voluntarily cut nets free from shipwrecks, even though that can be a dangerous job. At present, there is nothing to suggest that more nets are being picked up out of the sea than are being discarded in it, however.

Midway, a group of islands in the middle of the Pacific Ocean, is one of the most remote locations in the world. Even so, its beaches are full of plastic. Unfortunately for Midway, ocean currents bring a lot of trash to the islands. Some of that waste comes from Japan, a fact made especially clear by the items that washed up on Midway's beaches after a tsunami struck the Japanese coast in 2011. On Midway, which is a protected nature area, a striking number of plastic lighters were found. The writing on the reservoirs revealed that half of them certainly came from Japan. Midway is four thousand kilometers away from the Japanese smokers who, at some point, discarded these lighters.

LIGHTERS ON MIDWAY

→ *On Midway Atoll, nesting albatross chicks have bellies full of plastic that their parents mistook for food. Photos taken by Chris Jordan in 2009 shocked the world.*

Midway is home to the world's largest colony of Laysan albatrosses. More than four hundred thousand pairs breed there, feeding their chicks with whatever they can catch from the sea. The parent birds look for food such as small squid and strings of flying fish eggs to give to their young. The colorful lighters may resemble squid, or the strings of eggs may be attached to them. The birds pick up the lighters and other floating plastic objects from the sea and fly with them to their brood, covering thousands of kilometers with ease. A cigarette lighter on Midway, for example, may have been fished out of the sea off the coast of Alaska. Ocean currents are not the only reason so many disposable lighters, and other plastic waste, are found on the islands.

After a while, the chicks regurgitate a bolus, like the pellets of an owl. They contain everything that is indigestible, such as the hard pens of squids. Nowadays, plastic can be found in almost every bolus. Every year, tens of thousands of albatross chicks on Midway die a horrible death from hunger. This happens when they ingest so much plastic that they are no longer able to produce a bolus.Colorful lighters are found in the carcasses, sometimes several at a time. On top of that, there are bottle tops, toys, toothbrushes, golf balls and—always—huge numbers of tiny pieces of plastic of indefinite origin. These are the silent witnesses to the drama that is being played out in this bird colony. The number of pieces of plastic found in a single dead bird was once counted to be no less than 558. The gruesome images of dead and dying chicks recorded on Midway by the photographer and filmmaker Chris Jordan have now made the world sit up and take notice. Anyone who sees the photos cannot fail to conclude that the smokers who thoughtlessly threw away their lighters bear some of the responsibility for this catastrophe.

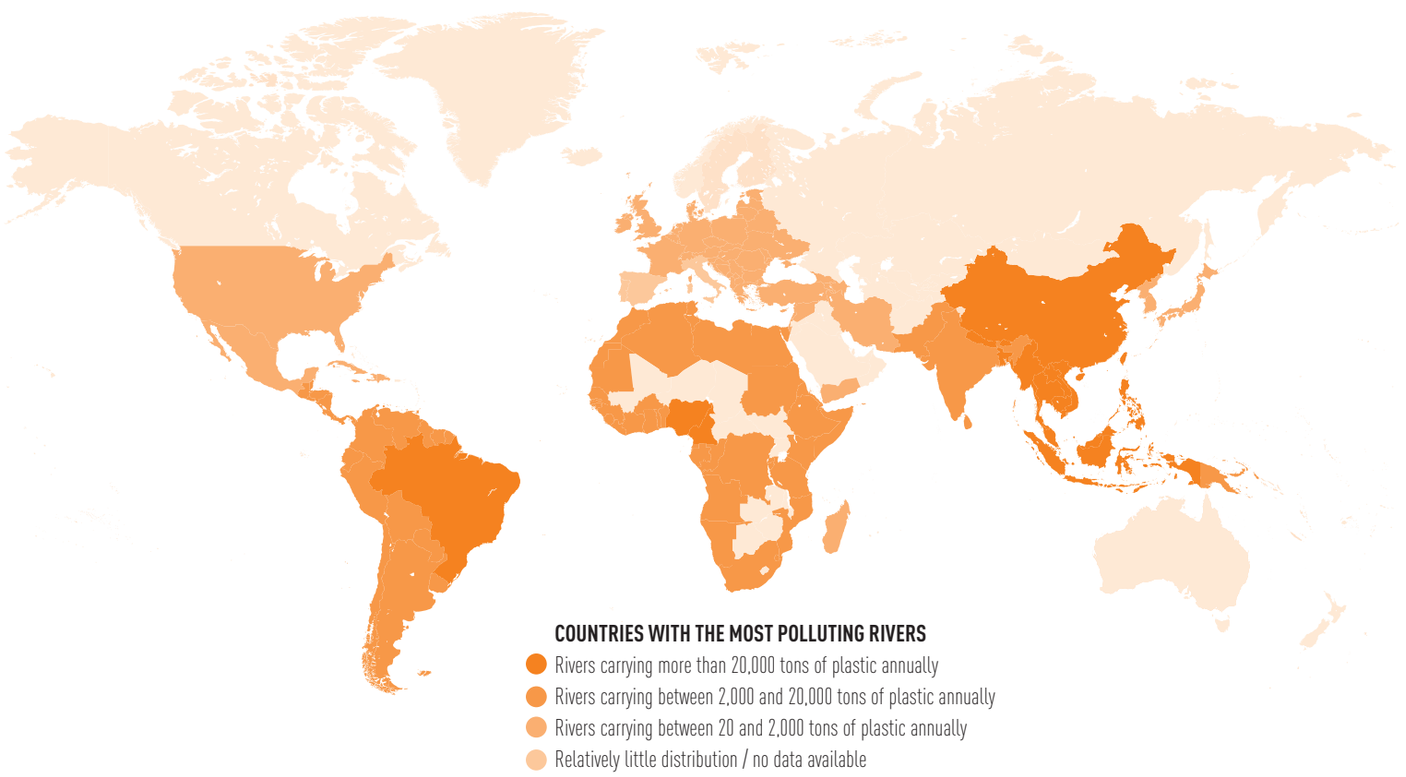
3

FROM SOUP TO BROTH

← *A manta ray feeds amidst plastic pollution off the Indonesian island of Nusa Penida. Filter feeders such as this species are particularly susceptible to ingesting plastic and associated toxins.*

Determining how much plastic ends up in the oceans each year is complex. Scientists often quote a 2010 estimate that the 192 countries in the world with coastlines were together responsible for about eight million tons. That is about as much as a truckload of waste being tipped into the ocean every minute of the year. Unless there are improvements, this will be two truckloads per minute by 2030. By 2050, it will be four truckloads a minute, and by weight, the seas will contain more plastic than fish.

ACCUMULATION AND CONCENTRATION



↑ *Tons of plastic reach the world's oceans annually via rivers—much more from some countries than from others.*

↑ *An incredible amount of litter accumulates along the high-water mark on Cuttings Beach south of Durban, South Africa. It is a regular occurrence following heavy rainfall.*

The contributions of each country to plastic soup vary greatly, determined primarily by population size and the presence or absense of a waste disposal infrastructure. The figure of eight million tons does not take into account what ended up in the oceans in the years before 2010, or the contributions that shipping and fishing make every year to the plastic soup. On average, about 80 percent of the plastic comes from the land and about 20 from maritime sources. In other words, the total amount of plastic added in 2010, including from maritime sources, was ten million tons rather than eight million. All that plastic does not degrade naturally and will remain in the environment.

Cleaning up beaches and coastlines does help reduce the amount of plastic soup. Everything that washes up and is cleared away has after all been removed from the environment. The amount of plastic in the world's seas is accumulating nevertheless: more is flowing in than is being cleared.

Although a proportion of the plastic is carried by the major ocean currents to the centers of the five subtropical gyres, the heaviest concentrations are found elsewhere. Specifically, they are found in the coastal waters off densely populated areas such as the many cities in Southeast Asia and elsewhere that are home to more than one million people. The beaches near Durban in South Africa, for example, are chock-full of plastic after every storm.

Inland seas are a separate problem. The concentrations in the Mediterranean are increasing, because that particular sea only has a limited connection to the Atlantic. What goes in, stays there. The Red Sea and the Black Sea are among the most polluted in the world for the same reason.

Countries that are located near the ocean currents are exporting their plastic, as it were. After a voyage lasting between two and five years, plastic from the United Kingdom ends up in the uninhabited Arctic zones. Even the most remote places cannot get away from the increasing levels of pollution from plastic.

About 3 percent of the plastic produced every year in the world ends up in the sea. Worldwide production in 2014 was 311 million tons. Taking into account the way that large pieces are broken up, a group of scientists calculated that the total number of microplastic particles on the surface of the oceans in that year was somewhere between 15 and 51 trillion. Altogether, these microplastics would weigh somewhere between 93,000 and 236,000 tons. That is, however, only a tiny fraction of the roughly ten million tons that were reckoned to have ended up in the sea in 2010 alone. Their conclusion was that there is, in fact, a lot less plastic to be found than might be expected. As of the time of writing, nobody has really been able to explain this mystery properly.

THE MYSTERY OF THE DISAPPEARING PLASTIC

← *Not much is yet known about the quantities of plastic that are suspended in the water. This photo was taken in 2011 in Roatan, Belize.*

A great deal of knowledge has been acquired about plastic soup by analysing the contents of dragnets. Fine-meshed nets extract plastic particles from the surface waters that are larger than 0.3 mm. The number of pieces is counted. It is then possible to calculate how much is floating around, for example per square kilometer. The method has its limitations. There may be a fraction that is already fragmented into pieces smaller than 0.3 mm that then slip through the mesh. Even less is known about the amounts of plastic that are floating lower in the water or lying on the seabed.

Researches are nevertheless getting more insights into the complex mechanisms that come into play regarding plastic soup. It is suspected that a lot of the floating plastic does sink over the course of time. Birds also transport the plastic, picking small pieces of plastic up out of the water and flying thousands of kilometers. In the meantime, that plastic gets ground down in their stomachs into little pieces that they can excrete. This is the case for the northern fulmar, for instance. In northwestern Europe, these birds have an average of 35 pieces of plastic in their bodies. There are about two million of them in the North Sea area, grinding up and dispersing no less than 630 million pieces each year, representing a total of six tons. A proportion of that will be deposited on land, far from the sea. So, these birds are making the seas a little cleaner while polluting the land.

Marine animals that swallow the plastic can also help clear up the mystery. Calculations based on an analysis of the stomach contents of fish that live at depths of two hundred to a thousand meters suggest that they ingest between 12,000 and 24,000 tons of plastic a year. All those animals with plastics in their bodies together represent a colossal and invisible reservoir of plastic waste.

↓ *Kamilo Beach in Hawaii, 2008. Plastic fragments from all over the world don't merely accumulate here; as time passes, they also keep getting smaller.*

Plastic does not break down chemically, but it does in a physical sense, under the influences of sunlight, oxygen, and wave action. To start with, there are the kind of plastic objects that everyone is familiar with. Then you get the larger, easily visible pieces, which are broken down in turn into even smaller fragments. And those become microplastics, sometimes invisible to the naked eye. The process can then continue further, with the microplastics becoming nanoplastics. This fragmentation does not reduce the overall weight of plastic soup, it only affects its composition. The amount of microplastics and nanoplastics have risen exponentially in a relatively short time. It may mean that it is already better to speak of a plastic broth rather than a plastic soup.

ONGOING FRAGMENTATION

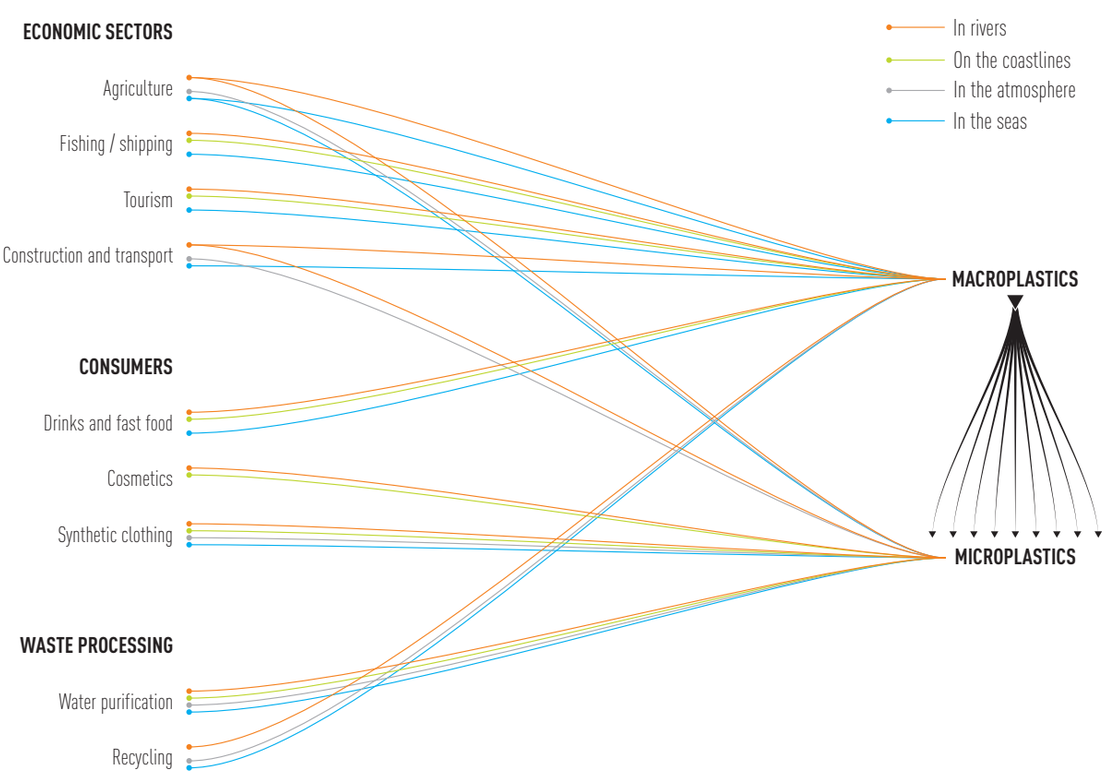
The process of continuous fragmentation means that the world is confronted with two insoluble problems. There is, after all, no possible way of getting all the fragments out of the water. Anyone attempting to extract the particles would also be catching living organisms, as the two are so closely intertwined. Even if it were technically possible, the costs would be exorbitantly high.

And then there is the second problem: the smaller the particles, the greater the chance that animal species will swallow them. Nanoparticles can spread through the bodies of animals and even reach organs. For that reason, it is suspected that they are particularly harmful.

The fragmentation process often starts before the plastic has even reached the sea. A lot of what the rivers disgorge is already no longer whole or recognizable. Researchers agree that the key source of microplastics is the ongoing fragmentation and that larger pieces such as bottles and plastic packaging gradually break down into smaller and smaller pieces as a result of exposure to ultraviolet radiation, oxygen, and friction. Fragmentation will proceed most quickly on rocky coastlines, where there are big waves and a lot of sunlight. The plastic becomes brittle, breaks, and is pulverized. On the other hand, plastic that is suspended in the water or that has, for instance, been encapsulated in ice will degrade little, if at all.

Animals contribute to fragmentation as well: gammarids can shred a single plastic bag into 1.75 million pieces. The fragmentation process is skipped in cases where microplastics contribute directly to plastic soup, and that happens on a large scale. Microplastics are sometimes produced to be used in that form, as particulates that are added to care products. They are then rinsed off and carried away in the wastewater, with a proportion inevitably ending up in the sea. In other cases, it is about wear and tear. Synthetic material in the rubber of car tires, for example, gets into the air, road shoulders, and groundwater as fine particulates. Plastic clothing wears away while being washed and dried in machines. A substantial proportion of these microfibers end up in the open water via the sewers.

→ *Where do macroplastics and microplastics come from, and where do they end up? Countless sources all contribute to plastic soup.*



→ *In the summer of 2012, millions of pellets washed up on Hong Kong beaches like this beach at Sam Pak Wan, Lantau Island.*

MERMAIDS' TEARS

Hong Kong was hit by Typhoon Vicente on July 23, 2012. A cargo ship was driven toward the coast, and seven containers went overboard. Six of them were filled with polypropylene pellets. Each container held a thousand 25-kilogram sacks. The sacks spread out and ripped open; millions of pellets washed up on the coasts near Hong Kong. Thousands of volunteers reported to help with the cleanup. Industrial vacuum cleaners had to be used and the sand was sieved. It was estimated, in the end, that 70 percent of the plastic was removed.

Pellets are oval-shaped grains between 2.5 and 5 mm in size. They are made from petroleum or from plastic that has been collected, and they come in various colors, although the majority are white or silvery. Pellets are used by companies as raw materials for making a huge variety of plastic products. Transportation takes place throughout the world, involving trucks, trains or container ships. Things regularly go wrong in the transfers from one mode of transport to another, for example when sacks tear. The pellets then often end up in the environment.

Measures taken by the industry so far have reduced the scale of the leakages, but have not been able to prevent them. In Europe, no more than 0.1 percent of all pellets are thought to end up in the environment. That doesn't sound like much, but it comes to nearly 50,000 tons. Losses of pellets therefore make a proportionally high contribution to contamination by microplastics in inland waters and seas. Plastic pellets are one of the most common ingredients of plastic soup. You can find them everywhere, particularly on river banks and coastlines near plastics factories.

Most of the pellets are polyethylene or polypropylene, which are lightweight and float on water. Because they can float, these grains cover great distances and wash up all over the place. Pellets are among the microplastics that are most often found on beaches, sometimes in extremely high concentrations. Cleaning them up is almost impossible, particularly if they are widely scattered. Examining the stomach contents of fish and birds shows that animals also swallow them.

Pellets are also sometimes called mermaid's tears, after the mythical sea creature. In old Chinese fairy tales, their tears turned into pearls. Pellets, however, are tears of silent sorrow. Each individual pellet in the environment is the result of a careless action, and of a worldwide production system that is unable to stop the leaks.

← *Industrial pellets in various colors can be found on beaches and shorelines throughout the world. Cleaning them up is particularly difficult because they are so small.*

MICROPLASTICS IN COSMETICS

Plastic soup is everywhere, including in inland waters, whether fresh or salt. A 2013 study of microplastics in the Great Lakes found an average of 43,000 plastic particles per square kilometer. Many of them turned out to have the same color, shape, and size as what are referred to as *microbeads* in care products. It became abundantly clear that these particles were not being captured by wastewater treatment plants. This topic ended up high on the political agenda in the United States. After a number of states had introduced legislation, a federal law followed that banned microbeads in 2015.

The industry had patented additions of plastics to care products as early as the 1960s. Plastic particles are cheaper and much softer on the skin than natural ingredients for scrubs, such as salt crystals or ground nuts. This allowed manufacturers to sell more scrubs, because the products could now be used daily without harming the skin. The microplastics were also designed in such a way that they would easily flush down the drain. Over the course of time, other types of microplastics would be added to many more products, including even smaller microplastics that have other functions than mere scrubbing—toothpaste, lipstick, shampoo and many other cosmetics, for example.

In the United Kingdom in 2015, 1.1 million women were using scrub products daily that contained microplastics; the quantities were estimated at about 5 ml each time. Investigation showed that a single portion contained between 4,600 and 94,500 microplastic particles. Because of their extremely small size, it is estimated that 75 percent of microplastics get through the wastewater treatment plants in the UK, ending up in the surface waters and finally in the sea. There are 64 million people living in the United Kingdom, and together they are responsible for annual pollution of 16 to 86 tons of microplastics from care products.

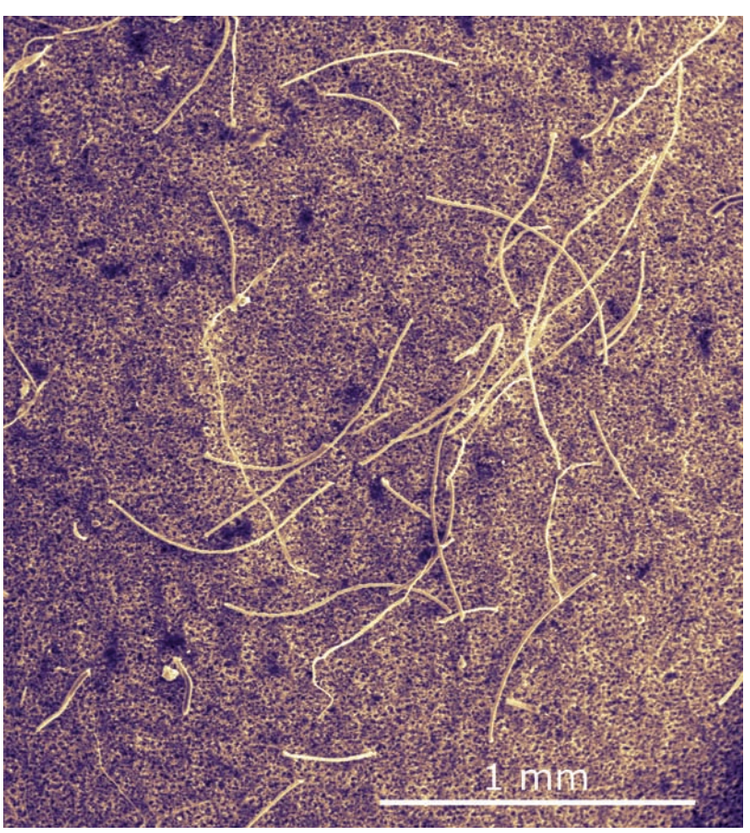
Cosmetics that are put on sale have to comply with strict requirements intended above all to make sure that they are safe for consumer use. The damage microplastics ultimately inflict on the environment is not covered by the rules. People wash and put on make-up daily. But consumers do not make the effort to study the complex labelling and are often not aware of how they are contributing to pollution and plastic soup. Cosmetics can be made without microplastics. There are plenty of alternatives, but not for the price of products that are full of microplastics—sometimes as much as 10 percent by volume.

