Plastic Pollution Solution

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How We Can Stop Plastic Pollution in the United States and Around the World

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This book is dedicated to my grandchildren and to future generations of inhabitants of the planet Earth.

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Introduction

"Water and air, the two essential fluids on which all life depends, have become global garbage cans."

–Jacques-Yves Cousteau, Legendary French Oceanographer

"I only feel angry when I see waste. When I see people throwing away things we could use."

–Saint Mother Teresa

"Preserve and cherish the pale blue dot, the only home we've ever known."

—Carl Sagan

"Plastics."

Advice from Mr. McGuire to Dustin Hoffman's Benjamin, he only had one word for the young college graduate. Movie, *The Graduate,* 1967.

"Plastic pollution is a global issue: killing wildlife, contaminating our oceans and waters, and lasting far longer than it is used."

–Leonardo DiCaprio, actor and environmental activist.

Plastic is a recently developed material. Before World War II, plastic was not very common. Now plastics are everywhere. Plastic bags are in our oceans and streams. Plastic toys are in our trash and landfills. We are in the midst of the Plastic Age.

The planet has endured other stages of human development. The Stone Age was a prehistoric period during which stone was widely used to make tools with an edge, a point, or a percussion surface. The stone age lasted for roughly 3.4 million years, and ended between 4,000 BC and 2,000 BC, with the advent of metal working.[1]

The melting and smelting of copper marks the end of the Stone Age. In Western Asia, this occurred by about 3,000 BC, when bronze became widespread. The term Bronze Age is used to describe the period that followed the Stone Age.

The third period of human development is known as the Iron Age.

The duration of the Iron Age varies depending on the region under consideration. It is defined by archaeological convention. The Iron Age began when the production of iron or steel has advanced to the point

[1] *Natural History Museum* magazine, August 18, 2010.

where iron tools and weapons replace their bronze equivalents in common use.

The Bronze Age is a historic period, lasting approximately from 3300 BC to 1200 BC, characterized by the use of bronze, the presence of writing in some areas, and other early features of urban civilization.[2] The Bronze Age is the second principal period of the three-age system proposed in 1836 by Christian Jürgensen Thomsen for classifying and studying ancient societies and history.

An ancient civilization is deemed to be part of the Bronze Age because it either produced bronze by smelting its own copper and alloying it with tin, arsenic, or other metals, or traded other items for bronze from production areas elsewhere. Bronze is harder and more durable than the other metals available at the time, allowing Bronze Age civilizations to gain a technological advantage.

While terrestrial iron is naturally abundant, the higher temperature required for smelting, 1,250 °C (2,280 °F), in addition to the greater difficulty of working with the metal, placed it out of reach of common use until the end of the second millennium BC. Tin's low melting point of 231.93 °C (449.47 °F) and copper's relatively moderate melting point of 1,085

[2] History.com.

°C (1,985 °F) placed them within the capabilities of the Neolithic pottery kilns, which date back to 6,000 BC and were able to produce temperatures greater than 900 °C (1,650 °F).[3] Copper and tin ores are rare, since there were no tin bronzes in Western Asia before trading in bronze began in the 3rd millennium BC. Worldwide, the Bronze Age generally followed the Neolithic period, with the Chalcolithic serving as a transition.

Bronze Age cultures differed in their development of writing. According to archaeological evidence, cultures in Mesopotamia (cuneiform script) and Egypt (hieroglyphs) developed the earliest practical writing systems.

The Plastic Age

We are now in the Plastic Age. While stone, bronze and iron are minerals, their use does not significantly adversely affect the environment.

History of Plastics

Plastic is a word that originally meant “pliable and easily shaped.” It only recently became a name for a category of materials called polymers. The word poly-

[3] History.com.

mer means “of many parts,” and polymers are made of long chains of molecules. Polymers abound in nature. Cellulose, the material that makes up the cell walls of plants, is a very common natural polymer.

Over the last century and a half, humans have learned how to make synthetic polymers, sometimes using natural substances like cellulose, but more often using the plentiful carbon atoms provided by petroleum and other fossil fuels. Synthetic polymers are made up of long chains of atoms, arranged in repeating units, often much longer than those found in nature. It is the length of these chains, and the patterns in which they are arrayed, that make polymers strong, lightweight and flexible. In other words, it’s what makes them plastic and pliable.

These properties make synthetic polymers exceptionally useful, and since we learned how to create and manipulate them, polymers have become an essential part of our lives. Especially over the last 50 years plastics have saturated our world and changed the way that we live.

The First Synthetic Plastic

The first synthetic polymer was invented in 1869 by John Wesley Hyatt. Phelan & Collender, a New York firm, advertised a $10,000 reward for a suitable replacement for ivory. The growing popularity of bil-

liards had put a strain on the supply of natural ivory, obtained through the slaughter of wild elephants.[4] By treating cellulose, derived from cotton fiber, with camphor, Hyatt discovered a plastic (celluloid) that could be crafted into a variety of shapes and made to imitate natural substances like tortoise shell, horn, linen and ivory.