↑ *A microplastic fragment attached to duckweed. Microplastics can have negative effects on floating aquatic plants like duckweed and block root growth.*

The penny dropped in 2011. A British researcher named Mark Anthony Browne observed that the proportions of polyester and acrylic microfibers in sediments were pretty much the same as in the synthetic clothing that is sold. That relationship held for areas where water from treatment plants flowed into the sea. The link was quickly made: the fibers come from washing synthetic materials in washing machines. The wastewater may indeed have been treated, but these microfibers are so small that they cannot be removed from it. Subsequent research showed that millions of fibers are involved in each wash cycle. Everyone with a washing machine is contributing to plastic soup.

MICROFIBERS FROM WASHING MACHINES

The washing machine was a revolutionary invention that allowed people to clean their clothes without much effort. Time savings on that scale were unheard of and helped women's emancipation in particular. The rise of the washing machine half a century ago coincided generally with the introduction of synthetic fabrics—two icons of progress. But the combination of the two was anything but favorable for the environment.



↓ *Plastic microfibers released during simulated washing of synthetic fabrics. Millions of microfibers can be released in every wash, many of which reach inland waters and oceans.*

While being washed and dried in a machine, synthetic clothing releases fibers in numbers that are mind-boggling. In a single wash of synthetic clothing (weighing five kilograms) the European Mermaids Life+ project counted between 600,000 and 17,700,000 fibers in 2017, equivalent to 0.43 to 1.27 grams. Washing at lower temperatures, using liquid washing detergents, and shorter wash durations all lead to considerably fewer fibers being released. Not that any of this ultimately offers a solution for tackling plastic soup: there is still wear and tear on clothing, and sooner or later, microfibers will be released that are carried away in the wastewater.

Fleece is one of the biggest villains. This fabric is made from used PET bottles. The public think they are being very responsible when they recycle PET; after all, the substance is being used again and fleece jackets are both comfortable and affordable. But fleece that is washed or dried in a machine releases extremely large numbers of microfibers. Water treatment plants are not designed to filter these fibers out of the water, so a large proportion of them end up in the surface waters and then in the sea.

Incomes are on the rise in many countries and buying a washing machine is high on many people's list of priorities. The growing world population has now become dependent on plastic clothes at prices that are extremely affordable, given the quality. Plastic microfibers that end up in inland waters and seas can never be extracted and will never decay.

4

RIP: REST IN PLASTIC

← *Sunfish trapped as by-catch near Carloforte, Sardinia, Italy. In the same way, dolphins, sharks, and turtles are caught through traditional Bluefin tuna fishing called* la mattanza.

→ *Over three thousand pieces of plastic in a single turtle. The ingestion of plastics may have all kinds of negative effects, like internal physical injury and inflammation of the intestines.*

ON THE MENU

The more modern plastic soup increases in scale, the greater the number of animal species that will no longer be able to avoid plastic on the menu—particularly when that plastic is being broken down into smaller and smaller pieces. Some fish and birds snap up plastic mistakenly believing that it is edible, because the plastic particles look very much like fish eggs, for example. Other animals filter their food out of seawater and ingest plastics that way. And others eat prey that has already swallowed plastic. Plastic affects millions of animals, but it is not yet clear to what extent the continued existence of individual animal species is threatened.

In March 2012, a dead male sperm whale was found washed up on the beach of Castell de Ferro in Spain. Of the various pieces of plastic in the cadaver, 26 could be directly related to agricultural activities in the coastal region of Granada. These included plastic flowerpots and 30 m² of plastic sheeting. Death was probably by starvation, after an accumulation of plastic created a hole in the whale's stomach.

All marine turtle species ingest plastic. They see transparent plastic bags as tasty jellyfish and so go after them. One young green turtle washed up in July 2010, in a much weakened state, near Florianópolis on the Brazilian coast, and it died a few hours later. There were no bags in this specimen, but it did have no less than 3,267 pieces of plastic in its intestines and another 308 in its stomach. And this was only counting pieces of plastic larger than 5 mm. All of this plastic was blocking its digestive tract. Younger marine turtles tend to stay closer to the coast, and those are the areas that are particularly badly polluted with plastic.

The total number of animal species known to be affected by plastic in 2017 was 1220. One-third of those, largely seabirds and fish, end up with plastic inside their bodies. The number is adjusted upward every year simply because the ingestion of plastic has not been studied in all species yet. The effects are legion, ranging from poor condition and internal injuries to starvation and dehydration. Isolated and weakened animals are easy targets for predators.

In France, polystyrene microplastics were fed to oysters at concentrations consistent with their natural living environment. The eggs and sperm of these oysters were poorer in quality and they produced 41 percent fewer larvae than specimens that were not exposed to plastic. That study was among the first to yield evidence that the future of entire species could also be at risk.

Sea lions, dolphins, and seals are regularly the victims of their own curiosity as they swim up to plastic objects and play with them. There are iconic photographs of these marine mammals with nets, rope, or plastic packaging strips around their necks. When they get caught tight, there is no escaping. If the animal is still growing, the plastic cuts more and more deeply into the flesh, resulting in a slow death. A dolphin that died of starvation in 2014 in Cork, Ireland had the plastic ring of a six-pack of beer around its snout. The animal died in front of the eyes of onlookers and its tragic death made the news. Usually, however, the animal suffering that these entanglements cause goes largely unseen and unreported.

ENTANGLEMENT

← *Of all seals, juveniles risk getting entangled most, because they play with abandoned fishing nets and other items in the water and on the beach.*

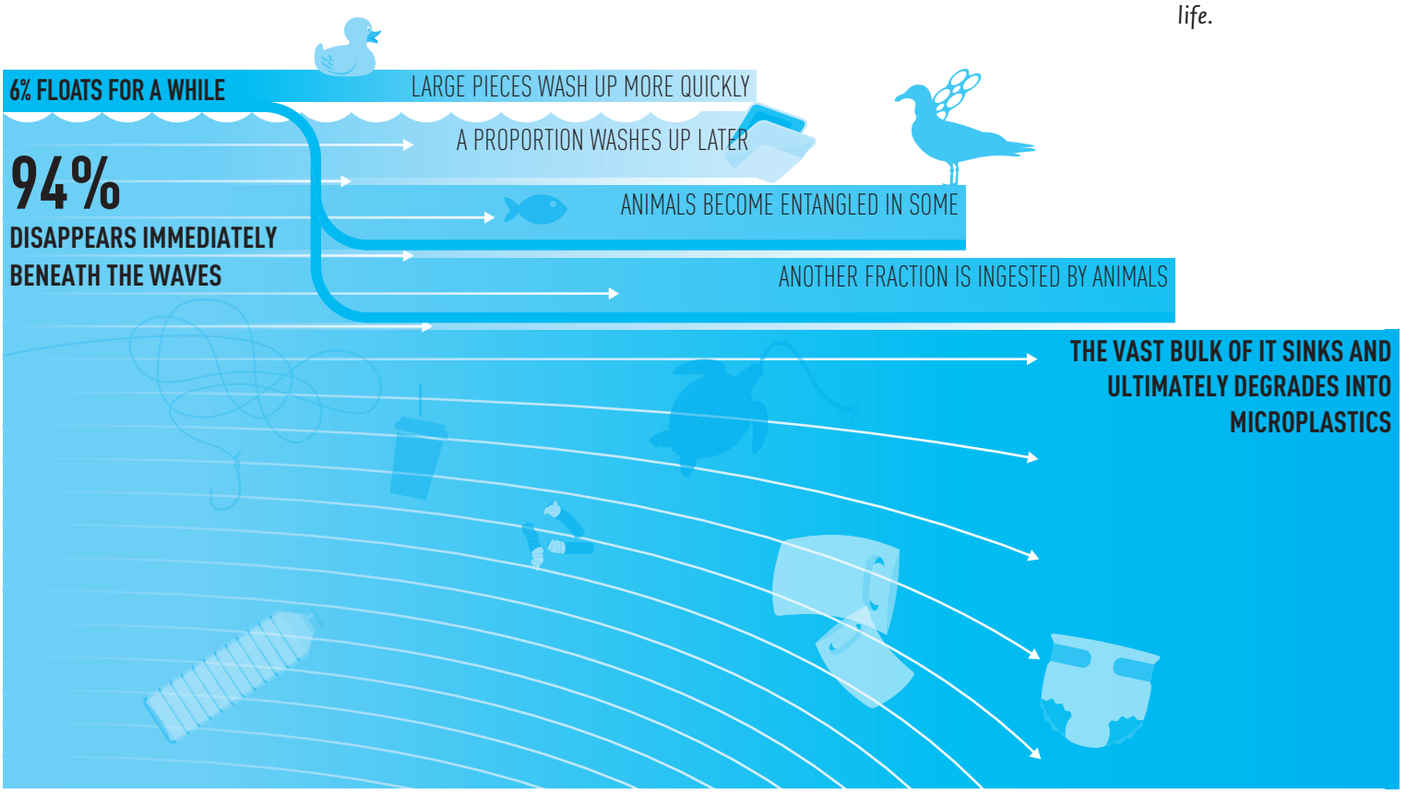
The consequences of becoming entangled can be horrible, including reduced mobility, starvation, inflammation, drowning, growths, amputation, or suffocation. Animals that are less able to find food, and therefore become weakened, are easy victims for predators.

Getting caught up like this is a bigger threat for whales than is whaling. The International Whaling Commission estimates that 308,000 whales and dolphins fall victim to entanglement every year. Some drown while others keep swimming but with a severe burden. The sharp threads of the netting cut into the flesh so that some whales lose a fin or a tail fluke.

The island of Grassholm, off the southwestern coast of Wales, is home to a colony of gannets, a large seabird that only comes to land to breed. Their nests used to be made of feathers, seaweed, and plant material. But on Grassholm, most of the nests are now largely made of plastic. The birds use nylon fishing lines, pieces of net, ropes, balloons, and packaging materials—in other words, whatever is plentiful in the environment. After the breeding season, a group of volunteers goes to the island looking for birds that have become trapped. They manage to free about fifty birds every year.

Off the west coast of the United States, between California and Canada, it is estimated that four hundred thousand traps or pots with bait are put out every year, fishing for the crabs and lobsters that live on the seafloor. The traps are attached to buoys by long lines so that the fishermen can then bring them back on board. It is, however, estimated that 10 percent of the traps are lost, for example as the result of storms. There are now millions of such traps wandering about the ocean floor, and animals can, of course, still get caught in them. Even whales can fall victim to this kind of fishing if they get stuck in the lines. That happened to at least 61 whales off the west coast of the United States in 2015, nearly twice as many as in the year before.

↓ *Most plastic in the seas sinks and becomes fragmented into smaller and smaller pieces. This disturbs aquatic life.*



UNBALANCED ECOSYSTEMS

It has taken Earth 3.5 billion years to produce about 9 million species—not just fish, amphibians, reptiles, insects, birds, and mammals, but also trees, plants, fungi, and bacteria. All these species have developed in mutual relationships thanks to adaptations to their continually changing surroundings. When the environment that a particular species lives in changes, there are three possibilities: the species can migrate to more favorable places, it can adapt, or it will die out. Plastic soup is changing animals' living environment. Migration isn't an option, because there's no escaping it. Evolutionary adaptations, such as learning to avoid plastic or finding ways to use it as food, are thought to be unlikely.

The ring-shaped Majuro Atoll of the Marshall Islands in the Pacific is badly polluted with household waste. That waste is blocking the sunlight underwater, having a suffocating effect on the coral; it is one reason why the coral is dying off. Scientists have found that more coral is able to grow in places where waste pollution is lighter. Coral reefs are the most species-rich ecosystems in the oceans. They are bustling with life, but exceptionally vulnerable. When there is a storm, coral easily gets torn to pieces by discarded nets and ropes.

Numerous organisms, both plants and animals, live on the seabed. When a plastic bag sinks down, it covers up a small piece of the seafloor. Oxygen can no longer penetrate that spot, and light and nutrients are blocked off. The microorganisms under the bag die, and these seafloor dwellers form the basis of the marine food chain. Less food is then available for animals that are higher up the food chain, such as worms, crustaceans, and fish. Research has shown that a single plastic bag closing off a patch of seabed can have a disastrous effect on the mini-ecosystem beneath it within just a few weeks. Waters with little flow and a lot of waste plastic are particularly vulnerable.

Ecosystems can also change because some species actually benefit from the plastic. The sea skater is a type of insect that normally lays its eggs on floating bird feathers or pieces of driftwood, but floating microplastics are an ideal alternative that are found in abundance everywhere in the seas. The insect eggs are found on about a quarter of pellets that are washed up on beaches. Today, sea skater numbers are increasing. The vast distances covered by microplastics are also making it easy for the species to spread.

The oceans have more to deal with than just plastic soup. Overconsumption, overfishing, warming, by-catches, acidification—these effects are all occurring at once. Together they are creating disruptions in marine ecosystems and an all-around depletion of biodiversity.

↓ *Billions of plastic items are entangled in coral reefs; research shows that coral that ensnares plastic has a twenty times greater chance of becoming diseased.*

Additives give plastics specific desired properties. Yet, over time, these added chemicals are slowly released from the plastics. This occurs in minimal quantities, both during daily use and when the plastic degrades into smaller and smaller pieces in the environment. Overall, thousands of different chemicals are used, largely as stabilizers, softeners, fire retardants, and dyes. Little is known about the long-term, cumulative effects of these small doses of chemicals. But evidence of damage to health is accumulating.

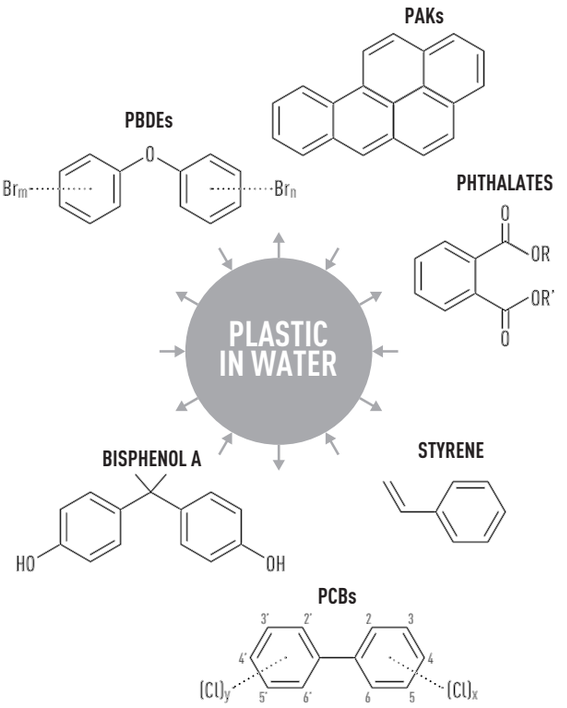
BPA, SOFTENERS, AND FIRE RETARDANTS

Bisphenol A (BPA) is used in the production of various types of plastic, but mostly for the tough and transparent plastic called polycarbonate. BPA can be found in all kinds of products, from food packaging to medical devices, paint, toys, and receipts. This chemical acts like a hormone and can now be detected in the blood and urine of humans. Excessive exposure to this substance is harmful to fertility, as well as the unborn child's immune system. People ingest BPA primarily through their food and drink. It can leach out of packaging material, bottles, or from coatings on the insides of cans and drink cartons. In terms of volume, this compound is one of the world's most widely produced chemicals. It can get into the body not only through the mouth, but also by skin contact and by inhalation.

Softeners (also called plasticizers) are added to make plastics such as polyvinyl chloride (PVC) more elastic. Over the course of time, a proportion of these plasticizers leaches out and the products lose that elasticity. In the environment, the softeners that are released—called phthalates—are not broken down chemically. They can accumulate in small organisms and end up in the food chain. Softeners are also likely harmful to health. Just like BPA, they are thought to disrupt the hormonal balance in humans and animals and have carcinogenic properties.

Plastics are made from petroleum, which burns well. To prevent plastics from catching fire too easily, fire retardants (flame retardants) are added. These additives are used in all kinds of electronics and insulation materials, for instance. Fire retardants are toxic and not easily chemically degradable. Incineration of plastic waste in the open produces toxic substances such as dioxins.

Because everyone is continually in contact with plastics, the health risks from all these additives are not easy to quantify. Ideally, two groups of test subjects would be compared, one in contact with plastics and the other entirely free of them. The latter group is virtually impossible to obtain, however. Today, no humans live in entirely plastic-free surroundings.



→ *Plastics leach chemical additives like bisphenol A into the surrounding environment. At the same time, they absorb organic toxins from the surroundings.*

When plastics end up in the environment, they also bind to persistent organic toxins such as PCBs and dioxins. Many of these compounds are very difficult to break down and can accumulate in plastics at concentrations that can be between ten thousand and one million times greater than the surrounding water. These toxic substances then build up in the fats and tissues of marine animals and in the food chain. The role of plastics in this bioaccumulation is limited, however. The principal source of the persistent toxins in animals' bodies is their normal food.

TOXINS IN THE FOOD CHAIN

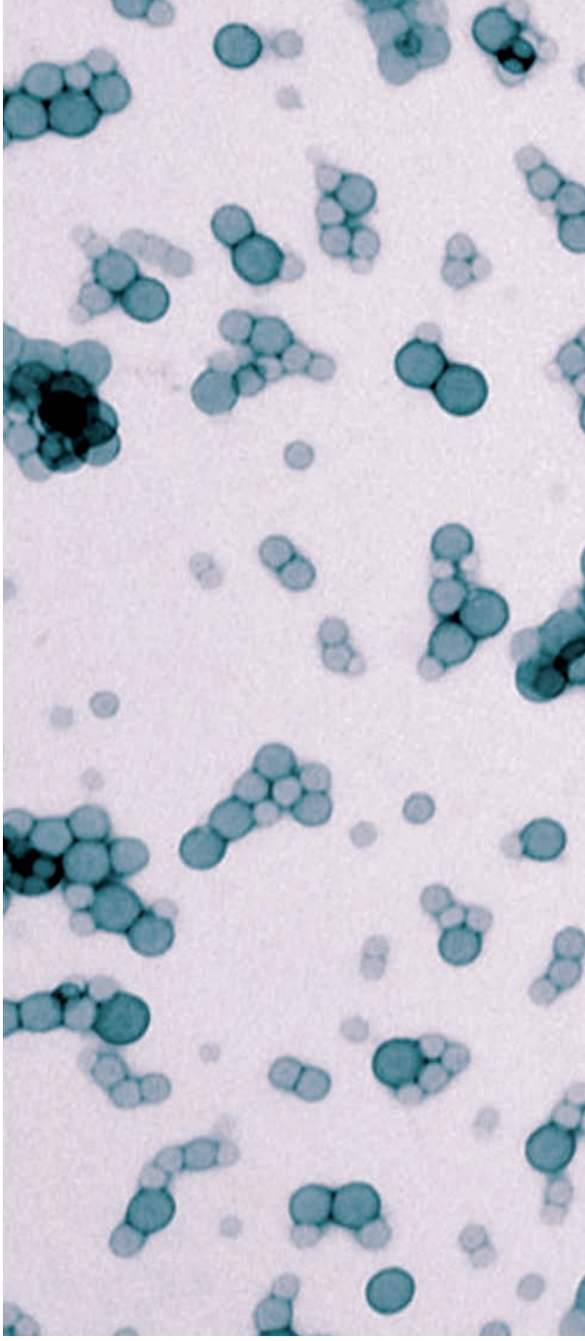
Although the use of persistent organic toxins was banned by the Stockholm Treaty of 2004, they are still widely found in the environment as a consequence of their use for many years.

Since 2005, International Pellet Watch in Tokyo has been asking volunteers throughout the world to send them pellets that have been found on beaches. These microplastics are examined for the presence of persistent organic toxins, which are indeed found on all the pellets that they receive. It has been shown that the concentrations of toxins on pellets from the coasts of industrialized areas are significantly higher than elsewhere, and also that the pellets are capable of transporting the toxins over long distances, to the remotest areas.

Little is yet known about the role of plastic in the bioaccumulation of these toxins in the food chain. It has not been demonstrated that the toxins remain bound to the plastics in the gastrointestinal tract. On the other hand, toxins that are already present in the body could bind to the plastic that is then excreted. The mechanisms involved are extremely complex. Additionally, the toxins will get into the food chain in other ways; plastic will never be the only carrier.

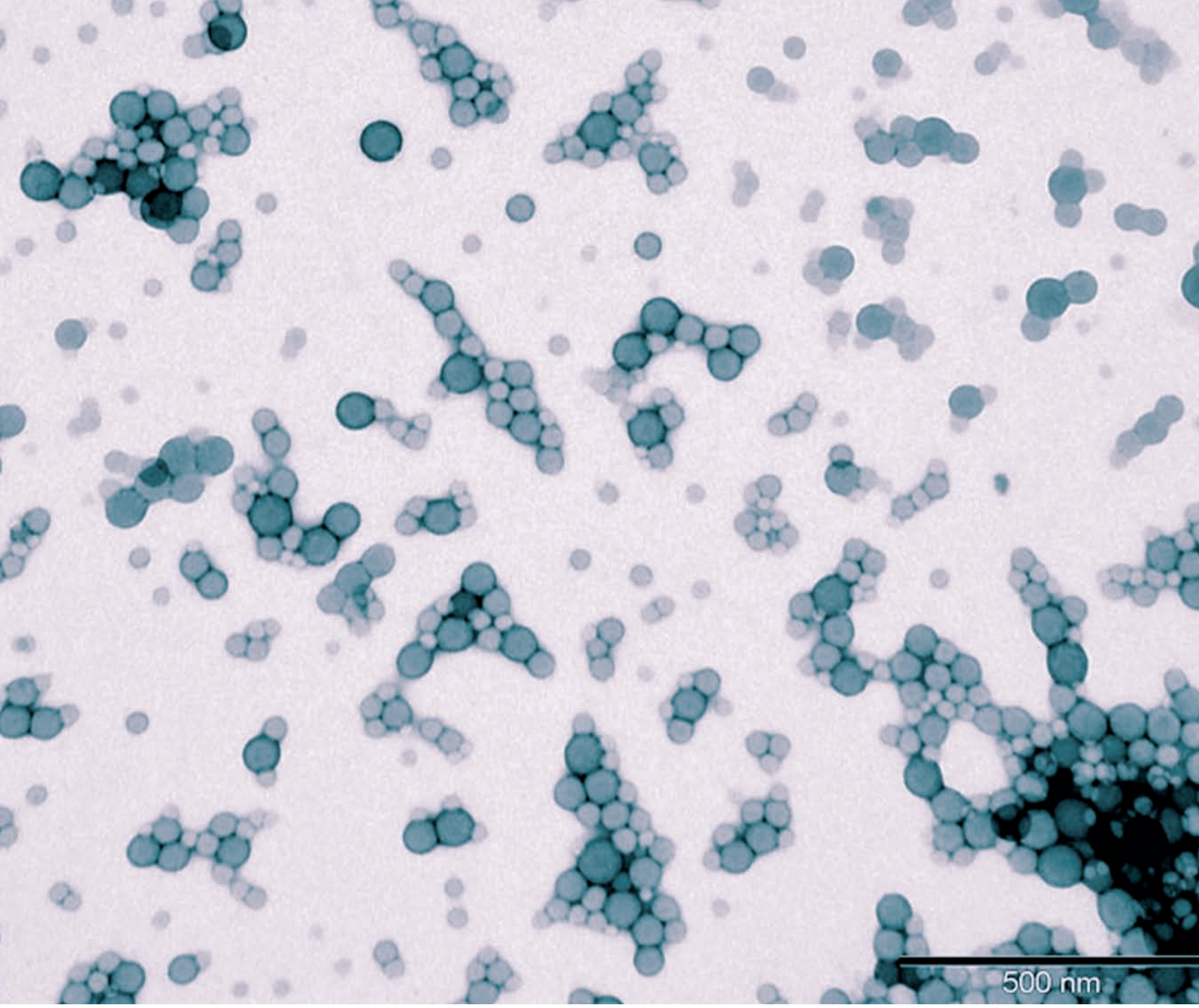
Japanese researchers found the flame retardant polybromodiphenyl ether in the tissues of a number of seabirds. This substance could not have come from their natural prey, but could originate with plastic that has been swallowed. Further research showed that oils in the birds' stomachs and from fish could be enhancing the leaching of additives from plastics inside the bodies of the birds.

Data have not yet concluded to what extent toxins are absorbed into the tissues of fish and then end up inside the animals and humans who eat those fish. The gastrointestinal tracts of fish that humans consume are normally removed, taking any poisonous microplastics with them. People do ingest these microplastics when eating shellfish, however, where the gastrointestinal tract is not removed first.



Although no one has seen them in the sea, it is clear that they are present and their numbers are growing hugely. Nanoplastics are so small that there is as yet no suitable method for observing and measuring them in the environment. The smaller the particles, the greater the chance that organisms will ingest them. Nanoplastics are so tiny that they can permeate anywhere in the body: into tissues, organs, the brain, and individual cells. These particles, which are proportionally far more toxic than larger plastics, can trigger local inflammation responses and all kinds of physiological effects. Nanoplastics are the least well-understood component of plastic soup, but they have the potential to be the most dangerous.

THREAT OF NANOPLASTICS



↑ *Nanoplastics might disrupt entire ocean ecosystems by changing the natural behavior of marine organisms.*

Nanoplastics are particles smaller than 0.0001 mm, created by the ongoing wear and tear on microplastics. French researchers have observed microplastics being broken down into nanoplastics by the action of sunlight. But nanoparticles can also be produced directly: industry is embracing these minuscule particulates because of their new and revolutionary applications.

Because nanoplastics are ultra-small, they have a massive surface area in comparison to their volume. This means that the same amount by weight is able to attract and bind far more toxins than larger pieces of plastics. For that reason, there are indications that nanoplastics are capable of binding one hundred to one thousand times more toxins than microplastics. Nanoplastics that are ingested remain in the gastrointestinal tract for at least a couple of hours. Researchers fear that toxins will migrate from the plastic into the organism in that time. Nanoplastics, including larger particles, can penetrate tissues, organs, and cells. It is therefore feared that those higher concentrations of toxins will be able to migrate deep inside the body.

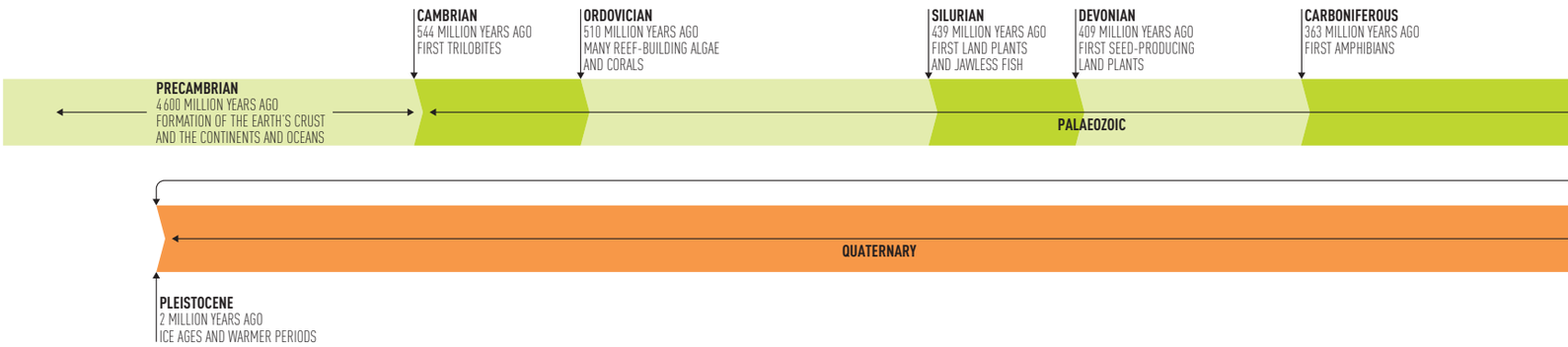
There is no country in the world where 'nanoplastics' are a recognized classification of chemicals, but it is known that comparable substances have an effect on the immune system, depending on the amounts of plastic that are able to reach that immune system.

Algae and zooplankton that are exposed to high concentrations of nanoplastics in laboratory conditions reproduce more slowly than normal and remain small. Mussels that are exposed to high concentrations are more lethargic and grow more slowly. Nanoplastics are able to move up through the food chain. The extent to which these effects are already occurring in nature is unclear. The likelihood of this will increase as concentrations of nanoplastics rise; it is merely a question of time.

The Food and Agriculture Organization of the United Nations—the FAO—does not exclude the possibility of microplastics and nanoplastics threatening our food safety in the future.

5

A PLANET FULL OF PLASTIC



Things have been moving quickly over the past decade: humans are producing and polluting like never before. We are affecting nature and the climate more and more, in all kinds of ways. Earth is warming up, forests are being razed, and sea levels are rising as the polar ice caps melt. A quarter of all the carbon dioxide (CO_2) that is emitted ends up in the oceans, changing their acidity. That acidification is making coral dissolve, among other effects.

PLASTIGLOMERATE

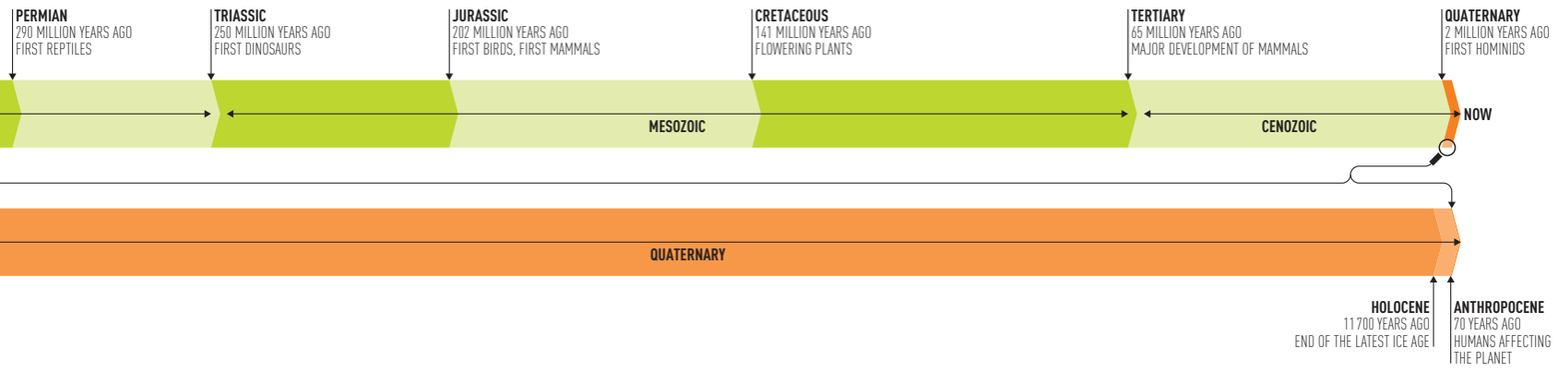
We are living in the Holocene, the era that began twelve thousand years ago when the climate became warmer and more stable. That was beneficial for *Homo sapiens*, a species whose numbers gradually increased, finally managing to colonize even the remotest parts of the planet.

At an international congress in August 2016, geologists proposed officially saying farewell to the Holocene. We are now living in the Anthropocene, the era dominated by humans. The geological timescale is subdivided into periods and intervals on the basis of rock layers. Earth is 4.6 billion years old, but human activities have begun to have consequences for the whole planet only very recently.

Plastic is anthropogenic, a material made by humans that does not occur in nature. This new material is now present everywhere and there are some locations where it is accumulating. At Kamilo Beach in Hawaii, geologists discovered a type of rock in 2014 that has been given the scientific name *plastiglomerate*, a combination of *plastic* and *conglom - erate*, the geological term for sediments that have become glued together. Melting plastic gets mixed in with other materials such as coral, lava, or sand and creates a new type of rock that basically lasts forever. Later generations will have no difficulty dating this rock as having arisen in our age of plastic pollution. Plastic will be a typifying characteristic for the geological strata that are currently forming.

Like geologists, archaeologists have plenty to say about plastic. When a new metro line was being laid through the historic center of Amsterdam at the start of the twenty-first century, seven hundred thousand items were found, photographed, and documented. That included a lot of objects and fragments made of plastic. There was a huge range of items, from a broken toothbrush from the 1950s, to a toy from the 1960s, and a modern cigarette lighter. Together, they hold up a mirror to our throw-away society. If that metro line was being dug thousands or millions of years later, rather than now, then these objects would probably be found as fossils in petrified sediments.

← *Ongoing increases in solid plastic waste are leading to ever bigger landfills in proximity to big cities all over the world.*



↑ *On geological timescales, the Anthropocene period is insignificant. Earth is 4.6 billion years old, plastic little more than half a century.*

→ *Plastiglomerate is now officially recognized as a new kind of rock, always with melted plastic as one of its components. Kamilo Beach, Hawaii.*

The biosphere, the zone in which all the organisms on Earth live, is a thin layer around the planet. Now there is also the plastisphere, a thin shell of microbes living on every piece of floating plastic. All the waste plastic floating around in the sea amount to a new human-generated ecosystem. A film of microbial life develops around even the tiniest microplastics, turning plastic fragments into tiny hotspots of nutrients. And given that microplastics remain in the environment for a long time, they can also act as a transport mechanism for spreading bacteria, including potential pathogens.

PLASTISPHERE

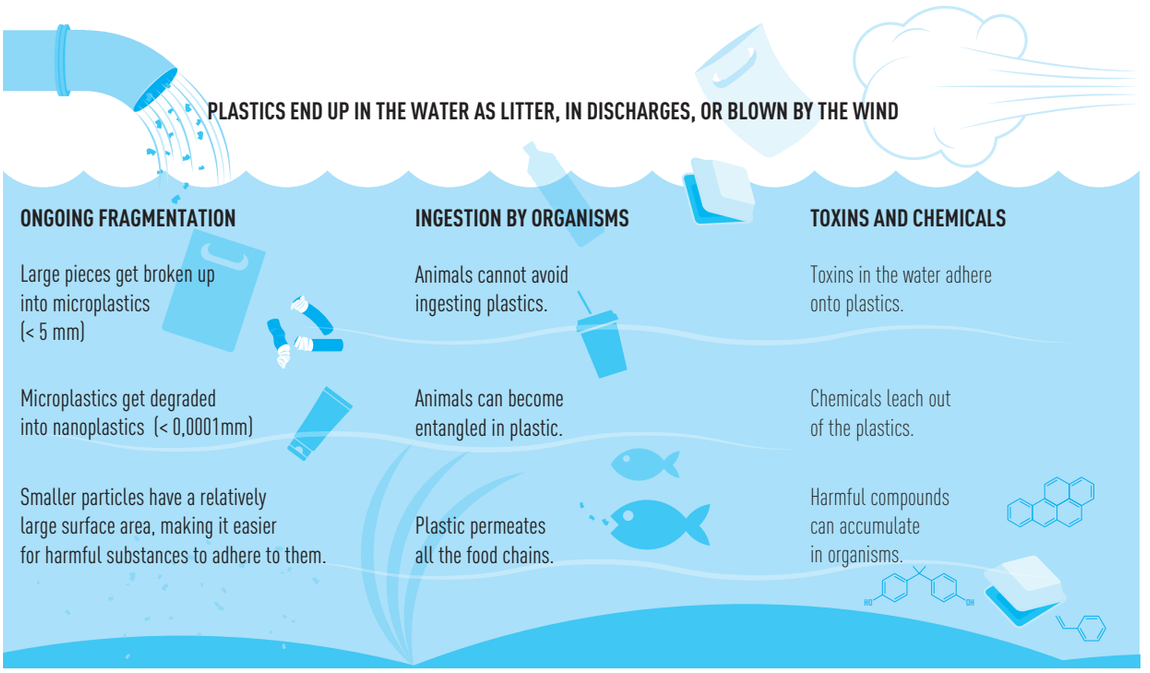
Microorganisms can float around in the ocean or stick onto floating objects. Those objects can be natural in origin, such as a piece of driftwood, or artificial, such as a piece of man-made plastic. Microbes thrive on floating plastic, and they live there in much greater densities than in the surrounding water. The biodiversity of microbes on a single piece of microplastic can be amazingly high, with more than a thousand different species of organisms present. The plastisphere is dynamic and bustling with life.

Not much is yet known about the plastisphere, as it has only recently been studied in detail. The composition of the communities is different in each ocean, and changes with the seasons. There are also differences depending on the type of plastic, and how long the object has been floating in the water. But it is not clear how the microorganisms colonize the fragment's surface; nor is it known how the plastisphere might affect marine ecosystems. Do the microbes assist the degradation of the plastic? When microbes hitch a ride on plastic and are transported from one ecosystem to another, do they displace the species already living there? Does the number of microbes increase as the plastic breaks up into smaller pieces? And how will zooplankton and other small organisms respond to the influx of these bacteria?

The plastisphere accommodates one unusual and widely dispersed group of bacteria, the *Vibrio* genus. Some *Vibrio* species can cause diseases in animals and humans after contact. American researchers first reported *Vibrio* on marine plastic in the Atlantic, and this was confirmed by German researchers who analyzed 39 samples of microplastics from the North Sea and 5 from the Baltic Sea. Almost all the samples showed signs of weathering and contained several *Vibrio* species, including some potential pathogens.

Plastic soup is putting pressure on marine ecosystems, while at the same time encouraging a new ecosystem of microorganisms. Nobody can predict exactly what the consequences of this will be.

→ *This scanning electron microscope image of the surface of a microplastic fragment from the Atlantic Ocean shows diatoms and filamentous microbes.*



→ *What happens to all that plastic in the water? The processes take place not only in the oceans but also in inland waters.*

Microplastics are also found in the air. These originate from degraded plastic litter, synthetic clothing, and carpets. The sludge from wastewater treatment plants is also a possible source, as it is spread on the land as a fertilizer. The microplastics in the sludge blow away when the weather is windy.

City dwellers may inhale more microplastics than they ingest by eating seafood. And while plastic particles in the air are blown along by the wind or slowly twirl and tumble down to the ground, something similar is going on underwater. Microplastics there are continually tumbling down like snow.

PRECIPITATION

The precipitation of microfibers was measured for a year in Paris at two locations: in the city itself and in a suburb. The results of this unique study were published in 2016. The measurements ranged from 2 to 355 microfibers per square meter per day, with twice as many in the city as in the suburb. Half the microfibers were cotton or wool; 21 percent were natural polymers; 17 percent were entirely made of plastics; and 12 percent plastic mixed with other materials. Given the composition, it seems that most of the fibers came from textiles. There were fewer airborne in dry weather than when it was rainy; the raindrops apparently bring the microfibers down with them. In Paris and its suburbs overall, an area of 2500 km², a cautious calculation gives an estimate of between three and ten tons of synthetic fibers precipitating out of the air annually.

Microplastics that are inhaled may be a health hazard, releasing chemicals that penetrate into the depths of the lungs and circulating within the body.

In 2014, researchers who studied the amounts of microplastics on the ocean floors at various places throughout the world said that it is like a kind of permanent snowstorm. Some plastics sink and others float. Floating plastics become fragmented into smaller pieces and will ultimately also sink as they become heavier when microorganisms attach to them. The small pieces of plastic tumble down to the seabed like miniature snowflakes.

For the Indian Ocean, the researchers estimate the numbers of microplastics as four billion per square kilometer of the seabed. The plastic polymers found (largely fibers) correspond to the plastics used in packaging, clothing, and electronics. The research in question stated that amounts of microplastics found on the seafloor are four orders of magnitude—ten thousand times—higher than in heavily polluted surface waters.

Plastic soup also consists of quasi-natural phenomena, which in this case refers to phenomena that are not visible to the naked eye.

Microplastics are contaminating seas and inland waters. On land, they are suspected to be an even greater source of pollution. It is estimated that about 90 percent of the microplastics in the western world end up in wastewater. They come not only from households but also, for instance, from car tires as they wear away. The sewer sludge that remains after wastewater treatment contains a lot of microplastics as well. That sludge is used as fertilizer in almost all countries. Applications of the sludge mix the microplastics in with the soil. When it rains, a proportion of them rinse away and ultimately end up in the sea via the waterways. Other microplastics remain in the soil forever.