This discovery was revolutionary. For the first time human manufacturing was not constrained by the limits of nature. Nature only supplied so much wood, metal, stone, bone, tusk, and horn. But now humans could create new materials. This development helped not only people but also the environment. Advertisements praised celluloid as the savior of the elephant and the tortoise. Plastics, their inventors believed, could protect the natural world from the destructive forces of human need.

The creation of new materials also helped free people from the social and economic constraints imposed by the scarcity of natural resources. Inexpensive celluloid made material wealth more widespread and obtainable. And the plastics revolution was only getting started.

[4] *Encyclopedia Britannica.*

The Development of New Plastics

In 1907 Leo Baekeland invented Bakelite, the first fully synthetic plastic, meaning it contained no molecules found in nature.[5] It was developed by Leo Baekeland in Yonkers, New York in 1907, and was patented on December 7, 1909.[6] Baekeland was already wealthy due to his invention of Velox photographic paper.

Baekeland had been searching for a synthetic substitute for shellac, a natural electrical insulator, to meet the needs of the rapidly electrifying United States. Bakelite was not only a good insulator; it was also durable, heat resistant, and, unlike celluloid, ideally suited for mechanical mass production. Marketed as "the material of a thousand uses," Bakelite could be shaped or molded into almost anything, providing endless possibilities. By 1910, Baekeland was producing enough material in the U.S. to justify expansion. He formed the General Bakelite Company of Perth Amboy, NJ as a U.S. company to manufacture and market his new industrial material and made overseas connections to produce it in other countries.

Hyatt's and Baekeland's successes led major chemical companies to invest in the research and de-

[5] *Encyclopedia Britannica*.
[6] .U.S. Patent 942699A.

velopment of new polymers, and new plastics soon joined celluloid and Bakelite. While Hyatt and Baekeland had been searching for materials with specific properties, the new research programs sought new plastics for their own sake and worried about finding uses for them later.

Plastic Explosion

World War II necessitated a great expansion of the plastics industry in the United States as industrial might demonstrated that it was as important to victory in war as military success. The need to preserve scarce natural resources made the production of synthetic alternatives a priority. Plastics provided those substitutes. Nylon, invented by Wallace Carothers in 1935 as a synthetic silk, was used during the war for parachutes, ropes, body armor, helmet liners and more.[7] Plexiglas provided an alternative to glass for aircraft windows. A *Time* magazine article noted that because of the war, "plastics have been turned to new uses and the adaptability of plastics demonstrated all over again."[8]

During World War II plastic production in the United States increased by 300%. The surge in plas-

[7] Science History Institute.
[8] *Harper's Magazine,* August, 1942, p. 306.

tic production continued after the war ended. After experiencing the Great Depression and then World War II, Americans were ready to spend again, and much of what they bought was made of plastic. According to author Susan Freinkel, "In product after product, market after market, plastics challenged traditional materials and won, taking the place of steel in cars, paper and glass in packaging, and wood in furniture." The possibilities of plastics gave some observers an almost utopian vision of a future with abundant material wealth thanks to an inexpensive, safe, sanitary substance that could be shaped by humans to their every whim.

Growing Concerns about Plastics

In the postwar years there was a shift in American perceptions as plastics were no longer seen as entirely positive. Plastic debris in the oceans was first observed in the 1960s, a decade in which Americans became increasingly aware of environmental problems. Rachel Carson's 1962 book, *Silent Spring*, exposed the dangers of chemical pesticides. In 1969 a major oil spill occurred off the Santa Barbara, California coast and the polluted Cuyahoga River in Ohio caught fire, raising concerns about pollution. As awareness about environmental issues spread, the persistence of plastic waste began to trouble Americans.

Plastic also gradually became a word used to describe that which was cheap, flimsy, or fake. In *The Graduate*, one of the top movies of 1967, Dustin Hoffman's character was urged by an older acquaintance to make a career in plastics. Audiences cringed along with Hoffman at what they saw as misplaced enthusiasm for an industry that, rather than being full of possibilities, was a symbol of cheap conformity and superficiality.