SLUDGE, SOIL, AND COMPOST

→ *Microplastics in the soil can trigger all kinds of adverse effects and could have a long-term negative effect on terrestrial ecosystems.*

The consequences of microplastics contaminating soil for plants and animals have hardly been studied at all. It is known that earthworms grow less well and die earlier if they are exposed to certain concentrations of microplastics. In addition, they spread those microplastics, taking the microplastics that they have consumed down to greater depths and then excreting them again. A second, disturbing mechanism is that organic toxins can bind to microplastics, and those toxins could then be absorbed by crops.

Plastics are used in agriculture throughout the world. Entire fields are covered with plastic to protect certain crops as they grow. Plastic is used as ground cover to prevent weeds. By no means is all of that plastic cleared away. If the plastic gets ploughed into the soil, it is mixed in and goes deeper into the ground. Any plastic litter on the fields gets ploughed as well. There are places where 1 percent of the soil consists of microplastics, an inconceivably high level.

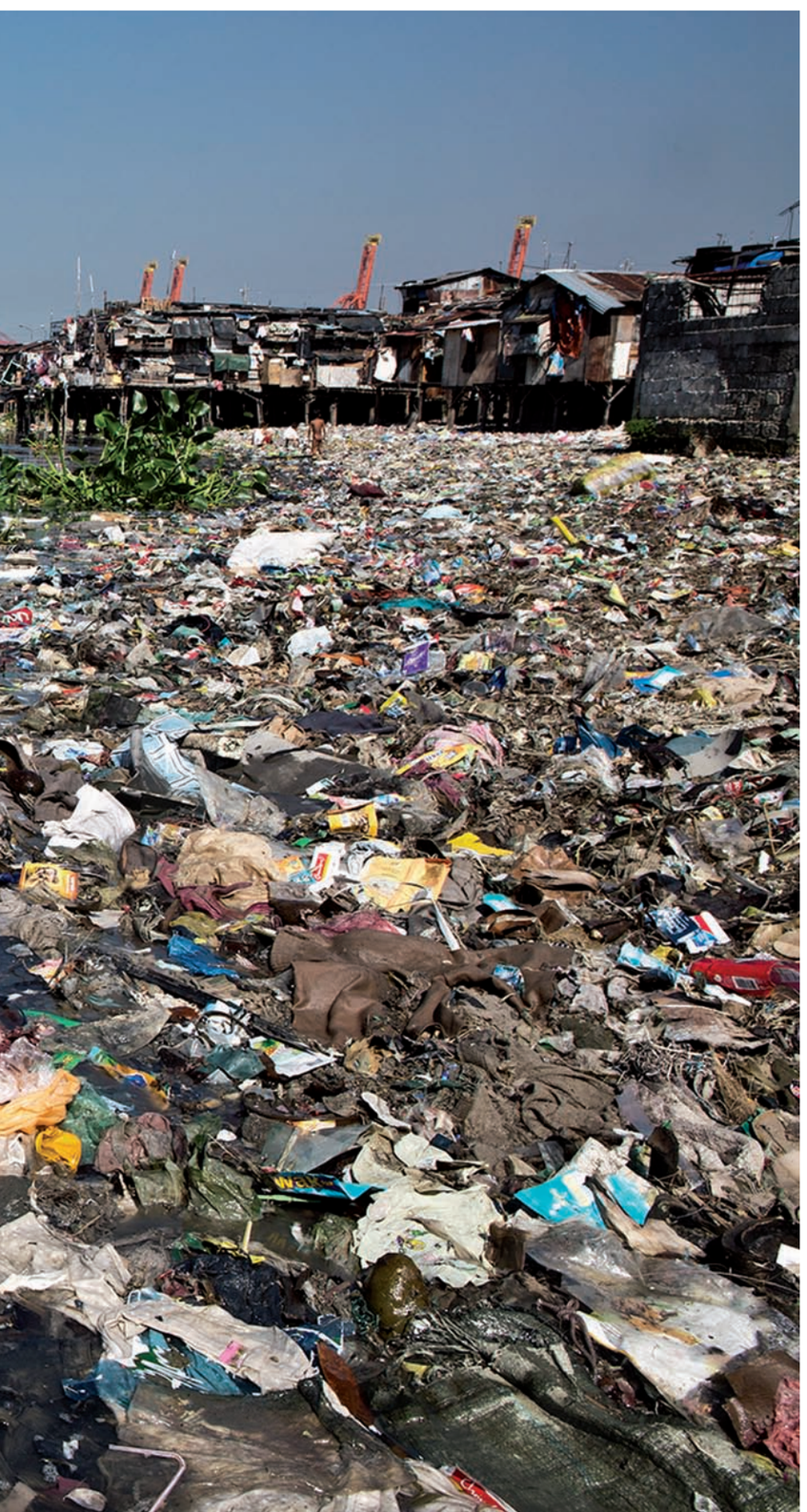
The regulations pertaining to the composition of sewer sludge used as fertilizer say nothing about microplastics, nor is it forbidden to plough or mow over plastics. The regulations also fall short when defining the composition of compost. In industrialized countries, it is made from kitchen and garden waste and the clippings from mowing road shoulders. All too often, these raw materials have plastic waste in with them. Larger pieces of plastic are removed during the composting process, but the smallest pieces are not. Bags of compost never state that they could contain microplastics. In the United States and Europe, hundreds of thousands of tons of plastic end up on the land every year.

And you have to be careful when making your own compost, too. Paper ought not to be a problem, but there is often a layer of plastic on it. Tea bags can be made of nylon, and many bioplastics can only be composted in industrial plants at high temperatures.

Increasing plastic pollution is a threat to the health of the oceans, to biodiversity, and to human health. Plastic soup is being presented to us quite literally on a platter when we eat mussels, prawns, or oysters. We wear clothes made of plastic. We grow crops on ground that is contaminated with plastic. We wrap our food and pack our drinks in it. The air we breathe contains plastic dust. Plastic particles penetrate deep inside our bodies. Do they accumulate there, causing chronic inflammation?

↓ *Happily posing in the middle of plastic soup, unaware of the potential health hazards. Manila, Philippines.*

HEALTH RISKS FOR HUMANS



Humans are at the top of the food chain and are highly dependent on food from the seas. Plastics are getting into that food chain. When plastics are made, the chemical additives used can then leach out, some of which can disturb the hormonal balances of humans and animals. On top of that, persistent organic toxins such as PCBs and DDT can bind to plastic particles in the water. Chemicals can accumulate in tissues and fats, ending up higher in the food chain thanks to biomagnification. Will the oceans, the source of life, end up making humans sick because of pathogenic bacteria that can stick onto the microplastics?

Nanoplastics that can hardly be measured are capable of penetrating the body, right into the brain and other organs. Toxins also bind to these tiniest of all pieces of plastic. Do they trigger immune responses in the body? Are they building up anywhere? Are there critical concentrations, and if so, when are they reached? Is there even any way of avoiding ingesting nanoplastics? To what extent do these plastic particles cause chronic inflammation in the body and trigger a series of disorders, including cancer and Alzheimer's? Nobody can guarantee that there are no nanoplastics in purified drinking water, for instance. In one study of microplastics in drinking water on various continents, larger pieces of microplastic were found in over 80 percent of the samples.

In past decades, almost everybody saw plastic as an inert and innocent material that does not react with its surroundings. For that reason, there were thought to be no risks to human health, and plastic was deemed to be safe. The consequence was uninhibited use of plastics. Now we do know that plastics do degrade into smaller and smaller particles that can now be found throughout the world, as well as in the air that we breathe. Those particles are like dust, and the concentrations of that dust are only going to increase. The idea that plastics present no danger is shifting rapidly. A growing number of scientists are ringing alarm bells.

PARADISE LOST

There is just a single species—*Homo sapiens*—that has profited to an exceptional degree from plastic. In 1950, when mass production of plastics really started, there were 2.5 billion people on the planet. In 2017, the head count had reached 7.5 billion. Plastic is one of the factors responsible for that unprecedented population growth rate. Thanks to plastic, supplies of unspoiled food increased. Plastic items are easy to clean and so hygiene improved, too. People are living longer and infant and child mortality have decreased dramatically everywhere. It is reckoned that the world population will be pushing 10 billion by 2050.

← *Because plastic does not decay and dumping it is the easiest option, bigger and bigger landfills are appearing everywhere, such as this one in Nepal.*

↑ *Overpopulation and the low quality of waste management systems in many coastal countries largely determine which contribute the most to plastic soup.*

The burgeoning global population is being accommodated in mega-cities. Most of these cities—those with over ten million inhabitants—are on the coasts. In developing countries, their growth is largely uncontrolled. It is estimated that one-third of all city dwellers live in shanty towns. A typical feature of these slums is the lack of facilities, including trash removal. High population densities within fifty kilometers of the coast are one of the key factors in explaining plastic soup. Three-quarters of the population of Indonesia lives in coastal regions, and the figure for the Philippines is over 80 percent. Most of the waste from these places is just dumped randomly.

There is no organized refuse collection service in the *favelas*, the shanty town areas of Rio de Janeiro, where about one-quarter of its residents live. The waste from about 7.5 million people flows untreated into the Bay of Guanabara. There are 55 rivers that empty into that bay; there is no longer any life in 52 of them because of pollution.

Kathmandu, the capital of Nepal, lies in a valley. Penetrating and almost permanent smog hangs over the city, partly due to the plastics that are simply incinerated in the open air everywhere. Along part of the banks of the sacred river, the Bagmati, there are layers of plastic waste meters in height as the result of many years of dumping. Waste that is not incinerated is dumped on a landfill site twenty kilometers outside the city. Hundreds of eagles circle endlessly above it.

The United Nations has estimated that only 10 percent of waste in Africa is dumped in a controlled way. The rest is just left lying around or burned. Plastic bags are the big villains. The water drainage in shanty town areas gets blocked by these bags, and the stationary and stagnant water creates the perfect breeding ground for malaria mosquitoes. Whereas a good rainstorm used to rinse the gutters and ditches clean, they now flood because of the plastic that has all accumulated, mixing with human fecal matter.

OFF

THE MAP

6

ART

→ System Accumulation *was made in 2011 by Steve McPherson from pieces of unmodified, colored plastic found on British beaches between 1994 and 2011. Private collection.*

OBJETS D'ART

Plastic washes up on beaches in various shapes and colors. So it is no surprise that artists collect this material and use it to make beautiful things. That happens all over the world. The result is almost always an artistic creation with a serious message: These artworks make the viewers aware of plastic soup. It is hardly surprising that figurative artworks often have a recognizable theme, such as threatened marine species or a globe. Colorful objects are made from the waste, objects that make the audience think.

← *Peter Smith made the floating work* World of Litter *in 2012.*

For more than twenty years, Steve McPherson has been roaming the northern coast of Kent in England looking for trash. He makes art from it. For him, it is about objects that were lost and have now been found again. There is a relationship between the finder and the person who threw the item away, maybe on the other side of the ocean. The sea is what connects them, what connects all of us, and the artist interprets that relationship in his own way. The prior history of any one object can never be known, but simply looking at it can bring that owner to mind.

Peter Smith, socially engaged artist, picks up litter from the street every day, cycling around with a grabber in his hand. In 2012, he made a globe from six thousand picked-up PET bottles. The floating globe is 5 meters and has been displayed in Amsterdam, amongst other cities. It is, of course, a protest against plastic soup. But protesting isn't enough for Peter. "I don't complain about litter—I clean it up," he says. If every 'nice' person would follow his example, and would pick up at least one item a day, he calculated the problem of plastic waste and plastic soup would soon be lessened.

Flip-flops wash up on the coast of East Africa, some of them from countries on the far side of the Indian Ocean, such as Indonesia. Ocean Sole, founded by Julie Church, collects the footwear on the coasts of Kenya. Artists use them as the raw material for creating colorful objects. Some 400,000 flip-flops and sandals are recycled this way every year, and the venture employs one hundred people. The products are sold to tourists, with whom representations of African animals such as elephants and lions as well as marine animals such as turtles are popular.

→ *Ocean Sole turns reclaimed flip-flops into colorful, hand-made animal toys and sculptures. Tons of flip-flops wash up on the East African coast every year.*

POIGNANT PHOTOGRAPHS

↓ *Benjamin Von Wong photographed a mermaid, washed ashore in a sea of 10,000 plastic bottles. This was one of a series that drew a lot of attention.*

When filming nature, people rarely ask how much garbage is cleared away in order to get a good shot. In many photos, the world is presented as being more pristine than it is in reality. On the other side, you have shots that are about plastic soup. Poignant pictures are now ingrained in the mind's eye of every citizen with a conscience: animals that have become entangled, children swimming between plastic items, beaches full of junk. Without photography, the plastic soup problem would receive far less attention than is currently the case. Now, nobody can say that they were unaware.

→ *The graceful flock of starlings—a murmuration—appears, on closer inspection, to be a mass of thousands of plastic bags. Alain Delorme,* Murmurations, *Ephemeral Plastic Sculptures,* 2012-2014.

In 2008, Marcus Eriksen and Anna Cummins sailed from California to Hawaii in 88 days on a raft made from 15,000 plastic bottles. They were doing research into plastic soup and used this unusual approach to draw attention to the issue. Today, they are the driving force behind the NGO 5Gyres. Onboard the raft—or perhaps it would have been more appropriate to call it junk—they ate fish that they caught along the way. Eriksen gutted a rainbow runner one day and found lots of pieces of plastic inside it. It was a shocking discovery. The photo that Eriksen took at the time has been printed and displayed innumerable times. The picture speaks volumes, and it has woken up the world.

Clouds of starlings flocking together are one of the most splendid sights in nature: thousands of birds dancing through the air as if by orchestrated choreography. The French photographer Alain Delorme took these clouds of starlings as the starting point for a series called *Murmurations*. The viewer recognizes the formations instantly, but a closer look at the photographs shows that these are not starlings flying in formation but thousands of plastic bags. Each photo has been carefully staged using more than a hundred thousand lightweight plastic bags. The *trompe-l'oeil* effect hits home hard. Instead of admiring a spectacular natural phenomenon, we are confronted with an ecological disaster. Those wonderfully pure formations suddenly become ominously threatening.

The Canadian photographer Benjamin Von Wong produced a series of staged photographs of a mermaid in a sea of ten thousand plastic bottles, the number that a single person uses, on average, over the course of their life. It is his way of making a boring and serious subject such as plastic soup speak more to the imagination: his photographs get people to think.

→ *In all its simplicity, this photo points out the fact that fish in the oceans are swimming around with plastic in their bodies.*

The first supermarkets appeared about one hundred years ago in the United States. Instead of a shop in which the customer was served from behind a counter, stores appeared in which the customers could serve themselves. Over time, these supermarkets became ever more extensive and more efficient. There are now megastores in which thousands of different products are sold, almost always wrapped in plastic. And a single product can require meters of space on the shelves. An increasing proportion of the world's population regularly goes to a supermarket where they are tempted to purchase products that look good and are attractively displayed.

PLASTIC SOUPERMARKET

↑ *Wherever* Plastic Soupermarket *is exhibited, the composition of the products is different, depending on what was found in the immediate vicinity.*

The British artists Lou McCurdy and Chloe Hanks went regularly to Brighton Beach where they saw lots of plastic lying around—bottles and bottle tops, wrappers, and so forth. The majority were packaging materials that had not been in the water long and that had come from products from local supermarkets. It was easy to find dozens of examples of any single product. This led to a brilliant idea for an exhibition: a replica supermarket.

They called their installation the *TrueCost Super M-Art* or *Plastic Soupermarket*, referring to themselves as Dirty Beach. Since then, they have been collecting packaging and wrappers from beaches or rivers in Europe, cleaning them and then laying them out on a display shelf in their unique, tongue-in-cheek *Soupermarket*. The *Soupermarket* seems familiar, but it is drastically different from what people are used to.

McCurdy and Hanks give the familiar wrappers a new lease on life by adding new labels to them, as well. The labels are a mixture of well-known marketing slogans and humorous advertisements. Because of their attractive appearance, all the products seem to be new at first sight. It takes a moment before the visitor realizes what they are. What seemed so attractive suddenly turns confrontational. What happens when the plastic items that had been thrown away are suddenly displayed again, right in front of you? You realize that discarded plastic never really goes away.

The installation has been shown in various places, and waste from the local area has been used each time. The composition of the waste has varied from one place to the next, with a clear link between what is on sale locally and what is on the beach. Visitors, including many schoolchildren, are thus given a further message: plastic soup starts on your own doorstep and isn't just something that happens far away.

↓ *As well as hats, Haak-In uses old plastic bags to make crocheted items such as necklaces, bracelets, vases, keyrings, baskets, and seat covers.*

Plastic litter is a persistent problem, particularly in countries where there is no proper refuse collection service. People invent creative ways of reusing it. Melted down plastic can be the raw material for new products and PET bottles get reused as solar collectors or building materials.

These kinds of initiatives provide employment, open up the possibility of a less polluted environment, generate income, or save on expenditure that would otherwise be required. Used plastic can also be given a new lease on life in the form of wonderful artworks.

CREATIVE REUSE

In 2002, a retired Brazilian engineer named José Alano developed a solar collector made from one hundred PET bottles that runs without pumps or electricity. Anybody can build this collector themselves, and indeed many people in Brazil have done just that. The sun heats the water up to 108°F and the bottles need to be replaced once every five years.

In the poorer districts of Manila in the Philippines,10,000 used PET bottles were installed in 2011 as solar lighting. Filled with limewater and fitted to roofs, they give light in rooms that have neither windows nor electricity. There are many more surprising applications, such as making brooms, roof tiles, or plastic cutlery. Instructional videos can easily be found online.

In the Indian state of Tamil Nadu, the Samarpan Foundation is building houses from plastic bottles. Used bottles are collected, sorted by size, and filled with sand. Then, the lid is screwed back on. The bottles then serve as bricks and can be cemented into place to form floors or walls. Used nylon fishing nets reinforce the structure. This generates major savings on valuable construction materials. People are then able to build their own houses. These houses are also earthquake-proof.

Kumasi, the third biggest city in Ghana, generates about 16,000 tons of plastic waste every year. The Recnowa Initiative uses this waste to make attractive new products, combating pollution at the same time. The project provides jobs for more than 130 people and 1,200 school children were given new backpacks made from waste plastic. In the Kenyan city of Kisumu, VictoPlast makes poles from waste plastic as a substitute for wooden ones.

There seems to be no end to the initiatives for making art from plastic. In Amsterdam, Corrie van Huisstede crochets artful objects. She asks people to collect used plastic bags that she then cuts into long strips and crochets into the most wonderful things. In 2011, Captain Charles Moore bought one of Huisstede's hats. The discoverer of plastic soup would later wear it to many events.

Plastic is a useful prop that can be used in an infinity of inventive ways, for example on stage, on the streets, or in video clips. Plastic soup is being brought to people's attention in all kinds of artistic ways. Socially engaged artists dress in plastic costumes as a way of confronting the public as they shop. There are fashion shows with creations made of waste, and choreographers have drawn inspiration from the plastic that moves elegantly in the wind or to the rhythm of the waves. The creations are as aesthetic as they are uncomfortable. You enjoy watching them, but the feeling isn't entirely pleasant—which is precisely the intention, of course.

PERFORMING ARTS

← *Andy Keller performing as the bag monster in Times Square, New York, to raise awareness about the waste and pollution caused by plastic bags.*

→ *Marguerite Donlon created the dance piece* Blue *to raise more awareness about plastic soup. She worked with plastic in various ways in her choreography.*

The oscillations of the waves are rhythmic, turbulent on some occasions, and barely noticeable at other times. Dance is the same. In the Irish choreographer Marguerite Donlon's show *Blue*, the dancers move among hundreds of upright PET bottles. Air is blown beneath large sheets of paper-thin plastic, creating wave-like movements: A sea of plastic that the performers seem to be drowning in. One dancer tries in vain to free himself of the plastic around his neck that is strangling him. In the end, only a single dancer manages to escape. Sorrowful tones from a cello accompany this ballet from 2011.

The activist Andy Keller dressed in a suit made from five hundred plastic bags and called himself the *Bag Monster*. The number was chosen deliberately: the average American uses five hundred bags a year. Keller went out and about in Seattle and other cities with a sign that read "Don't feed the bag monster!" It was his way of showing the dark side of plastic bags and powerfully making the case for them to be banned.

Underwater performer and filmmaker Christine Ren dons a blindfold underwater in a piece entitled *Blind Spots*. Her movements in the water are those of someone walking, as she pushes a shopping cart from which various pieces of plastic packaging escape. They float away and become plastic soup. She is making a direct connection between consumers' everyday shopping and plastic soup. The blindfold symbolizes our ignorance or even unwillingness to acknowledge what is going on, while the shopping cart represents the insatiable urge to buy. In *Blind Spots*, Christine Ren calls on people to live without creating plastic waste.