Plastic Problems: Waste and Health

Plastic's reputation fell further in the 1970s and 1980s as anxiety about waste increased. Plastic became a special target because, while so many plastic products are disposable, plastic lasts forever in the environment. It was the plastics industry that offered recycling as a solution. In the 1980s the plastics industry led an influential drive encouraging municipalities to collect and process recyclable materials as part of their waste-management systems. However, recycling is far from perfect, and most plastics still end up in landfills or in the environment. Grocery-store plastic bags have become a target for activists looking to ban one-use, disposable plastics, and several American cities have already passed bag bans. The ultimate symbol of the problem of plastic waste is the Great Pacific Garbage Patch, which has often been

described as a swirl of plastic garbage the size of Texas floating in the Pacific Ocean.[9]

The reputation of plastics has suffered further because of a growing concern about the potential threat they pose to human health. These concerns focus on the additives (such as the much-discussed bisphenol A [BPA] and a class of chemicals called phthalates) that go into plastics during the manufacturing process, making them more flexible, durable and transparent. Some scientists and members of the public are concerned about evidence that these chemicals leach out of plastics and into our food, water and bodies. In very high doses these chemicals can disrupt the endocrine (or hormonal) system. Researchers worry particularly about the effects of these chemicals on children and what continued accumulation means for future generations.

There are at least ten times more plastic polluting the Atlantic Ocean than previously believed a new study has found.[10] The National Oceanography Center (NOC) study, the first to measure the "invisible" microplastics beneath the surface of the entire Atlantic Ocean, found that there were between 12-21 million metric tons (approximately 13-23 million U.S. tons) of

[9] National Geographic Society.
[10] National Oceanographic Center, Southampton, England.

them floating in the top 200 meters (approximately 656 feet under the surface. According to the National Oceanic and Atmospheric Administration, it takes a plastic bottle 450 years to biodegrade.

The Future of Plastics

Despite growing understanding of their environmental harm, plastics are critical to modern life. Plastics made possible the development of computers, cell phones, and most of the lifesaving advances of modern medicine. Lightweight and good for insulation, plastics help save fossil fuels used in heating and in transportation. Perhaps most importantly, inexpensive plastics raised the standard of living and made material abundance more readily available. Without plastics many possessions that we take for granted might be out of reach for all but the richest citizens. Replacing natural materials with plastic has made many of our possessions cheaper, lighter, safer and stronger.

Since it's clear that plastics have a valuable place in our lives, some scientists are attempting to make plastics safer and more sustainable. Some innovators are developing bioplastics, which are made from plants instead of fossil fuels, to create substances that are more environmentally friendly than conventional plastics. Others are working to make plastics that are

truly biodegradable. Some innovators are searching for ways to make recycling more efficient, and they even hope to perfect a process that converts plastics back into the fossil fuels from which they were derived. All of these innovators recognize that plastics are not perfect but that they are an important and necessary part of our future.

Some key facts:

- Half of all plastics ever manufactured have been made in the last 15 years.[11]
- Production of plastics has increased exponentially, from 2.3 million tons in 1950 to 448 million tons by 2015. Production is expected to double by 2050.[12]
- Every year, about eight million tons of plastic waste escapes into the oceans from coastal nations. That's the equivalent of setting five garbage bags full of trash on every foot of coastline around the world.[13]
- Plastics often contain additives making them stronger, more flexible, and durable. But many of these additives can extend the life of products if they become litter, with some estimates ranging to at least 400 years to break down.[14]

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[11] *The Atlantic*, July 19, 2017.
[12] *University of Rhode Island Magazine,* Fall, 2020. *"World's Plastic Pollution Crisis Explained."*
[13] *National Geographic,* June 7, 2019.
[14] *National Geographic,* June 7, 2019.

- What happens when a marine animal eats a piece of plastic? The plastic can end up, undigested, in the animal's belly. This was the case when scientists discovered a dead sperm whale (*Physeter macrocephalus*) with 22 kilograms (50 pounds) of plastic of all sizes—from drinking cups to flip-flops—in its stomach. Ingested trash like this can hurt and clog the digestive tract, leaving little room for real food. This can be observed in a great variety of animals, with seabirds particularly affected.[15]
- The average person eats at least 50,000 particles of microplastic a year and breathes in a similar quantity, according to the first study to estimate human ingestion of plastic pollution. The true number of plastic particles eaten by the average person is likely to be many times higher, as only a small number of foods and drinks have been analysed for plastic contamination. Scientists have reported that drinking a lot of water from plastic bottles drastically increased the particles consumed.[16]

- The health impacts of ingesting microplastic are unknown, but they could release toxic substances. Some pieces are small enough to penetrate human tissues, where they could trigger immune reactions.

[15] *USA Today,* April 1, 2019.
[16] *The Guardian,* June 5, 2019.

- Microplastic pollution is mostly created by the disintegration of plastic litter and appears to be ubiquitous across the planet. Researchers have found microplastic particles everywhere they look—in the air, soil, rivers and the deepest oceans around the world.
- Plastics have been detected in tap and bottled water, seafood and beer. They were also found in human stool samples confirming that people ingest the particles.[17]
- The new research, published in the journal *Environmental Science and Technology*, took the data from 26 previous studies that measure the amounts of microplastic particles in fish, shellfish, sugar, salt, beer and water, as well as in the air in cities. The scientists then used U.S. government dietary guidelines to calculate how many particles people would eat in a year. Adults eat about 50,000 microplastic particles a year and children about 40,000, they estimated.[18]
- Scientists have described a new disease called plasticosis, caused by ingesting microplastic particles, in seabirds. Scientists have described a new disease called plasticosis, which is directly caused by plastic waste in the environment.[19] While the

[17] *Time* magazine, May 29, 2019.
[18] *The Guardian,* June 5, 2019.
[19] *The Guardian,* March 3, 2023.

disease has so far only been identified in the digestive tracts of seabirds, the scale of the problem suggests it could be widespread in other species and different parts of the body. For the new study, scientists from London's Natural History Museum have now examined the ill effects on the health of a seabird species known as flesh-footed shearwaters, which previous studies have found to be among the most plastic-contaminated birds in the world. In doing so, the team found that the birds' symptoms were so consistent that it warranted describing a new disease. Plasticosis got its name due to its similarity to other fibrotic diseases caused by inorganic materials, like silicosis and asbestosis. Tiny shards of plastic become lodged in the birds' digestive tracts, causing chronic inflammation and scarring that leads to a host of other problems. The team found that exposure to microplastics inflames and scars the proventriculus, the first chamber of their stomach, until it eventually starts to break down. That can stunt the glands that secrete digestive compounds, which can affect their vitamin absorption and make them more vulnerable to infection and parasites. In extreme cases, chicks can starve to death because their stomachs become full of undigestible plastic.

For those that survive, plasticosis seems to stunt their growth. Larger amounts of plastic were associated with smaller overall weight and shorter wings.

So far, plasticosis has only been documented in the digestive systems of these flesh-footed shearwaters, but given how common the pollutant is, the team says it's likely that the disease affects other species as well, and could cause similar scarring in other parts of the body. Investigating this could be an important step for future work. The research was published in the *Journal of Hazardous Materials*.

- Plastics are entering the food chain through plants.[20] This work provided insights into the uptake pro-cess of polystyrene microplastics in strawberry plants using confocal laser scanning microscopy and scanning electron microscopy. "Our results clearly showed that PS-MPs can enter the root of strawberry and be trans-ported to the shoot via the apoplastic pathway. The critical sites for introducing polystyrene microplastics into roots were shown to be the apical zone and lateral root emergence sites." Considering the large quantity of global plastics waste, concerns about microplastics pollution in terrestrial ecosystems are

[20] *Journal of Hazardous Materials,* Volume 449, May 5, 2023,

growing. Microplastics can penetrate plant roots, move upward to the aboveground portions, and finally enter the food chain.

In summary, plastic pollution is everywhere. Humans throw it into rivers, landfills, lakes, streams and the ocean where it has accumulated in massive amounts. Plastic pollution threatens fish, wildlife, bees and humans.

We need to take drastic action to regulate the use and disposal of all products and packaging that use plastics. We can no longer be guinea pigs.

Chapter Two

Plastic Pollution Presents an Existential Threat to Humans

"Water and air, the two essential fluids on which all life depends, have become global garbage cans."

—Jacques Yves Cousteau

"Only within the moment of time represented by the present century has one species—man—acquired significant power to alter the nature of the world."

—Rachel Carson, *Silent Spring*

"If the bee disappears from the surface of the Earth, man would have no more than four years to live."

—Albert Einstein

There are at least two warning signs that plastics are killing off the human race. These are two canaries in the coal mine.

The phrase a canary in the coalmine denotes an early indicator of potential danger or failure. It refers to the former practice of taking live canaries into coal mines to test for the presence of toxic gases, particularly carbon monoxide. The illness or death of the canaries serves as an indication that such gases are present. The idea of using canaries is credited to John Scott Haldane, known to some as "the father of oxygen therapy." His research on carbon monoxide led him to recommend using the birds, writes Esther Inglis-Arkell for *Gizmodo*. He suggested using a sentinel species: an animal more sensitive to the colorless, odorless carbon monoxide and other poisonous gases than humans. If the animal became ill or died, that would give miners a warning to evacuate.

Why was a canary Haldane's suggested solution? Canaries, like other birds, are good early detectors of carbon monoxide because they're vulnerable to air-borne poisons, Inglis-Arkell writes. Because they need such immense quantities of oxygen to enable them to fly and fly to heights that would make people altitude sick, their anatomy allows them to get a dose of oxygen

when they inhale and another when they exhale, by holding air in extra sacs, he writes.

The two warning signs about the harm that plastic is causing are the connection between bees dying out and human sperm counts plummeting. Bees and sperm country are the new canaries in the coal mine, deadly warning signs that life is in danger.

Both bees and sperm appear to be very sensitive to plastic pollution and other environmental hazards like pesticides.

There is also growing evidence that plastic pollution causes, or increases the risk of, heart disease and cancer.