EXHIBITIONS

Exhibition curators are always aiming to achieve something. The visitors are amazed, moved, are taught something, or are made to think. What happens to the visitors to exhibitions that have plastic soup as the theme? Even if the objects exhibited are intrinsically cleverly thought out and well made, the message that we are polluting our oceans with plastic is anything but pleasant. Do the visitors suppress that message, or are they instead spurred to take action? It is clear that the growing number of exhibitions about the subject are increasing people's awareness hugely.

→ Washed Ashore *makes larger-than-life sculptures of marine animals, like this parrot fish, to make people aware of plastic pollution in the oceans and waterways.*

↑ Bounty, Pilfered *is made of over a thousand pieces of ocean plastic, referring to the ubiquitous plastic waste as a 'squandered horn of plenty'.*

Christian Brändle, director of the Museum für Gestaltung Zürich—the Zurich Design Museum—in Switzerland, had read about plastic soup in 2009 and decided to devote an exhibition to it.He arranged for plastic ocean waste to be collected at various places in the world and sent to his museum. A full container came from Hawaii, for instance. The exhibition *Out to Sea? The Plastic Garbage Project* was opened in 2012. Visitors were immediately confronted with a huge pile of plastic waste, the same amount as was assumed at the time to end up in the sea on a daily basis. An unusually high number of visitors came to see it, and the exhibition has toured museums throughout the world since then, right through to today.

In the Anchorage Museum in Alaska, an exhibition called *Gyre: The Plastic Ocean* was put on in 2014. One of the artworks, made by Pam Longobardi, represented a black cornucopia. Normally this would be overflowing with all the good things that the earth produces. This time, however, it was filled with the bitter fruits of pollution, such as balls and toys that had been battered and degraded by the seas. The artist sees the washed-up plastic as holding up a mirror to the worldwide capitalist society that is so focused on consumption.

Washed Ashore, set up in Oregon in 2010 by the artist Angela Haseltine Pozzi, makes sculptures of marine animals at life size or bigger. They are animals affected by plastic soup, such as turtles, birds, fish, or seals. The sculptures are made exclusively from plastic that has been found on nearby beaches. Volunteers search for pieces of plastic on the beaches and then clean and sort them. By 2017, Pozzi and her team had made 70 sculptures from over 21 tons of marine debris. Among other places, this travelling exhibition was shown at the National Zoo in Washington, DC, where the plastic animal sculptures stood in amongst their living counterparts. Pozzi says she will not stop until beaches are clean again.

7

BETWEEN BELIEF AND HOPE

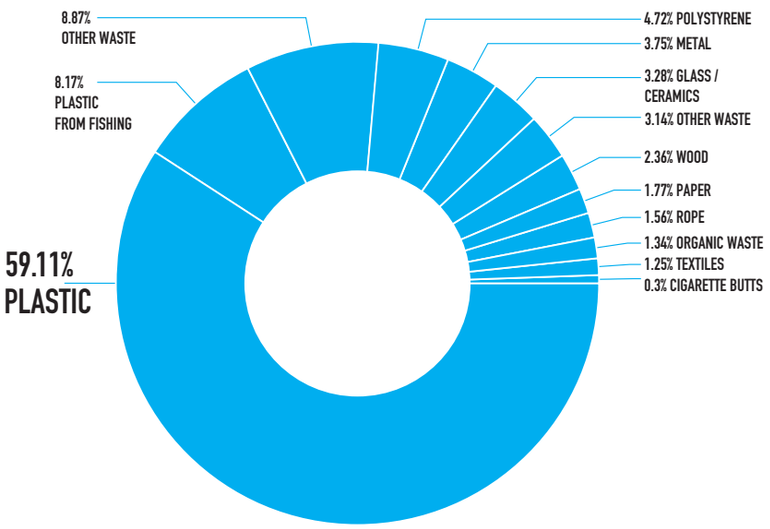
← *Plastic is slowly but surely becoming interwoven with life on Earth. Can we still turn the plastic tide?*

CLEANING UP THE OCEANS

The concentrated area of plastic in the Pacific Ocean is sometimes referred to as the *Great Pacific Garbage Patch*, a term that quickly evokes an image of an island of floating trash followed rapidly by the idea of sailing there and clearing the waste away. There are not actually any islands of garbage, but over the course of time, various ideas have been proposed for using vessels or systems—unmanned in some cases—for clearing up plastic soup. These initiatives generate a great deal of attention for the plastic soup problem. Of all these concepts, The Ocean CleanUp invented by Boyan Slat of the Netherlands is the best known.

↓ *In 2016, to test the design, The Ocean CleanUp deployed a barrier segment 100 meters long in the North Sea, 23 kilometers off the coast of the Netherlands.*

↓ *The waste in the oceans is 60 to 90 percent plastic. It ranges from discarded fishing nets to bags, bottles, and cups.*



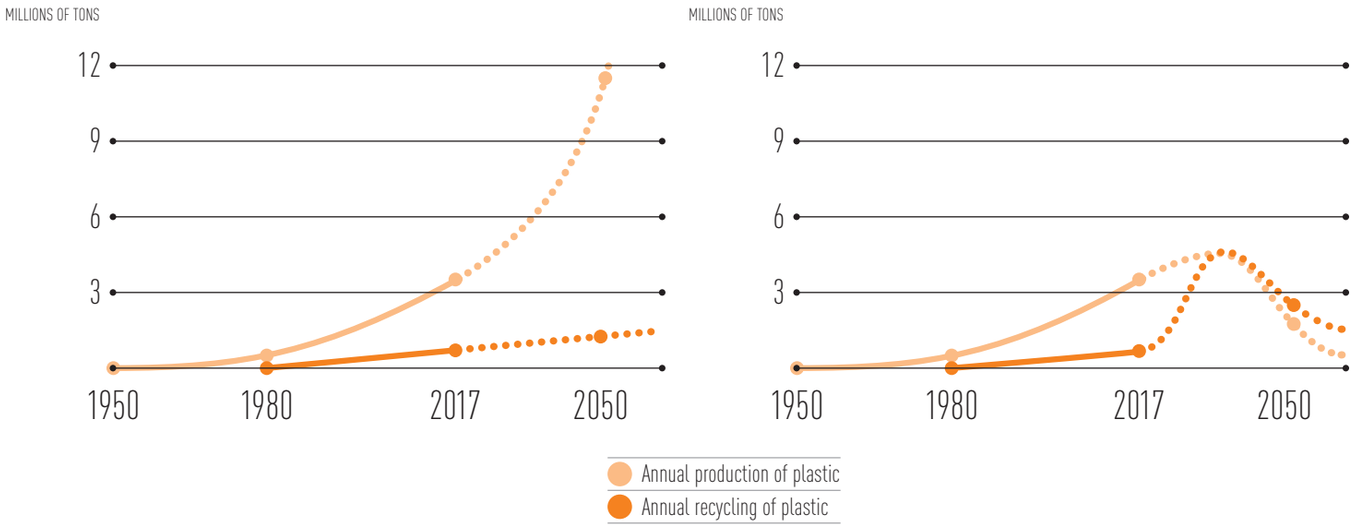
→ *Air bubbles in a river create a barrier. The Great Bubble Barrier is a Dutch invention that traps more than 80 percent of the plastic in rivers.*

While still in high school, Boyan Slat thought up a system for collecting floating plastic using long floating booms. If those booms are anchored to the bottom, the water flow ensures that the plastic on the surface is collected. When there are two arms in a V shape, the plastic concentrates in the point of the V. A system powered by solar energy picks the plastic up out of the water. A ship then comes along at regular intervals to collect the waste.

Oceanographers and other specialists inevitably treated the idea with scepticism. There is indeed a concentration of plastic in the gyres in the middle of the oceans, but the floating plastic is only a small proportion. The rest of the plastic has sunk or is suspended deeper in the water. The system itself, with hundreds of kilometers of floating booms, is vulnerable to the forces in the ocean and the booms are difficult to anchor in place.

Boyan Slat stuck to the principle of iterative engineering. Step by step, his team improved the concept. Prototypes were tested in laboratory situations and out at sea, and the test results led to the concept being modified drastically. Using differences in the current speeds at the surface of the sea and at a few hundred meters' depth, much smaller collection systems can be anchored in the sea itself. Special screens allow the plastic in the topmost few meters to be caught. These modules drift naturally to the places where plastic also drifts—in other words, the locations where plastic concentrations are highest. Given that these modules are considered to be much more efficient than the original design, Slat claimed in May 2017 that he could clean up half of the plastic soup in five years.

All the plastic that can genuinely be removed from the oceans can no longer degrade into microplastics. If The Ocean CleanUp turns out to be a system that is not only technically but also economically viable, the benefits will be unprecedented. It is, of course, essential that no more plastic is added in the meantime.



RECYCLING

The world economy features a three-way split between *take* (using primary resources), *make* (producing as much as possible), and *waste* (discarding the garbage). The result is the exhaustion of natural resources and the creation of environmental problems, of which plastic soup is only one. Nature teaches us that there is no such thing as waste. A dead tree provides nutrients for a subsequent tree, allowing it to grow. We, therefore, have to move towards what is known as a circular economy in which all the cycles are closed loops. This circular economy cannot be achieved without recycling. Recycling plastics is, however, complex and problematic.

← *How will we deal with plastic from now on: continue as we are (left) or make efforts to reduce and recycle (right)?*

In a circular economy, the refuse collection rate for used products is 100%, and the collected products are used for making equivalent items. But today, only a tiny percentage of all the plastics in the world is collected for recycling. The bulk of it is burned or dumped in landfills. If used plastic is to be retrieved, a properly functioning infrastructure is required. Most areas have nothing of the sort. Even in the United States, more than 90% of plastics are not collected and are, instead, simply dumped in landfills.

Even if the collected plastic is reused as a raw material, other issues are lying in wait. There are major differences in the quality of the plastics collected, making it difficult to sort them before reuse. Recycling packaging materials is particularly complex: they can't simply be used for making more packaging. The net result is therefore almost always *downcycling*. The new products are inferior to the originals and will, in turn, be discarded or incinerated after use. To keep making equivalent products, new plastic from petroleum is therefore often preferred.

Recyclers cannot tell the composition of the old plastic that they receive. Plastics in electronic devices contain flame retardants, for example. Recycling could lead to these toxic substances ending up in new products such as toys. Ensuring that harmful substances are removed from the products is a challenge in this circular economy.

Improving recycling will mean that less plastic ends up in the environment and lesser amounts of primary raw materials, such as petroleum, will be needed. The real solution, however, has to be found in drastically reducing the use of plastic. Where the use of plastic is unavoidable, it must be recycled as well as possible. But even that does not yet create a closed loop. Old plastic must be given some kind of economic value, so that collecting it for recycling is also financially attractive.

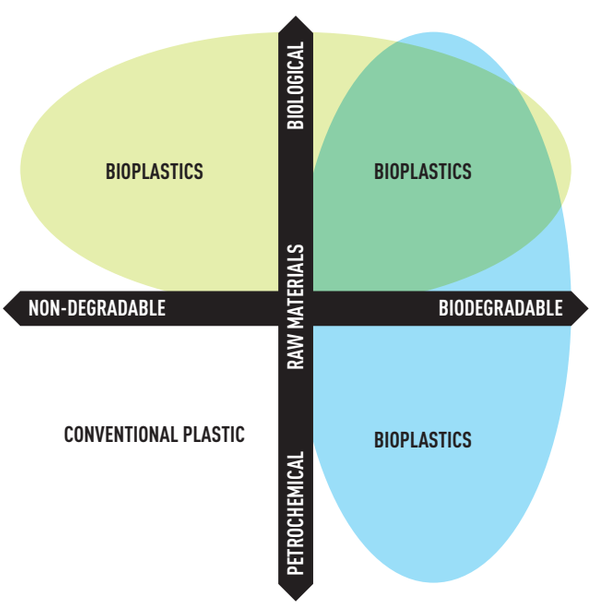
↓ *Only 9% of all plastic discarded since 1950 has been recycled. The other 91% has been taken to landfills, turned into incinerator emissions, or ended up in the oceans.*

Plastics can be made from natural raw materials such as maize, sugar cane, or potatoes instead of petroleum. Bioplastics are currently used for food packaging and disposable tumblers and bags, for instance. Biodegradable plastics behave in the environment in the same way as normal plastic. It is possible to compost them, but this is primarily done in separate systems that work at temperatures of up to 65°C. Sadly, bioplastics do not present a solution for plastic soup or for reducing plastic litter, unless bioplastics are developed that can be degraded entirely in the environment in a short time frame.

BIOPLASTICS

↓ *Consumers get very confused by the way the term* bioplastics *is used for three of the four segments.*

The market share of bioplastics is minimal compared to plastics from petroleum, although that may soon change. A number of comapnies want to switch to bioplastics to make them less dependent on oil as the raw material. Coca-Cola has introduced the *plant bottle*, which is made from up to 30% plastics of vegetable origin. These bottles can be recycled, but do not degrade in the environment. This example also shows just how confusing the term *bioplastics* is. Is it referring to plastics made from biomass, with properties that are identical to normal plastic? Or is it referring to plastics that are genuinely biodegradable?



Consumers have great difficulty dealing with bioplastics correctly. Which plastics can you throw on the compost heap and which can you not? How likely is it that, despite all your good intentions, you mix bioplastics with ordinary plastic, creating a mixture that makes recycling even more tricky? Companies that make compost out of kitchen and garden waste are faced with this issue as well. Their composting processes are dispupted by contamination with normal and bioplastics. Therefore, some composting companies remove all types of plastic.

It becomes particularly unfortunate when the consumer thinks that so-called oxo-degradable plastics are good for the environment. In contact with oxygen, this type of plastic rapidly degrades into small particles, which you can no longer see, but which are actually still there and do not break down further chemically.

In the struggle against plastic soup, the key question is primarily whether a bioplastic is genuinely chemically broken down in water at low temperatures, with little oxygen and little sunlight.

Other environmental effects also play a role in the choice for plastics of vegetable origin. Bioplastics are generally associated with lower CO_2 emissions. PEF (polyethylene furanoate), a new plant-based alternative to PET for bottles, has better properties than PET made from petroleum, so products stay fresh for longer. It is true that no oil is used for making plastics from biomass, but valuable agricultural land is generally needed for obtaining that biomass.

→ *Will we ever see ships with equipment that converts plastic into oil, so that cleaning the plastic up from remote coasts becomes commercially viable?* Scourie, Scotland.

Plastic is made from oil. The idea of converting plastic litter back into oil is already old hat. It is termed *plastic to fuel*. Plastics are first melted and then converted into gas in large plants at high temperatures in an oxygen-free environment. The gases are then cooled, so that they condense out into usable fuels. As a solution to plastic soup, this method of pyrolysis offers some promise. This is particularly true if it turns out to be technically possible to carry out the process in small, mobile units. Those units could then be taken by ships or trucks to the places where there are large amounts of plastic litter.

PLASTIC TO FUEL

Systems that convert plastic into oil are operational at various places around the world. In developed countries, the emphasis is on large-scale systems. This technology an alternative for dealing with plastics that are difficult to recycle. Problems can include the constant supply of waste plastic and the composition of that supply. Not all plastics are suitable and contamination with organic material harms the process.

In countries with landfill sites or insufficient local refuse disposal, smaller plastic-to-fuel systems could be an answer, and could help create a plastic-free environment. The technology is, however, still in the pioneering stage and a number of companies have already given up.

In Poona, a district in India, Medha Tadpatrikar has not only designed a facility that can convert all kinds of plastics into fuel, but has also founded Rudra Environmental Solution. This organization collects the plastic from 10,000 households. After conversion, the fuel is bottled and sold in 122 villages. The system itself is easy to operate.

The Filipino inventor Jayme Navarro of Poly-Green Technology and Resources Inc. has held a patent since 2008 on a relatively simple method for converting plastic waste into oil. His plant is in Rodriguez, in the province of Rizal, and it makes fuels that are cleaner and cheaper than the ones bought from the pump. The production costs are low because of the overabundance of available plastic litter.

A maritime captain by the name of James E. Holm founded Clean Oceans International in Santa Cruz, California. Together with the chemist Swaminathan Ramesh of EcoFuel Technologies, he developed a small, mobile reactor that operates at relatively low temperatures. The plastic that washes up on beaches, is in principle, plastic that floats. And as it happens, lightweight floating plastics are the ones that are most suitable for the process they have patented. Depending on the price of oil, a reactor can pay for itself in just a few years. Holm's aim is to equip ships with these reactors and send them to places where a lot of plastic washes up.

PRODUCTS MADE OF OCEAN PLASTIC

Plastic waste from the oceans can be used as a raw material for new products. When people buy those products, they help solve the plastic soup problem. That is the simple idea behind a business model that is used by an increasing number of companies: making products from ocean plastic in order to save the oceans. Is that really the case, or are the people who buy these products mostly just improving the public image of those companies? You can already buy shoes, surfboards, glasses, sandals, carpet tiles, and bottles of liquid soap that are made entirely or partly from ocean plastic. The list of products is steadily growing.

Fishermen on the island of Guindacpan in the Philippines go diving for old nylon fishing nets. One of the reasons why fish catches there have gone down is that nets that have been left behind are damaging the coral reefs. The fishermen are repairing their fishing grounds as well as being paid for the nets that they take out of the water. The Net-Works program sends the nylon in bales to a factory in Slovenia, where it is processed for use as the raw material for carpet tiles made by Interface. This company's aim is to use 100% recycled material for all its carpet tiles. The program is a great success and has already been extended to other countries.

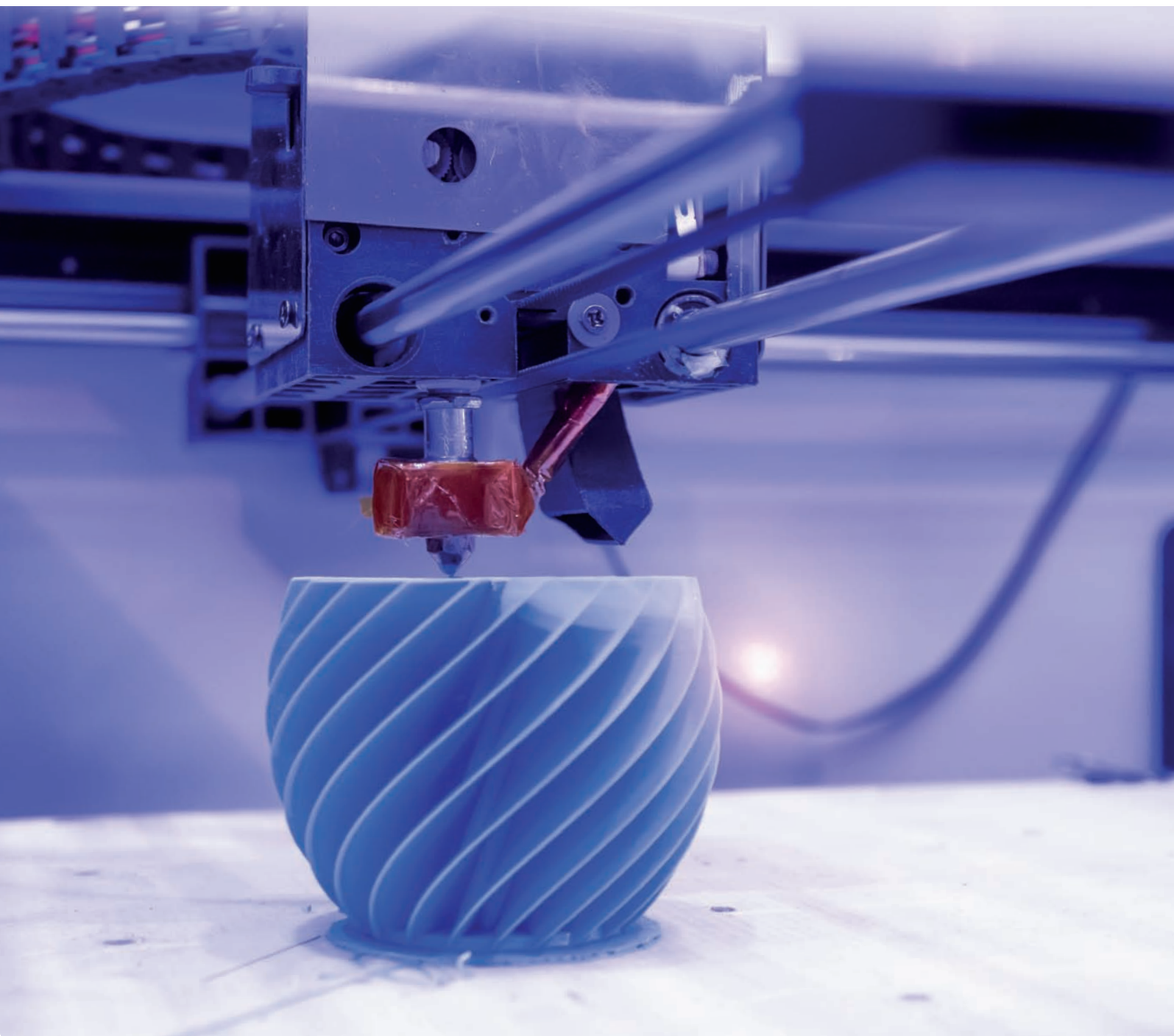
The German company Adidas presented a prototype of an ocean shoe in June 2015 and promised to use ocean plastic for high-quality, modern sports shoes. Two years later, three variants of the Ultra-Boost shoe went into mass production. Eleven plastic bottles are used for each pair. These come from cleanup actions organized by Parley for the Oceans. In addition to the shoes, Adidas has also made 250 million sports shirts from ocean plastic.

The Swedish fashion chain Hennes & Mauritz (H&M) produced a collection called Conscious Exclusive in 2017. Each item of clothing is made from sustainable materials, including recycled polyester made from plastic that has been collected from the coasts.

These companies reach a large number of people and are, therefore, raising awareness about plastic soup. However, only a small proportion of ocean plastic—the PET bottles and the nylon from fishing nets—is really suitable for recycling. Collecting those materials specifically, and processing them into high-quality products, is difficult and expensive. In terms of serious solutions for plastic soup, these products are therefore scratching the surface at best. Anyone who buys clothing made from ocean plastic is, in fact, contributing to plastic soup. After all, every machine wash releases hundreds of thousands of plastic fibers that immediately end up back in the water again.

It is possible that increased awareness will lead to changes in purchasing behavior.

←↓ *Products made from ocean plastic undeniably help consumer awareness, but hardly make an impact on plastic soup.*



↑ *Using recycled plastic for 3D printing gives the waste added value. Plastic trash goes in, valuable items come out.*

ADDING VALUE

Plastic is cheap, abundantly available, and has virtually zero value as waste. Adding value is a key weapon in the struggle against plastic soup. If that can be done, plastic will be kept, collected, and recycled. The added value is not only in terms of economic worth; the social and ecological value increases as well. Plastic that is otherwise worthless can create employment opportunities and generate more income. Added value leads to a cleaner environment and prevents the plastic from ending up in the oceans. Numerous initiatives attempt to achieve this.

The Plastic Bank, set up by David Katz in Vancouver, Canada, creates a market for recycled plastic litter by getting companies to purchase that plastic as part of their corporate social responsibility programs. The Plastic Bank encourages poorer people in places where there is no refuse collection to collect plastic themselves. In return for that plastic, they are given fuel for cooking, for instance, or an opportunity to recharge their phone. Consumers are asking companies to make use of *social plastic*. The more that happens, the more its value increases. The higher that value, the less plastic will disappear into the seas and the greater the reward that can be disbursed to the people who collect the plastic.

An initiative set up by the Dutchman Dave Hakkens is called Precious Plastic. His idea is that anyone, anywhere in the world can start up their own miniature recycling company. He has developed a simple machine. One part of it chops the waste plastic into tiny pieces and another part melts it. Then, there are two options. You can inject the liquid plastic into a mold to make useful objects from it, or you can make filament from it: the plastic thread that 3-D printers use for printing objects. His device is simple to put together, and the blueprints are available online. This lowers the threshold for people who want to make new things from plastic litter and sell them. His concept is now being used all over the world.

Suchismita and Jayant Pai started a social venture called Protoprint in 2012 in Poona, India. Waste pickers only get tiny amounts of cash from the plastic that they collect and sell. If they were able to make an interesting product from that plastic, its value would increase. Together with an organization representing the waste pickers, Protoprint set up a production facility for manufacturing filament for 3-D printing from plastic bottles. The challenge is to be able to offer filament of the same quality as the regular manufactured type.

8

INSPIRATIONAL INITIATIVES

← Natural branding *is the technique in which lasers are used to mark fruit and vegetables by burning a little pigment away from the outermost layer of the skin.*

LASERED FOOD

In the European Union, it is mandatory to keep organic fruits and vegetables separate from non-organic products. Otherwise, the consumer and the cashier cannot see the difference. For that reason, even loose vegetables and fruits often have stickers or are packaged separately. A new technology called natural branding could render those stickers and wrappers unecessary. Lasers are used to apply information directly onto a product by burning off a little bit of pigment from the outer layer of the peel or rind. A growing number of shop chains are working with this technology, which was developed in Spain. This saves large quantities of packaging material.

↓ *The machines that can add the laser brand marks are getting cheaper, smaller, and better every year. This means that they are becoming viable for increasing numbers of products.*

↑→ *Eosta, a Dutch distributor of organic fruit and vegetables, saves a huge amount of packaging plastic by marking fruit and vegetables with laser light.*

Whether it's a coconut, a piece of ginger, a sweet potato, or a mango, the laser technique can mark them all, though the technique is currently less suitable for some vegetables, such as zucchini. The burned-in logo and text—branding in more ways than one—cannot be seen underneath the peel and has no effect on the shelf life, taste, or quality of the product. Fruit that is eaten with the skin on, such as apples and pears, can also be branded using laser light with no problems for consumers. The energy needed for lasering on an image or text is only a fraction of the energy that is currently used for making a sticker.

The machines are expensive to purchase, but that cost is recouped because no consumables, such as plastic, ink, glue, dyes, or paper are used. In addition, major savings are claimed on energy and CO_2 emissions. The additional savings on plastic packaging are also gigantic. As volumes increase, we can assume that it will easily be viable for supermarket chains to introduce laser machines. In early uses, consumers have accepted lasered food items with no reservations; after all, the quality is the same. Plastic wrapping is one of the things that annoys consumers most. This technology is an ideal alternative.

Packaging individual fruits and vegetables—organic or otherwise—is not merely a European phenomenon. To help resolve plastic soup, this technology also offers plenty of possibilities for the rest of the world. If preventing waste is the initial premise, it is very important to see what kinds of packaging can be rendered unecessary by lasering information. Shop chains would no longer have an excuse for not using this technology. Consumers could enforce it by asking for it.

BEAT THE MICROBEAD

In August 2012, the Plastic Soup Foundation and the North Sea Foundation started a campaign against the use of microbeads in personal care products. That campaign, Beat the Microbead, was an immediate success, first in the Netherlands and then internationally. Hundreds of brands, both large and small, were adding plastic particles to face scrubs and toothpaste. Those particles are comfortable to use and do not damage the skin, but are then rinsed away with the wastewater down the drain. Wastewater treatment plants do not filter them all out and so these miniscule plastic particles end up in the environment and in the seas.

← *When microplastics are added to cosmetics, polythene grains for scrubbing aren't the only thing to look out for. Dozens of different types of microplastic are used. A shower scrub is pictured here.*

↓ *When a manufacturer states that microbeads have been removed from the scrubs, that is no guarantee that the products are free of all microplastics.*

→ *Manufacturers who declare that their products are entirely free of microplastics are allowed to use the Look for the Zero logo.*

The cosmetics companies sputtered against the campaign initially, claiming that microbeads *were* all retained in water treatment plants, that their share in pollution was negligible. Indignation among the public at large and politicians, too, was so great that some companies were soon changing their minds. However, retailers also became reluctant to sell the products. In addition, the campaign launched a multilingual app. Since then, consumers have been able to scan barcodes with a smartphone and find out whether the product in question contains microbeads.

At the end of 2012, Unilever became the first multinational to announce that it was voluntarily removing microbeads from its products. A federal law was enacted in the United States three years later that banned the production and sale of personal care products containing microbeads. The announcement by Unilever, matched in the meantime by other major cosmetics companies, transpired to be nothing more than a strategic move, however. Whereas it was previously thought that microplastics were primarily present in face scrubs and toothpaste, it now turns out that they are also used in lipstick, mascara, deodorant, nail polish, and many other cosmetics. There are dozens of different microplastics that fulfill various functions. Because the industry has given a very narrow definition of what they will remove voluntarily (abrasive particles of polyethylene), they have left the possibility open of continuing to use all kinds of other microplastics.

The campaign is supported by nearly one hundred organizations throughout the world. With help from consumers, the Beat the Microbead cooperative venture wants to enforce a worldwide ban on all types of microplastics in cosmetics. Legislation is indispensable because voluntary elimination leaves the companies too many loopholes through which to escape. In the meantime, the complex ingredient names on the labels do not let consumers work out whether it is a plastic or some other substance. The Beat the Microbead campaign has therefore shifted its emphasis. From 2015 onward, cosmetics companies are asked to issue a declaration that all their products are 100% free of plastics. If they do, their products may bear the Look for the Zero logo. A growing number of cosmetics companies are now giving consumers that clear statement.

FISHING FOR LITTER

In 2002, Fishing for Litter was started by KIMO, an association of about 150 coastal municipalities in 13 Northern European countries. When fish is sorted, the waste that has also been caught is put in a basket. That basket is emptied regularly into a Big Bag, in which 200 to 250 kilograms of waste can be collected. When they reach port, the bag is placed on the quayside using a crane, and later taken to a container or storage area. Every port has its own waste plan in which the collection and processing of the refuse is arranged. The vessels can get new Big Bags in every harbor. The initiative has been taken up by Denmark, Sweden, Germany, England, Scotland, and Norway.

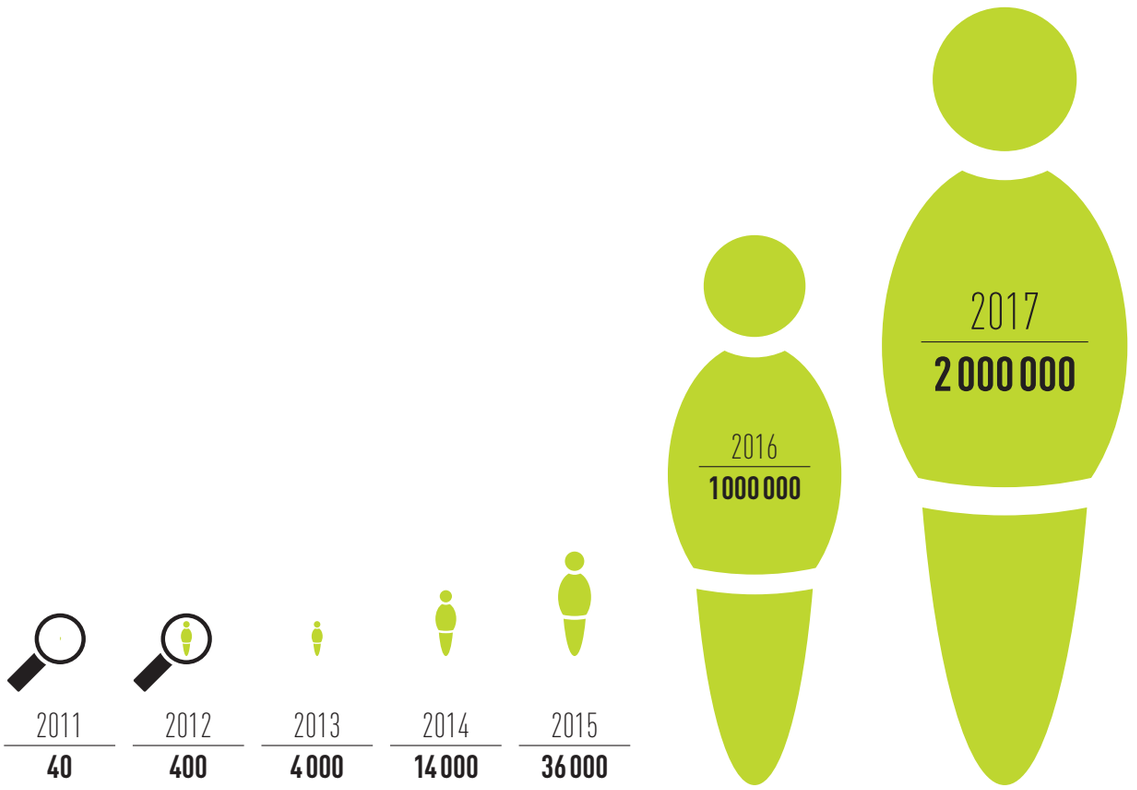
South Korea has had the Buyback Program for Fishing Gear since 2003. Its aim is to deposit unclaimed fishing gear that is caught in nets into special bags. These bags, which vary in format, are handed over again on land. In contrast to Fishing for Litter, these fishermen do receive a payment from the government. Another initiative in South Korea is floating waste bins of nine by six meters in which fishermen can voluntarily deposit the waste they have caught. The full bins are towed to the quayside, where the waste is processed further.

All of these initiatives are about waste as a by-catch. It is a relatively cheap way of removing waste from the sea because the ship and its crew are, after all, already on the water. There are also active variants of Fishing for Litter. In those cases, a vessel goes looking for waste with the aim of fishing as much junk as possible out of the water. This only makes sense in locations where the concentration is high, such as ports and bays. The European organization Waste Free Oceans uses a cleverly designed floating receptacle that is towed behind a boat. Once that collector is full, a crane lifts it out of the water so that it can be emptied. Waste Free Oceans sees waste as raw material and wants to recycle it into new products.

↓ *One of the 300 Scottish vessels participating in the Fishing for Litter scheme. There are 18 harbors in Scotland where garbage can be handed in.*

The underlying idea for Fishing for Litter comes from the Netherlands. Bottom trawlers and prawn fishermen in the North Sea get a lot of waste in their nets as a by-catch. In the past, that waste went overboard while the fish were being sorted, with every chance that it would later be caught once again. That waste is now separated out into Big Bags. In the Netherlands, about 75 fishing vessels are doing this without receiving any reimbursement. They are able to get rid of their Big Bags full of junk in all fishing ports. The bags are then picked up by a refuse collection service.

→ *The number of people taking on the challenge of not using any plastic in the month of July is increasing every year.*



PLASTIC-FREE JULY

In Australia, in 2011, Rebecca Prince-Ruiz wondered why she had so many plastic things in her house and what could be done differently. She decided not to use any single-use plastics for the entire month of July. Colleagues and friends joined the challenge and the Plastic-Free July Challenge was born. There are now more than 2 million people in 159 countries who avoid disposable plastic in the month of July and go looking for alternatives. Plastic-Free July encourages people to 'Choose to refuse single-use plastic during July!'

The concept of Plastic-Free July assumes that all these small steps can have a large effect. The initiative encourages people to change their own behavior and provides tools to encourage others around them, for example at school, to follow their example. The website provides lots of practical information to help members of the general public combat plastic pollution.

One part of the challenge is to make a study of your own trash can at the start of July. Turn the can upside down and spread the trash out over the ground. Analyze the garbage by making stacks (bottles, bags, packaging) and make a note of the numbers and the weight. The next step is to look at each item and see if you can do without it: whether there are alternatives and which items could have been used again. At the end of the month, you repeat this little test to see if you have managed to use less plastic.

Plastic-Free July has developed a toolbox that consists of four steps. The first step is about gathering ideas. On the Plastic-Free July website, people taking part can read about what others have achieved. The second step is to set up a meeting. Organize a Plastic-Free Morning Tea with colleagues or friends to talk about the challenge, for example. The third step is to get organizations on board, for instance schools, markets, and shops. There are lots of inspirational examples available for that, too. The final step is to share the successes you achieve so that you can inspire others.

You can download an action picker from the Plastic-Free July website that provides practical recommendations for eighteen categories of plastic products that you can avoid, such as plastic bags, drinking straws, and fruit that is wrapped in plastic. On top of that, there are recipes for making your own shampoo and toothpaste, for example. Plastic-Free July focuses on providing practical solutions and sharing stories of success.

↓ *After participating in the* Plastic Free July *challenge, many participants change their behavior.*

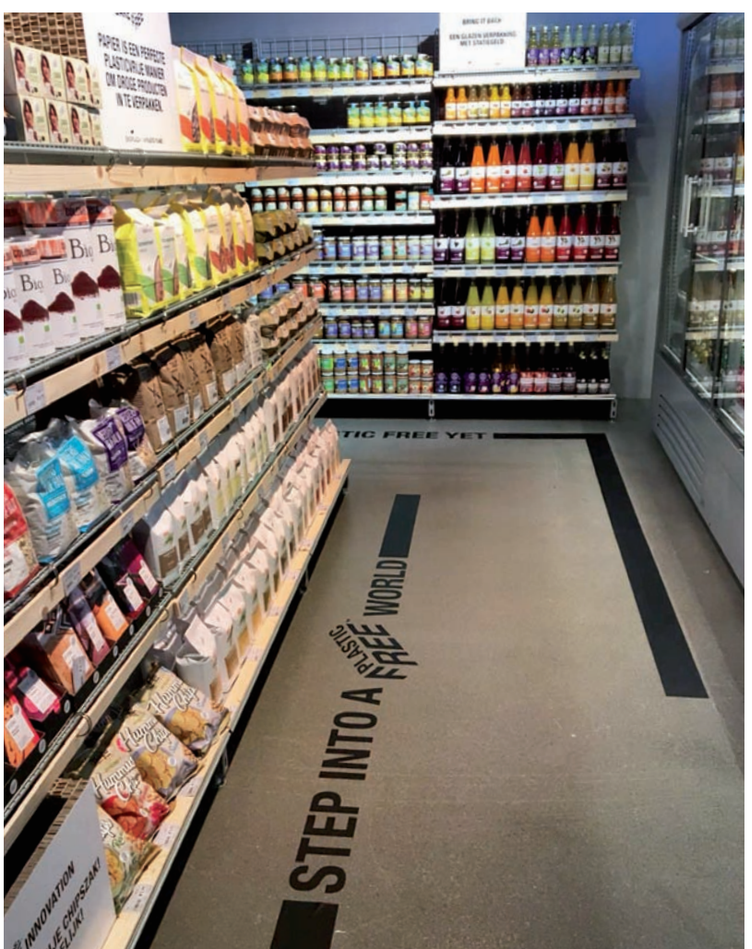
Consumers have an abundance of choice in the major supermarkets—from gluten-free, non-fat, and low-sugar to vegetarian and organic. But the option of buying products without plastic packaging is hardly ever available. One of the first packaging-free shops was opened in September 2014 in Berlin. Whether you're buying muesli, cleaning supplies, sugar, pasta, eggs, or personal care products, you can take the quantity you want in your own bottles, pots, or bags. Everything is paid for by weight and you never have to take more home than you need. These and other plastic-free shops are showing the supermarket chains the way.

PLASTIC-FREE SUPERMARKETS

↓ *Plastic-free supermarkets show that not using plastic is perfectly possible. Dutch supermarket chain Ekoplaza opened this plastic-free shop in 2018.*

Plastic packaging from products that are sold in supermarkets makes a major contribution to plastic soup. Consumers who want to buy products without plastic currently have to make quite an effort. The market is still the simplest way: you can put fruits, vegetables, and other products in your own pots and bags, which is virtually impossible in supermarkets.

The shop in Berlin is meeting a need, and it is not the only one. Over recent years, increasing numbers of plastic-free shops have appeared, all sharing the same zero-waste philosophy: preventing waste by selling products without packaging. Because food products come from the local area, there is no need to pack them up in order to lengthen the shelf life. The shops impose their own requirements on their suppliers. The individual products must not be wrapped in plastic, and the outer bulk packaging must not be made of plastic, either. These kinds of requirements make the local suppliers adapt.



Consumers who are in a hurry opt for easy solutions. The zero-waste concept will not be embraced immediately, particularly in cities, given how addicted people are to the single-use lifestyle and its many on-the-go products. The plastic-free shops have sent an important message, however: they have shown that zero waste is possible.

In 2017, the A Plastic-Free Aisle campaign was stared, calling on the large supermarket chains to set up at least part of their shops to offer plastic-free products. Consumers get a choice and can avoid all that waste plastic. Buying plastic-free goods lets them make sure that the range of options increases.

In 2017, the Dutch organic supermarket chain Ekoplaza replaced three-quarters of its own-brand plastic packaging with degradable or non-plastic alternatives. Nuts, rice, and dried beans have been offered in compostable packaging since 2013. Checks are made for every product to see if reduced plastic use is possible, not only in the shops but in the warehouses, too, where wheeled containers are no longer wrapped in plastic. So plastic use is being rolled back, step by step.

When synthetic clothing materials are washed in a washing machine, hundreds of thousands or millions of microfibers are released. The plastic fibers rinse away with the wastewater. Wastewater treatment plants are not designed to filter out these minuscule plastic particles. Solutions are being sought, on various fronts, for this kind of plastic pollution. Filters, bags, and balls are being developed that may give consumers a chance to act. The industry needs to make a move as well, changing textiles and encouraging washing methods that reduce or prevent this shedding of fibers.