Declining Sperm Counts

Declining sperm counts are an "indicator that there is something very wrong in our modern environment or lifestyle," says Dr Hagai Levine, head of the environmental health track at the Hebrew University-Hadassah School of Public Health in Israel. "We need to identify what the causes are and fix them. Otherwise, it's dangerous to our future and maybe irreversible."

Understanding why sperm counts are critical involves three statistics: First, a human male who has fewer than 15 million sperm per milliliter is considered infertile; second, that in the 1970s sperm counts in Western countries (where there is available data) showed an average of 99 million sperm per milliliter; and third, that this number had dropped to 47 million sperm per milliliter by 2011. Scientists agree that plastic pollution is a likely culprit.[21]

Microplastics—that is, plastic particles which are five millimeters or less across or in length—have entirely covered the planet. Animals accidentally eat microplastics all the time and plants regularly absorb them through their roots. Humans themselves ingest the rough equivalent of a credit card's worth of plastic each week.

In a recent study, scientists at Nottingham University found that two chemicals common in home environments damage the quality of sperm in both men and dogs.[22]

The culprits implicated are diethylhexyl phthalate (DEHP), used to make new plastics more pliable, and polychlorinated biphenyl 153 (PCB153), found in older

[21] National Health Service, United Kingdom. *The Guardian,* July 25, 2017.
[22] *The Guardian,* May 24, 2019.

plastics and electrical equipment. Companies stopped producing PCBs in the late 1970s due to their health risks–including a possible increased risk of cancer, hormone disruption, liver damage and behavioral or cognitive deficits in children exposed to the chemical in utero–but the chemical persists in the environment.

The Nottingham study is just one in a mounting pile of research findings indicating that the quality and quantity of men's sperm is declining significantly. Research suggests that sperm counts have dropped by half in the last 50 years and that a higher percentage of sperm are poor swimmers–slow, ungainly or beset by genetic flaws and thus unlikely to fertilize eggs.

The number of semen samples in the scientific reports study–nine from men and 11 from dogs–is too small to draw conclusions about cause and effect, says the lead author Richard G Lea, an associate professor of reproductive biology at the University of Nottingham's School of Veterinary Medicine and Science. "Of course, we have to be cautious based on these numbers," he says. "But our data add to the weight of evidence that chemicals in the home environment degrade sperm."[23]

[23] *The Guardian,* May 24, 2019.

If the cause is environmental, you would expect to see a similar effect on man's best friend, says Lea. "Dogs live in our homes. They often even accompany us to work," he says. "They share our environment basically so they're exposed the same chemical contaminants."

And, in a 2016 study of sperm collected from stud dogs, Lea's team discovered that the number of good swimmers decreased by 30% over a 26-year period.

Chemicals from plastics are particularly worrisome because they are so ubiquitous. Roughly two-thirds of the plastic ever produced has been released into the environment and shows up as tiny particles in the air, water and soil. Eventually those plastics collect in the tissues and fluids in our bodies. Lea says he focused on two compounds that "consistently popped up" in his analysis of dog food, sperm and testes tissues from routine neutering procedures. The most obvious concern of dropping sperm counts is infertility. Even with sperm counts in decline, most men retain their fertility potential, says Skakkebæk. But birth rates have been declining in industrialized countries for decades, he says, and it's not clear that's entirely by choice.

Recent studies suggest that 20-30% of young men today have sperm counts in a range that is associated with reduced fertility, says Skakkebæk.

Some research suggests we may be reaching “a tipping point” where more couples will take longer to conceive or may need the help of assisted reproductive technology such as in vitro fertilization (IVF), he says. He points out that in Denmark, the number of couples seeking help for infertility has increased significantly since 2001. “Almost 10% of children are now born after assisted reproduction,” he says

Current estimates are that 12-18% of couples have problems conceiving, but there isn’t good data to show how that is changing over time. Most researchers view the declining population data in western countries as a worrisome trend, but there is nothing to link that specifically to sperm decline.

There’s also a worry that decreasing quantity and quality of sperm is a marker for worsening health in general says Dr. Levine. Research has linked problems with sperm to a higher risk of a number of serious health conditions, including cancer, diabetes and heart disease, as well as death.

“I do see an analogy to climate change in the sense that we have clear scientific signs of the problem–a very serious problem, which endangers humanity,” Dr. Levine says. “But we are not taking the needed steps to reverse it or even just to start to understand what is going on.”

Much of the planet is swimming in discarded plastic, which is harming animal and possibly human health. Once at sea, sunlight, wind, and wave action break down plastic waste into small particles: the microplastics. Currently, particular attention has been drawn to their effects on aquatic environments but the health risks, especially in mammals, are poorly known. These non-biodegradable materials can act as a vector for environmental pollutants, can be ingested by humans in food and water, and can enter and accumulate in human tissues with a possible risk for heath. Recent studies revealed the deleterious effects of microplastic exposure in male reproduction and sperm quality, making them a potential hazard to reproductive success. This manuscript summarizes the main changes in sperm quality along the lifespan and the upcoming studies on the effects of microplastics in male fertility in mammals.