OCEAN CLEAN WASH

↑ *Is there a way to wash clothing made of synthetic materials without shedding fibers? That is the main challenge that the clothing industry worldwide is facing.*

The Plastic Soup Foundation set up Ocean Clean Wash in 2016 to resolve the problem of plastic microfibers. This is an international cooperative venture involving scientists, NGOs, people in the public eye, clothing brands, and textile manufacturers. Brands such as G-Star RAW have also become involved and are searching actively for solutions to what is seen as one of the most difficult causes of plastic soup to tackle. More than 30 fashion chains have been given access to the latest scientific insights through Ocean Clean Wash.

These insights into the critical factors relating to fiber loss have been obtained thanks to the European Mermaids Life+ research program, as well as other sources. The way in which yarns are woven or knitted matters; for example, reinforcing the fibers with coatings, washing at lower temperatures, and the use of liquid detergents can help prevent shedding.

There are also some noteworthy initiatives from the public. The Guppy Friend, a German invention, is a washing bag that goes in the drum. The bag is made of nylon and has a mesh size of 50 microns. Soapy water can get in and out of it, but the fibers are kept inside. The washing bag acts as a filter. The Cora Ball from the United States is a ball that collects dirt during the wash—everything from hairs to microfibers. You can simply pluck the ball clean after the wash. The Cora Ball was inspired by the natural action of corals, which filter minuscule particles out of flowing water. A reusable sheet is being developed in Canada that attracts microfibers during the wash; initial tests with the PolyGone are highly promising.

Legislation to tackle this source of plastic soup is not even on the drawing board. The clothing industry is global; introducing international norms for plastics to deal with fiber shedding is exceptionally complex and not on the agenda anywhere. So, it is all the more important that the industry itself takes responsibility and develops synthetic materials that can be washed in the machine without shedding. Until then, the Guppy Friend, the Cora Ball, and the PolyGone are offering a certain amount of relief.

9

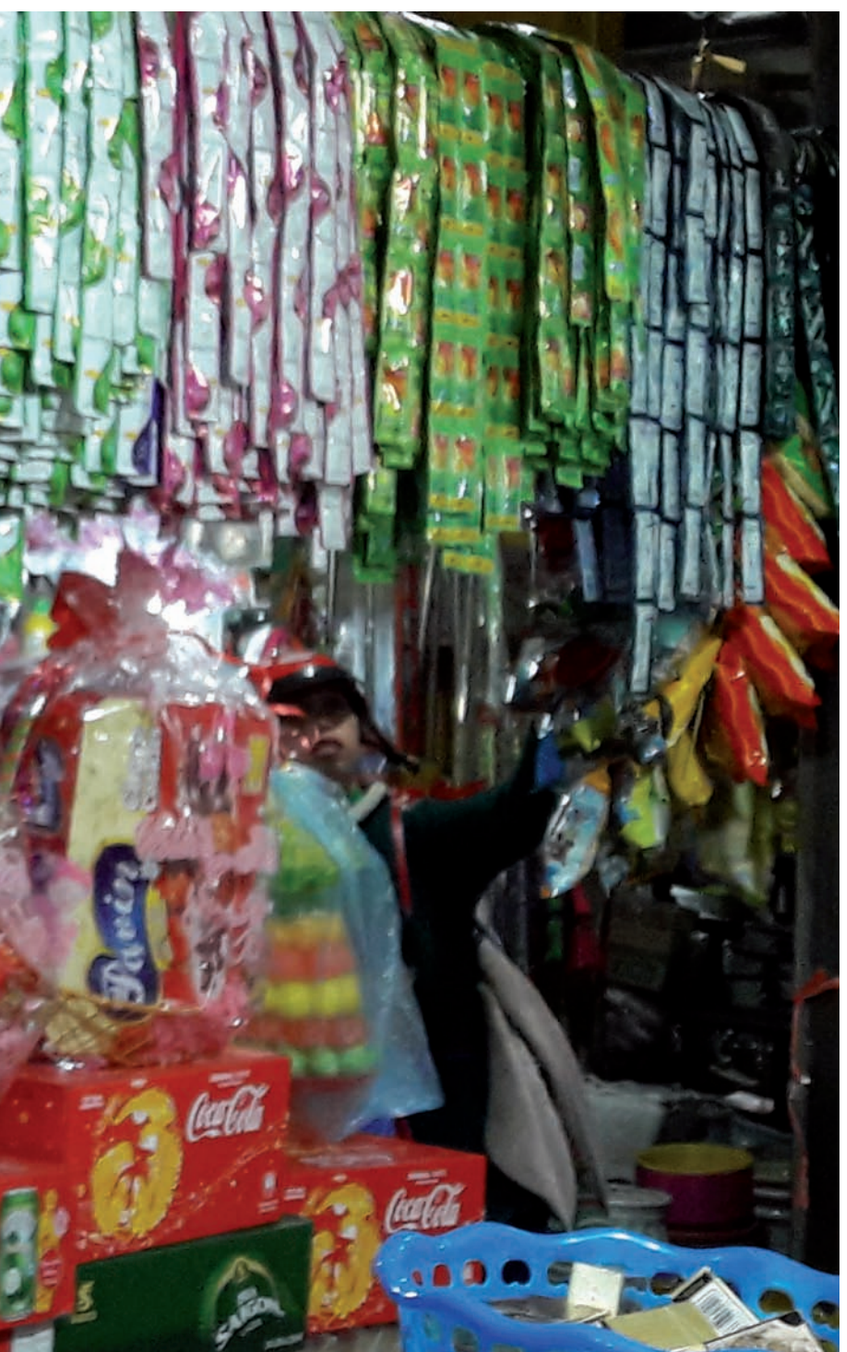
NO TIME TO LOSE

← *Floating plastic, shown here in the Philippines, is not cleared away. Only the plastics that can be resold are fished out.*

LOW-HANGING FRUIT

Plastic ending up in the environment has to be avoided. Asking a few simple questions makes it relatively easy to spot quick wins—the easy pickings that will benefit the environment a lot for relatively little expense. Which plastic items are found most often on beaches? Can we easily do without those things? Are alternatives available? Is it possible to tackle the problem at the source? Are voluntary actions sufficient, or is legislation required? Simple changes can be enough to make significant gains.

↓ *A shop in Vietnam selling products in mini-packages. There are thousands of these shops, largely in areas where people do not have much disposable income.*



In the United States, 500 million plastic drinking straws are used every day. Those straws are used once only, and rarely for longer than twenty minutes. They are essentially unnecessary and there are perfectly acceptable alternative straws made of bamboo or metal. In 2018, only after much external pressure, the fast food chain McDonald's started to test alternatives in a limited number of restaurants in some countries. In the same year, Seattle became the first US city to ban straws and plastic utensils in restaurants and bars.

In South Korea, polystyrene buoys are used in aquaculture. There can be 100,000 of them per square kilometer in the open sea, where they are used for mussel and oyster culture. Under the sun, they slowly crumble away: a single buoy containing a volume of 62 liters can decay into up to 7 million particles. The beaches of South Korea are white because of all the polystyrene, but the simple solutions are not being adopted. The buoys could be replaced with equivalents made from another material, or a system of deposits could be used to make sure that the old buoys are handed back in again. They could be marked with the name of the company, so that they can be called to account if their buoys are found drifting loose.

Unilever sells products such as shampoo and washing powder in small, single-use packages that consist of layers of different materials—in developing countries in particular. The multinational company acknowledges that these packs present a major environmental problem and contribute to plastic soup. Instead of stopping using this type of packaging, Unilever has developed an advanced recycling technology for recycling the mini-packs. It is, however, an illusion to think that those packages, which represent no value, will be collected. In reality, Unilever and other multinationals would rather continue use of the packaging for economic ends than exchange it for a genuinely more sustainable and perfectly achievable alternative, such as tanks out of which the consumers can tap the desired quantities into a bag or tub they have brought themselves.

Even these easy pickings will often not be plucked if short-term economic interests are in the way.

Education and information about plastic soup are indispensable if we want to counteract plastic litter. The relationship between behavior and plastic soup is not difficult to comprehend. Even young children understand that you must not throw plastic away because it can kill animals. Some pertinent questions need to be asked, though. What can you do if education doesn't help and pollution continues to increase? There will always be some groups of people who simply won't allow anyone to tell them what to do. Educating people is very important, but that alone will never be enough.

EDUCATING

Since the 1950s, major multinationals such as Coca-Cola have invested in public information campaigns. These companies have even set up and financed special organizations for the purpose. Keep America Beautiful has been around since 1953 and sister organizations in other countries have been added since. Only the consumer is ever held responsible for littering. The public, therefore, needs to be educated. Plastic soup shows that these campaigns have not been even vaguely effective.

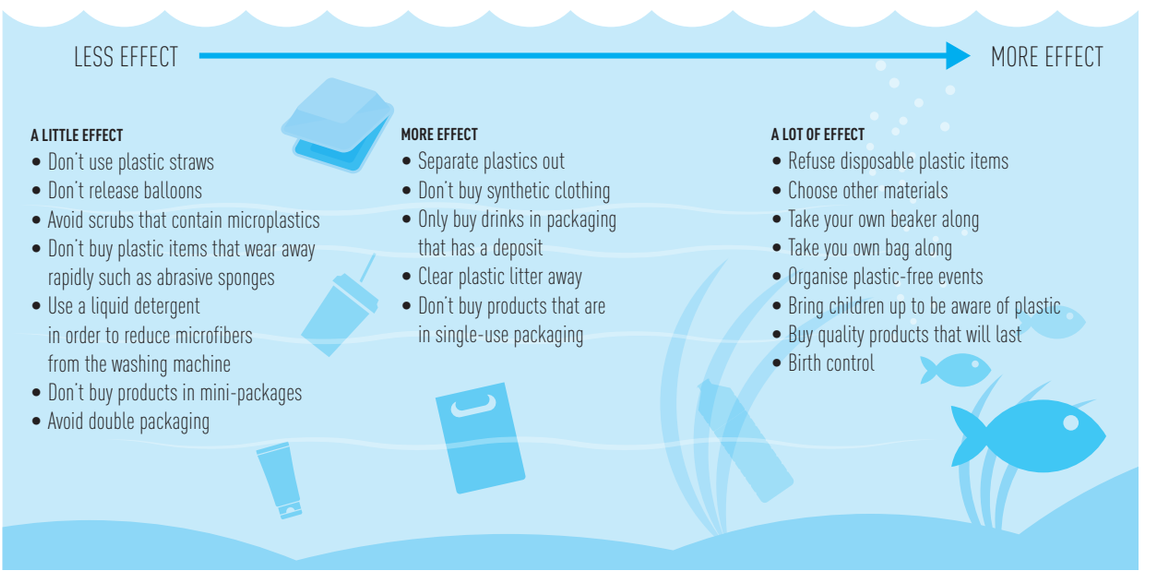
Keep America Beautiful was formed in direct response to a new law in the state of Vermont designed to combat litter, which included a ban on non-refillable bottles. The bill lasted only four years due to intense lobbying from the beverage industry that presented litter as a people's problem. To this very day, organizations such as Keep America Beautiful have the same aims: to educate the general public and—less visibly—to ensure that the production of disposable products, which is growing every year, is not restricted by inconveniences such as laws, deposits, and taxes.

Information campaigns are also an attractive and cheap way for governments to influence behavior. The effect of information and education is generally overestimated, however. Growing environmental awareness is by no means always going to result in the desired, environmentally friendly behavior. In that context, it is important to make a distinction between people who are acting out of their own intrinsic motives and exhibiting the desired behavior pattern after being educated, and those who only act in the environmentally aware way because of external driving forces, for example the 'reward' of getting their deposit back.

Those who study behavior know that the actions of teenagers, in particular, are difficult to affect. Younger people are, after all, busy with things other than simply avoiding litter. What does seem to work well for this target group are extrinsic motivators such as financial stimuli.

Education is extremely worthwhile, but it is much more important to combine it with other methods of combating pollution, such as financial compensation for handing in waste.

→ *What can you do to counteract pollution by plastic, and what has the most effect?*



→ *The Plastic Footprint, for people or for companies, aims to give greater insights into the way plastic is used.*

Every consumer and every company has a plastic footprint. This is a measure that expresses how much plastic you use. Deeper insights are crucial if you are going to be able to reduce that footprint. This can be done not only by reducing the use of plastic, but also by preventing leakage to the environment and encouraging reuse. Not many people realize the interrelationship between the production of plastic and other major environmental problems. The plastic footprint helps in more than just combating plastic soup; if you start using less plastic, you simultaneously reduce your water and carbon footprints.

PLASTIC FOOTPRINT

The Plastic Footprint can be used to help map out the flows of plastic within an organization. This essential first step should result in a much more critical attitude toward plastic. Companies hardly ever report on the use of plastic at present. Consumption of plastic is often a major unknown within the company and reducing plastic use is rarely an explicit objective. The Plastic Soup Foundation and the Impact Centre Erasmus in Rotterdam are developing the Plastic Footprint together with the consultancy firm PwC. A standardized questionnaire gives a picture of ways for dealing with plastics better, and being more aware of them, whether just internally or together with customers and suppliers.

For consumers, there is My Little Plastic Footprint, an app that gives you a picture of your use of plastic in a light-hearted way and points out alternatives. The United Nations Environment Programme is asking people throughout the world to become personally involved and reduce their plastic footprint. This app can help them do that. Users learn about plastic pollution as they go, and they are challenged to reduce their personal footprints. The app was created by Smäll (Barcelona), Ocean Recovery Alliance (Hong Kong), EA (Geneva), and the Plastic Soup Foundation (Amsterdam).

Plastic has a large carbon footprint and contributes to the greenhouse gas emissions that are warming Earth. Eight percent of global oil production is used for plastics; half of that is for the energy that is required to produce plastics. To give an example, 17 million barrels of oil are needed every year to produce plastic bottles in the United States alone. Further millions of barrels of oil are needed for transporting the filled bottles to shops and cooling them there. In addition, a great deal of water is needed for the production of plastic: bottling one liter of water in a single plastic bottle requires about three liters of water.

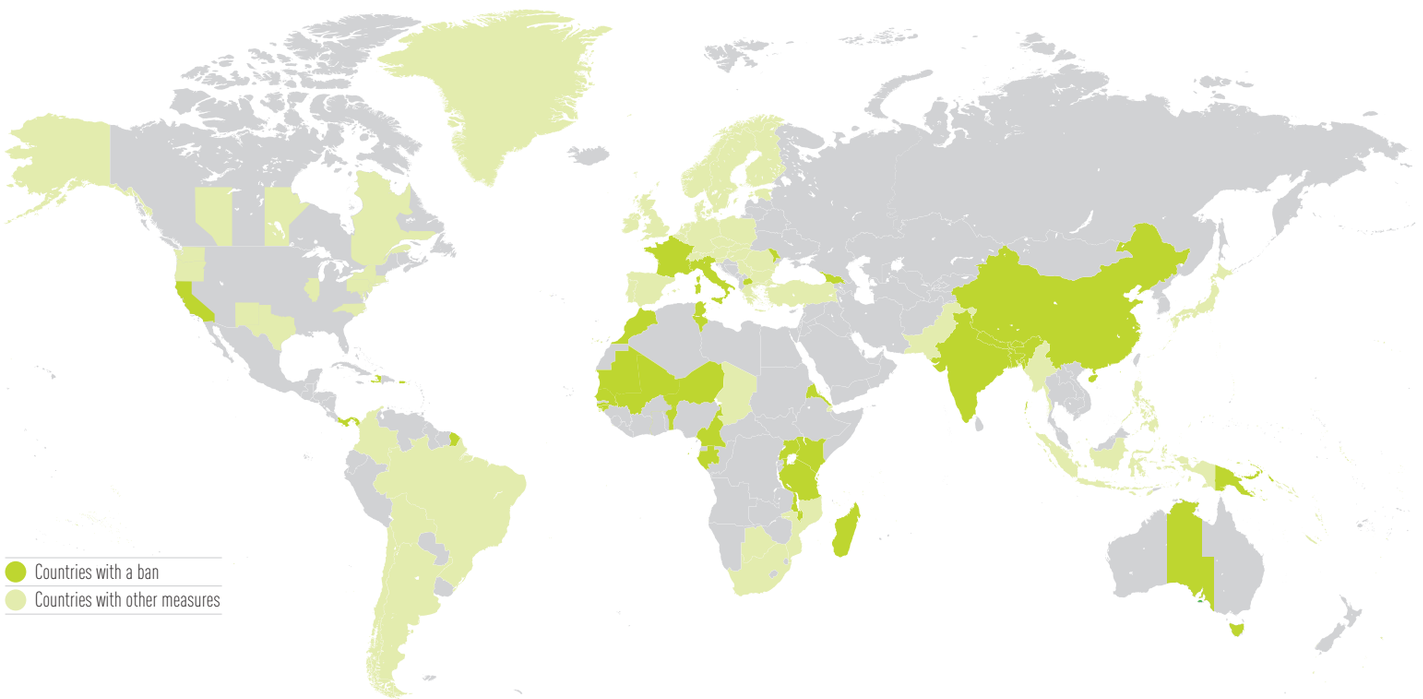
Any direct use of plastic that is avoided generates major gains for the environment.

It is estimated that more than one million plastic bags are used every minute worldwide. Bags that are discarded or blown away litter the streets, get caught in trees and shrubs, block waterways, get eaten by animals, and contribute to plastic soup. They are a major environmental problem, but one that is relatively easy to tackle. A growing number of cities, provinces, and countries are taking measures. Plastic bags are being banned entirely, or customers are being charged for them. Those measures, once they come into effect and are enforced, immediately lead to a large reduction in the number of bags blowing around.

LIGHTWEIGHT PLASTIC BAGS

← *This plastic lump weighing 52 kilograms has the shape of a camel's stomach. The camel's carcass was found at a dumping place for dead camels in the United Arab Emirates.*

↑ *Because of their light weight, plastic bags easily blow out of landfills. They get eaten by animals, clog up waterways, or end up in the sea.*



↑ *Countries that have banned lightweight plastic bags or taken other measures (2017). There are more of them every year.*

Marine turtles see plastic bags floating in the water as jellyfish. This effect has received a lot of attention, but there are other reasons for taking measures against plastic bags.

In 2002, Bangladesh became the first country in the world to ban thin plastic bags. For that particular country, the key reason was that the waste plastic was blocking drainage systems everywhere. In Bangladesh, it rains a lot and it rains often. If the rainwater cannot be drained away, flooding is the result. The major floods of 1998 were reckoned to be 80 percent ascribable to blockages caused by waste plastic.

In Delhi, the capital of India, plastic bags and other disposable plastic items have been banned since the beginning of 2017. The ban was introduced in order to combat air pollution caused by illegal incineration of plastics.

In the United Arab Emirates, plastic accounts for half of all deaths among camels. The animals eat litter and garbage. Lumps weighing up to ten or even sixty kilograms have been found in their stomachs. Because the plastic cannot get out of the stomach, it collects and grows until the animal dies of starvation. Plastic bags have been banned in the United Arab Emirates since 2013, but there is no effective enforcement.

Kenya banned the 100 million plastic bags that are used in the country annually yet again in 2017, after earlier attempts had little success. Dumped plastic bags are a health hazard, among other issues. Plastic litter can fill with water, creating an ideal breeding ground for mosquitoes that can transmit dengue and malaria. Blocked drains are another cause of stationary water.

The measures being taken vary from one country to the next and address production, imports, sales, distribution, or the weight of plastic bags. In some countries, consumers are required to pay for plastic bags. Alternatives such as paper bags are sometimes also covered by these rules, but using paper bags runs afoul of different environmental concerns. What is important, above all, is that consumers start using their own sturdy shopping bags again.

Chucking the waste that is generated on ships overboard is simple and cheap. Illegally dumped waste from shipping and fishing is responsible for about 20 percent of plastic soup, although that percentage does vary a great deal from one region to the next. MARPOL, the United Nations treaty to prevent waste from ships, forbids plastic and other waste from being dumped at sea. With the exception of organic waste, all garbage must be handed in back on dry land. MARPOL leaves the precise implementation of this rule to the ports.

SHIPS' WASTE IN THE PORTS

→ *Relatively few vessels separate their waste flows onboard; most bring all their waste to shore unseparated. Too many ships still dump their waste at sea.*

↑ *You can sometimes see that the waste washed ashore comes from ships. In this case, fishing baskets on the coast of Galloway in Scotland.*

In the tightened-up Annex V to the international MARPOL treaty, which has been in force since 2013 and covers waste from seagoing vessels, there is a general ban on discharges. Deliberately dumping waste in the sea is forbidden. There are requirements for a waste management plan to be present onboard, and waste records have to be kept. However, ships weighing less than 400 tons are excluded from this mandatory registration of waste. The majority of fishing vessels are therefore not required to be able to show where they left their waste.