One of the main consequences of industrialization is the production, use and discharge of several environmental pollutants that can result as harmful for animal, human and environmental health.

Many environmental pollutants can act as endocrine disrupting chemicals (EDCs), mimicking the activity of endogenous steroid hormones and inter-

fering in the endocrine functions with different mechanisms. In recent years, particular emphasis was placed on plasticizers, plastic additives, and contaminants of emerging concern (CECs) which includes pharmaceuticals, personal care products, food additives, natural and synthetic hormone and plastic debris in micro and nano range.

Chemicals like phthalates, bisphenols poly- and perfluorinated alkyl substances, among others, are commonly used for the production of daily use goods. They are frequently released into the environment as waste. For example, bisphenol A (BPA), a plasticizer used for the synthesis of phenol resins, polyacrylates, polyesters, epoxy resins, and polycarbonate plastics, is used for the production of drink and food packaging. It leaches into wastewater, contaminates foods and beverages, thus representing both ecotoxicological and health risks.

In recent years, the growing rate of infertility has displaced attention to gametogenesis and gamete quality. Once considered a “woman’s trouble,” infertility is on the rise in males and semen quality has declined in recent decades. In about 40% of men with impaired spermatogenesis, the etiology remains unknown after a complete diagnostic work-up.

Spermatozoa are not only the carrier of a haploid nucleus into egg cells, but emerging evidence has revealed that sperms contribute to early embryo development and offspring health with an epigenetic signature highly sensitive to both environmental factors, including EDCs, and paternal lifestyle. Decreased sperm quality has been reported in subjects exposed to environmental pollutants, suggesting that the evaluation of sperm quality may represent a biomarker for general health.

Currently, particular attention has been drawn to the effects of microplastics on the aquatic environment; however, the health risks of these environmental pollutants—especially with respect to mammalian reproduction—are poorly known. However, in the past three years, preliminary assessments of the effects of microplastics exposure in mammalian reproduction have emerged with the publication of peer-review articles that revealed the effects on spermatogenesis and sperm quality in exposed animal models and the indirect effects on the offspring occurring via gestational exposure. This manuscript summarizes the main ecotoxicological and health risk of microplastics in mammals, the main threat for sperm quality along the lifespan and the upcoming studies on the effects of microplastics in male fertility in mammals.

About 6,300 million tons of plastic waste was generated between 1950 and 2015. Most of this waste, about 4900 million tons, ended up in landfills and the environment. Based on the trends of that period, the researchers estimated that by 2050 the amount of plastic waste in landfills and the environment would reach 12,000 million tons. Nonetheless, the potential dangers of escalating plastics pollution, particularly microplastic pollution, have remained largely ignored by governments and policymakers.[24]

Use of plastics in everyday items and manufacturing processes has resulted in a deluge of slowly degradable materials entering our environment and our food chain. As plastics breakdown into tiny particles the consequences on human, animal and ecosystem health need to be studied.

Plastics are synthetic organic polymers. Their long-term durability, increasing scale of production, unsustainable usage coupled with the inadequate waste management systems have led to the accumulation of plastics in ecosystems worldwide.[25] Plastic is the most prevalent type of marine debris found in our ocean and the Great Lakes. Plastic debris can come in

[24] Science.org.
[25] Encounteredu.com.

all shapes and sizes. However, the most important and emerging threat posed by plastic pollution is the breaking down of plastic into smaller pieces called microplastics.

Microplastics have been identified in many food substances like salt (50–280 microparticles/kg of salt), branded milk (6.5 ± 2.3 particles/L), fish and other seafood, and tea from teabags (11.6 × 109 s/plastic teabag).[26] According to a recent study, three coffees in disposable paper cups are enough to make us ingest about 75 thousand microplastic particles.[27] The commonly used paper cups have a thin layer of plastic which, in contact with the hot liquid, releases microplastics. The researchers poured boiling water into shot glasses. After 15 minutes, they proceeded with analyzing the water based on the possible presence of microplastics and additional ions. They observed that about 25,000 micron-sized microplastic particles are released into 100 mL of hot liquid (85 to 90 °C).