MARPOL leaves the responsibility for the organization of reception of ships' waste to the port authorities. Although countries are supposed to ensure that the requisite facilities are present, that is often not the case, especially in smaller ports. There are also major differences between ports in terms of the waste collection rules. A ship in port will sometimes have to deal with multiple parties and jump through a lot of administrative hoops, whereas in another port the waste can be handed over more cheaply and more efficiently. There are ports where the ships have to pay separately for refuse collection, and others where it is free or included in the port fees.

Port authorities throughout the world have, to date, not really succeeded in preventing ships from dumping their waste illegally. If the authorities ensure that ships are able to hand in their refuse in any port and also require every ship to do so before leaving port again, gains can be made in the battle against plastic soup.

There are other measures that can be taken relatively simply, too: making sure that the ships' waste policies in the ports are harmonized so that there can be no economic, administrative, or organizational reason for ships not using the facilities that are present; and making sure that the existing rules are being observed seriously.

DEPOSITS

→ *Multinationals such as Coca-Cola have always vigorously opposed the introduction of deposits. A slightly more flexible attitude has only sometimes started to appear since 2017.*

Consumers need a financial incentive to not litter. Deposits are a prime example. Currently, lots of plastic bottles end up in the environment, but if consumers get money back after handing back their empties, many of them will do it. And if those drink packaging materials do end up on the street, there are always people who will collect them to earn a little money. Charging deposits has proved to be an extremely effective system in the battle against plastic soup. It is relatively easy to introduce and yields results right away. Nevertheless, the world's soft-drink giants and supermarkets are resisting it; for them, other considerations weigh more heavily.

↑ *In countries where a deposit has been introduced, more than 90 percent of bottles and cans are handed back in. This is the case in almost forty countries so far.*

Both PET bottles and metal cans can be used for making more PET bottles and metal cans, respectively. The waste must not be mixed in with other garbage, however. Deposits provide a nicely controlled return stream of the same material. Optimum recycling goes hand in hand with deposits, and very little raw material is lost. A sturdy PET bottle can be cleaned after being collected, then refilled and sold again—up to forty times.

Soft-drink multinationals such as Coca-Cola, however, have a history of resisting the use of deposits with every means at their disposal. In Germany, the industry has filed more than 7,000 lawsuits in an effort to sabotage a nicely functioning deposit plan. They claim, for example, that the deposits are merely a means to an end, not a goal in their own right. Alternative proposals are also presented, such as improved information to consumers. A key argument is that the soft-drink manufacturers do not want to sell their products at a price that appears higher, even if the consumers do get their deposit back later. The supermarkets, in turn, are cautious about the extra work and the space required.

There are alternative options as well as deposits for returning bottles at a premium. In Beijing, for instance, there are more than 5,000 machines in public areas such as metro stations where bottles can be handed in. In return for the bottles, you get money or a ticket for public transportion. That is paid for from the bottles' value in the recycling industry.

Bottlers are proud of their environmental efforts, such as reducing consumption of water, energy, or materials by producing even more lightweight PET bottles. Their contribution to litter and plastic soup is, however, rarely included in the calculation. The costs of cleaning up are shifted to residents and the authorities. In addition, many costs of plastic soup will be paid for by future generations. Short-term gains and the interests of shareholders are thus preventing war being waged effectively against plastic soup. Governmental authorities are often not strong enough to force the introduction of deposits on plastic bottles.


Coca-Cola
Coca-Cola zero
Fanta
CITRON FRAPPE
Fresh tea
Peach
Vittel
ACTIFF
liquide vaisselle
afwasmiddel
1000 ml
LIMONADE
STEENLE
Tropica

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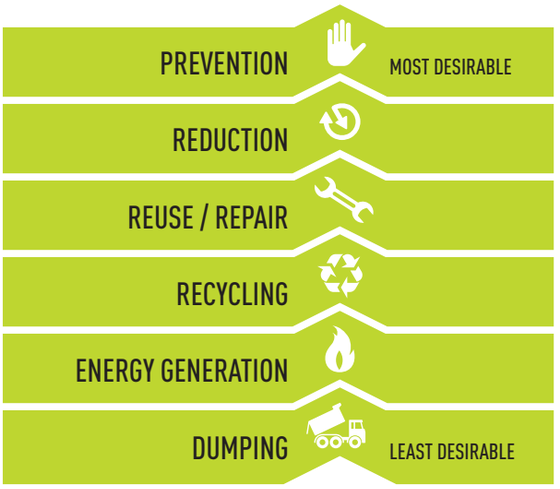
TURNING THE TIDE



↑ *There are good ways and bad ways to deal with garbage. Dumping, the least desirable in the list, is the most common method worldwide.*

REDUCE, REUSE, RECYCLE

These three R's are a handy and widely used mnemonic for helping you to produce less waste. Consumers are encouraged to use fewer products, to use existing products again as much as possible, and to promote recycling. The principle of the three R's targets what is referred to as the waste hierarchy: some of the R's outweigh the others. Preventing waste in the first place has the highest priority, followed by repeated use. Recycling is only the final option. Applying these three R's is necessary if plastic soup is to be tackled, but is not enough in itself. More R's are going to need to be taken into account, and not only by consumers.

Reject. Refuse to accept or buy plastic products that could be harmful. You are an individual and you always have a choice. There is absolutely no need for a plastic straw in a milkshake. Cook for yourself instead of buying ready meals. If you really try hard, you can live without a great deal of plastic. The purchasing policies of governmental authorities, institutions, and companies are very important. If large buyers impose requirements on the products, the suppliers will make changes.

Redesign. Packaging plastic needs to be fundamentally redesigned so that it can either be reused, recycled, or composted. Another example of redesign is the face scrubs and toothpastes in which plastic abrasives are replaced with natural ingredients.

Repair. Make sure that you produce and purchase products that are easy to repair. That extends the service life. Smartphones and other electronics can be designed modularly, so that there is no need to replace an entire product: just replace the defective module. Refurbished devices are the first step. That saves a lot of waste.

Replace. Replace a product that you would only use once with one that you can keep reusing. Ask yourself if there is a suitable alternative for every product that you buy. Take your own shopping bag or tumbler with you, for example.

Recover. If recycling seems to be impossible, there is still the option of reclaiming energy from the plastic waste in incinerators. The waste hierarchy shows us that this option must only be used if none of the others are feasible.

Restore. Pick up what others leave behind and take an active role in restoring your surroundings. Help to clear away plastic litter, not just in a joint action once a year but every day, for instance on your way to school or work. This has a direct effect as well as working preventively: other people are less likely to discard things in a clean environment than a dirty one.

← *Think globally, act locally. By making a positive difference locally—even if it's just picking up a single piece of plastic—you help create a better environment for everyone.*

Measures are being taken to tackle plastic soup, binding ones in some cases, that all have underlying principles. Regulations, international treaties, and action plans often refer to such principles. There may be, for instance, a stipulation that the best available technology must be used, that the plans must be based on the latest scientific knowledge, or that countries have an obligation to work together constructively. Generally accepted principles are crucial in the battle against plastic soup. Together, they constitute the logic that underpins the desired measures that the countries are taking.

KEY PRINCIPLES

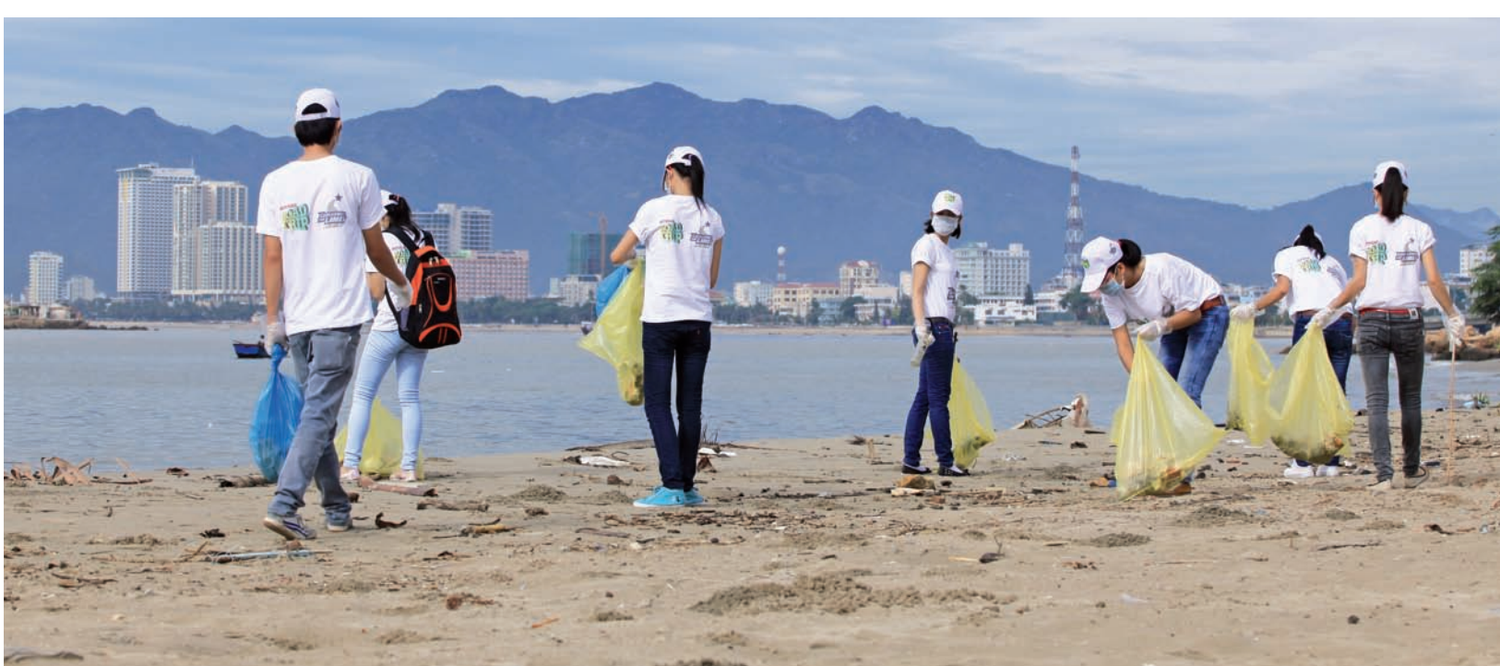
↓ *Plastic keeps washing up on beaches, even with frequent cleanups. The only things that really help are reducing plastic production and changing usage.*

The principle of *sustainable development* stated in many treaties aims for economic and social development without detriment to future generations. In essence, development is therefore dependent on the ability of Earth's ecosystems to take the burden.

If there is a realistic chance of severe and irreversible environmental damage, the lack of hard scientific evidence must not be used as an argument for postponing regulations or other measures. This is the *precautionary principle*. Plastic soup itself can only be cleared up to a limited extent. The one thing that really helps is preventing yet more plastic from ending up in the environment and increasing the damage further. The precautionary principle also applies to requirements imposed on the production of plastic. This could include banning certain chemical additives or plastics that cannot be recycled.

In *the pollutor pays* principle, the person who pollutes the environment is financially responsible for that pollution and for eliminating or reversing it. If it is not possible to apply this, society then has to pay the costs associated with that pollution. A typical feature of environmental problems is that they are generally shifted onto the community at large or onto future generations.

It is more efficient to tackle pollution at the source than to deal with the negative consequences that turn up later. This is referred to as the *source principle*. Plastics leaking out into the environment should be stopped early on and not after the event, for instance by cleaning up beaches. There is rarely a single source for plastic soup. There are numerous sources and various types, spread across many countries. The source principle can, however, be effectively applied for each individual type of waste. Take applying a levy on plastic bags, for example, or banning microplastics in care products.



AUTHORITIES' MOVE

Individual countries each bear some of the responsibility for plastic soup in the oceans. On land as well as at sea, plastic litter is associated with increasing levels of environmental damage and social costs. The role of national and other authorities in the battle against plastic soup is crucial, because they are the only ones who can draw up and enforce legislation and regulations. Plastic soup is, however, a relatively new topic for governments, and an awkwardly multifaceted one. An effective approach to the problem is not possible without cooperation from industry, but the players there will quickly resist any measures that they see as overly rigorous and petty. The measures that are taken voluntarily turn out, however, to have far too little effect. The authorities themselves are still looking to see how they can best fulfill their role.

← *Our efforts to clean up plastic from the environment will never keep up unless governments succeed in turning off the tap.*

Countries' constitutions generally state that environmental protection is a task for the government and that the government is obliged to promote the right to health protection. The negative consequences of plastic soup for the environment and the potential damage to public health provide sufficient legitimacy for preventive interventions, even if not everything is scientifically proven to the last detail.

Thanks to their jurisdiction over their own land area, coasts, and waters, as well as international agreements, countries have the requisite leverage to tackle plastic soup. Other problems lie in wait: plastic in water has so far been regarded as a harmless material and overarching legislation for this new problem is not yet in place.

Authorities do have a range of instruments at their disposal. They can, for instance, impose levies, introduce bans, make agreements for certain products to be taken off the market within a given time frame, impose penalties, reward desirable behavior, and make agreements with neighboring countries and others. Concrete measures that have been taken so far are designed to rein in the worst excesses. A series of countries have already banned the free plastic bag, for example.

The introduction of umbrella legislation aimed at prevention, reduction, and management of plastic litter will make it simpler to define the details of specific rules that are based on identifying the key sources. The various sources require targeted solutions, and governments can bank on getting the necessary backing from the people affected. Take tackling discarded bottles by introducing a deposit scheme, for instance.

Authorities can impose rules on private companies, which in turn benefit from clarity, so that they and their competitors understand all of the regulations. The reticence of governments to actually impose such rules is one of the major causes of plastic soup.

→ *Governments have an arsenal of possibilities for combating plastic pollution, but so far they are rarely used.*

In September 2015, the United Nations drew up a sustainable development agenda for 2030. That agenda contains 17 sustainability objectives, the familiar *Sustainable Development Goals*, that apply for all member states. The UN's members have to ensure that the goals are transposed into national policy. This is a best-effort obligation, as the agreements that were made are not legally binding. The international sustainable development agenda is a key outcome of the environment summit that was held in Rio de Janeiro in 2012. The fourteenth goal relates to sustainable management of the seas and oceans, and underwater life. This goal also covers the war against plastic soup.

↑ *Humans created the immense problem of plastic soup. Only humans can solve it.*

→ All countries made agreements in 2017 to intensify their efforts and prevent pollution of the oceans.

GLOBAL SUSTAINABILITY TARGETS

Managing the oceans sustainably is essential. The oceans cover more than two-thirds of the surface of the globe and contain 97 percent of all its water. More than 3 billion people depend on them for their food and their livelihoods. The oceans are vast reservoirs of biodiversity and provide much of the oxygen that we breathe. But the oceans are under pressure, and not only from plastic soup. Scientists fear that there may be tipping points in our oceans' health; if those are reached, recovery may no longer be possible.

The fourteenth sustainability goal aims to prevent and greatly reduce pollution in the seas, particularly where the sources are land-based. Given the estimate that 80 percent of the waste in the seas comes directly from land, agreements about clean water and hygiene are also applicable. The sixth sustainability goal stipulates that the quality of fresh water must be improved. Pollution of inland waters must be reduced and a great deal more water must be purified so that it can be reused safely. One element of the agreements is that international cooperation in these areas needs improving, particularly in order to support developing countries.

The United Nations Environment Programme calculated that plastic soup is costing at least 13 billion dollars a year worldwide. These costs are not seen in the annual accounts of companies. The environment agency believes that the costs of plastic pollution are being passed on and that companies should be made accountable for their use of plastic.

People cannot survive without the oceans. The reverse is now also true: the oceans can never recover and become healthy again without human intervention. Current global sustainability objectives will help achieve this. But, at the same time, they are falling woefully short. Without binding international agreements, there is plenty of space to continue with the old, polluting ways, unpunished.

Who is responsible for a plastic bottle floating in the ocean? That bottle will have had a number of owners. First, there was the manufacturer, then the bottler, the brand owner, the shopkeeper, and finally, the consumer. The manufacturer, bottler, brand owner, and shopkeeper can all argue that they have nothing to do with that floating bottle and that the responsibility resides with the consumer who bought it and disposed of it carelessly. But the buyer is anonymous and cannot be addressed directly. There are, therefore, substantial gains to be made from making manufacturers responsible for their products in the waste phase.

RESPONSIBLE PRODUCING

Extended producer responsibility (EPR) aims to reduce the overall environmental burden of a product. Producers are deemed responsible for the entire lifecycle of their products, including the waste phase. This strategy has been embraced by a relatively large number of enterprises in an increasing number of countries. The products are separated out after use and collected or returned so that the raw material can be used again.

Companies in a specific sector often outsource the collection to specially created organizations that they finance jointly. This mechanism helps bring the circular economy one step closer. Until now, producers have put the emphasis on reclamation of valuable raw materials, such as the materials from discarded electronic products. Countries that use this mechanism achieve higher recycling percentages.

EPR as a tool should result in companies modifying the designs of their products to encourage sustainability, optimum recycling, and reuse. Other goals are conceivable, too: making sure that broken items can be repaired more easily or that certain proportions of a product are made from recycled material. EPR is a principle that is adopted relatively often for consumer electronics, car tires, batteries, and other products from which usable raw materials can be reclaimed. A return system for PET bottles, for instance, could be considered.

EPR is, however, scarcely used for the products that contribute most heavily to plastic soup. Much of plastic litter has little or no value, and collecting it is tricky to organize. In most cases, EPR is implemented on a voluntary basis. And companies will only do it if they get something out of it.

Companies can ensure that their products no longer end up discarded in the environment as waste. This can be achieved by making the prevention of waste in the environment an important criterion that needs to be embraced while weighing up all the environmental costs. To achieve this, all that is needed is to apply EPR more broadly and embed it in a legal framework.

↓ *What makes plastics especially harmful to life on Earth is that they are not biodegradable.*

Plastic soup is recognized internationally as one of the biggest environmental problems on the planet. There is now a patchwork of rules, action plans, and strategies for tackling it. Some are national, others regional or international. But despite these good intentions and promises, the initiatives are having little or no effect; plastic soup is continuing to get worse. What is missing is an international treaty targeting plastic soup in particular, one in which states are obliged to take effective measures and work together to achieve defined objectives.

INTERNATIONAL TREATY

↑ *The artist Angelika Heckhausen from Germany made* Firework *from pieces of clothespins that were found on the beach.*

Plastic soup is an environmental problem that is largely beyond the jurisdiction of individual countries. No state can be held responsible for the plastic that is floating in the middle of the oceans. The need to tackle plastic soup internationally is acknowledged by all, but the existing international treaties fall short. Some treaties focus on tackling pollution, others on protection of biodiversity, yet others on banning specific substances. No single treaty addresses tackling plastic soup itself.

A significant shortcoming in the existing international treaties is that plastic coming from the land is not addressed. It is generally assumed that about 80 percent of the plastic in the seas comes from land and about 20 percent is caused by shipping and fishing.

Agreements about elements such as reducing the production and use of plastic, waste management and recycling, banning harmful chemicals, and trade restrictions can only be made at the international level. Existing treaties can be amended to achieve this. It is also possible to use the options in the United Nations Convention on the Law of the Sea (UNCLOS) to create new and binding agreements about specific topics such as plastic soup. A third option would be a new and unrelated international treaty.

The United Nations Environment Assembly (UNEA), attended by all the environment ministers, agreed in December 2017 to establish an international working group tasked with identifying legally binding options for combating plastic soup. A new treaty under its aegis could monitor the transposition of international agreements about plastic soup into national legislation and regulations. It could also help countries work together better and adopt a much more active approach. A separate fund could support developing countries in this regard.

There is also another reason why an international treaty about combating plastic soup is extremely important. It would mean worldwide recognition of an environmental problem that is affecting biodiversity to an increasing extent, is associated with health risks, and is causing an unprecedented number of social costs. We must not saddle future generations with the plastic soup crisis.

ACKNOWLEDGMENTS

A great deal has been published about plastic soup in recent years. The research results are receiving a lot of media attention and are being shared worldwide. The information and infographics in this book are based on recent scientific data and insights.

This book could never have been produced in this form without the willing and expert assistance of a large number of people who are involved in the issue of plastic soup and those who selflessly made their photographs available. We would particularly like to thank Jeroen Dagevos, Edwin Foekema, Linda Gottmer, Heather Leslie, Marlies van Maarseveen, Harmen Spek, Sanja de Vries, Maria Westerbos, Tristan Wolters, and Erik Zettler.

PHOTO CREDITS

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