Microplastics and other harmful substances are released from disposable paper cups (lined with plastic) into hot water.[28] Microplastics act as carriers of contaminants such as ions, toxic heavy metals, and hydrophobic organic compounds which, if ingested

[26] Souza V.G.L., Fernando A.L. Nanoparticles in food packaging: Biodegradability and potential migration to food—A review. *Food Package. Shelf Life*. 2016;8:63–70.
[27] Ranjan V.P., Joseph A., Goel S.
[28] *J. Hazard Mater*. 2021.

regularly, can have serious health implications. Dangerous microplastics are not a specific kind of plastic, but rather any type of plastic fragment that is less than 5 mm in length according to the European Chemicals Agency and the U.S.[29] Microplastics enter natural ecosystems from a variety of sources, including cosmetics, clothing, and industrial processes. Microplastic pollution is the one of the most challenging ecological threats the next generation will face.

Microplastics are divided into two types: primary and secondary. Examples of primary microplastics include microbeads found in personal care products, plastic pellets (or nurdles) used in industrial manufacturing, and plastic fibers used in synthetic textiles (e.g., nylon). Primary microplastics enter the environment directly through any various channels—for example, product use (e.g., personal care products being washed into wastewater systems from households), unintentional loss from spills during manufacturing or transport, or abrasion during washing (e.g., laundering of clothing made with synthetic textiles).

Secondary microplastics form from the breakdown of larger plastics; this typically happens when larger plastics undergo weathering, through exposure to, for

[29] National Oceanic and Atmospheric Administration (NOAA).

example, wave action, wind abrasion, and ultraviolet radiation from sunlight. Microplastics are not biodegradable. Thus, once in the environment, primary and secondary microplastics accumulate and persist.

Apart from aquatic ecosystems that are directly and daily exposed to plastic debris with different outcomes on the health of aquatic microorganisms, plants and animals, the exposure risk for terrestrial species also emerged.[30]

In particular, fibers are the dominant shape of microparticles in the atmosphere and synthetic textiles are the main source of airborne Microparticles are widely distributed in the environment because of atmospheric conditions and human activities. In addition, airborne microparticles further contribute to the pollution of the aquatic environment. As a consequence, the exposure routes have been expanded from the food-chain to contaminated food and drinks and inhalation. Emerging evidence revealed the presence of microplastics in human stools and colectomy (removal of the colon) specimens, confirming that

[30] Yong C.Q.Y., Valiyaveetill S., Tang B.L. Toxicity of Microplastics and Nanoplastics in Mammalian Systems. *Int. J. Environ. Res. Public Health*. 2020.

human exposure to microplastics through ingestion does occur.[31]

Tissue-accumulation kinetics and distribution pattern strongly depend on the size of microparticles. Therefore, studies on microparticles have been recently translated into mammals and cell lines, revealing toxicity effects in different cell lines and the main effect of gut–microbiota (i.e., dysbacteriosis and inflammation), liver, and kidney in animal models, for recent review, with exposure-induced oxidative stress, inflammation and interference in energy and lipid metabolism, altered blood biomarkers and neurotoxicity.[32] Tissue accumulation of microplastics in mice and biomarker responses suggest widespread health risks of exposure.[33] Polyethylene microplastics affect the distribution of gut microbiota and inflammation development in mice.[34]

Ovarian fibrosis, apoptosis and pyroptosis of granulosa cells are the main consequences of microparticle-induced oxidative stress in female

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[31] Koelmans A.A., Mohamed Nor N.H., Hermsen E., Kooi M., Mintenig S.M., De France J. Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Res.* 2019.
[32] Yong C.Q.Y., Valiyaveetill S., Tang B.L. Toxicity of Microplastics and Nanoplastics in Mammalian Systems. *Int. J. Environ. Res. Public Health.* 2020; Deng Y., Zhang Y., Lemos B., Ren H.
[33] *Sci. Rep.* 2017; Li B., Ding Y., Cheng X., Sheng D., Xu Z., Rong Q., Wu Y., Zhao H., Ji X., Zhang Y.
[34] *Chemosphere.* 2020.

rats.[35] Polystyrene microplastics cause granulosa cells apoptosis and fibrosis in ovary through oxidative stress in rats.[36]

The first report of microplastics in human placenta has recently been published.[37] Although this study is limited to six samples, 12 microplastic fragments (5–10 μm in size), were found in four placentas, in chorioamniotic membranes, maternal side and fetal side, suggesting possible consequences on gestation, embryo development and health.

In this respect, microparticles represent an eco-toxicological problem and a health risk. Their impact deserves attention to preserve reproductive health, pregnancy and the disease load of exposed subjects and offspring. In the next paragraph, we focus on the preservation of male fertility along lifespan and analyze upcoming reports concerning the effects of microparticles on mammalian male reproduction.

Successful reproduction depends on the production of high-quality gametes. In human, the

[35] An R., Wang X., Yang L., Zhang J., Wang N., Xu F., Hou Y., Zhang H., Zhang L.
[36] *Toxicology*. 2021.
[37] Ragusa A., Svelato A., Santacroce C., Catalano P., Notarstefano V., Carnevali O., Papa F., Rongioletti M.C.A., Baiocco F., Draghi S., et al.; Plasticenta: First evidence of microplastics in human placenta. *Environment International* 2021.

production of sperms occurs throughout life starting from puberty and requires an orderly succession of mitotic proliferation, meiotic division and differentiation events within the testis and a further phase in male and female reproductive tract to make the sperms acquire motility and fertilizing ability. Intricate endocrine, paracrine and autocrine signaling networks are responsible for the production of high-quality sperms and the process is susceptible to the modulation by lifestyle and environmental factors.[38]

A literature review published in the *International Journal of Environmental Research and Public Health* suggests that ingested microplastics can lead to decreased sperm quality and sperm counts in humans. December 31, 2021

Polystyrene-microplastic exposure can lead to vas deferens damage, decreased sperm viability and concentration, increased sperm malformation, disruption of blood–testis barrier integrity, and spermatogenic cell apoptosis.[39]

Due to the problematic degradation properties of plastics, the decomposition of plastic results in the

[38] Chianese R., Troisi J., Richards S., Scafuro M., Fasano S., Guida M., Pierantoni R., Meccariello R. Bisphenol A in Reproduction: Epigenetic Effects. *Curr. Med. Chem.* 2018.

[39] S. Li et al., 2021. May 24, 2022

formation of numerous microplastics, less than 5 mm in diameter. These microplastics enter the soil and the ocean, eventually passing through the air, water, or food chain back to the human body and harming human health. In the last 80 years, male semen analysis parameters have shown a significant decline. No studies examined the relationship between human microplastic exposure and male infertility. The article reviewed the relevant animal experimental research literature in recent years and calculated that the minimum human equivalent dose of microplastics leading to abnormal male semen quality is 0.016 mg/kg/d. The literature comparison found that microplastic exposure in Japan and South Korea was close to this value. These results suggest that microplastics can affect male semen quality and that microplastics may significantly impact male fertility.

Cancer and Plastic Pollution

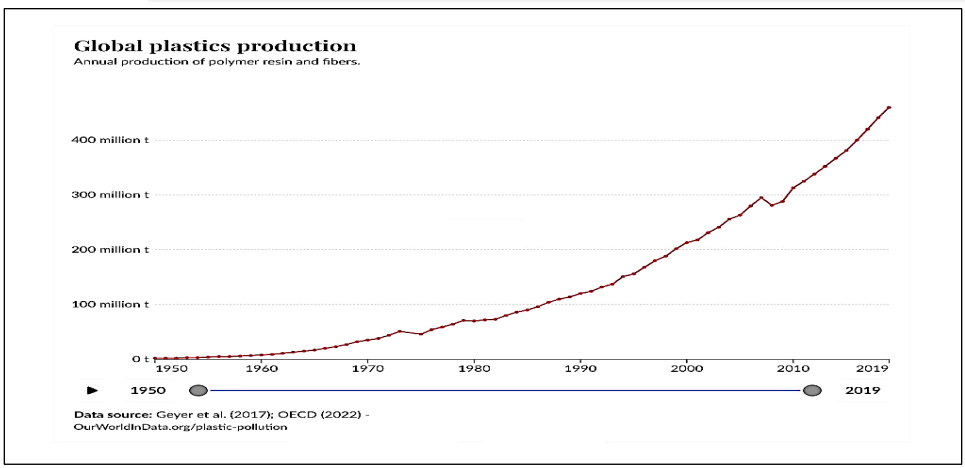
Cancer has many causes: viruses, pollution and genetics. Plastic pollution is a new source that is creating more cancers. Plastics contain a witches' brew of chemical contaminants. The World Health Organization determined that more than 35 million new cancer cases are predicted in 2050, a 77% increase from the estimated 20 million cases in 2022.

A study by researchers from Brigham and Women's Hospital reveals that the incidence of early onset

cancers—including breast, colon, esophageal, kidney, liver, and pancreas—has dramatically increased around the world, with the rise beginning around 1990.

Shuji Ogino, a professor at the Harvard Chan School and Harvard Medical School and a physician-scientist in the Department of Pathology at the Brigham said, “From our data, we observed something called the birth cohort effect. This effect shows that each successive group of people born at a later time — e.g., a decade later — have a higher risk of developing cancer later in life, likely due to risk factors they were exposed to at a young age.” Professor Ogino continued, “We found that this risk is increasing with each generation. For instance, people born in 1960 experienced higher cancer risk before they turn 50 than people born in 1950, and we predict that this risk level will continue to climb in successive generations.”

Plastic production has sharply increased over the last 70 years. In 1950, the world produced just two million tons. It now produces over 450 million tons per year. It has gone up 400% since 1990.



The increase in plastic pollution parallels the increase in many cancers.

BPA, Bisphenol-A

According to Breastcancer.org, BPA is a synthetic estrogen found in many rigid plastic products, food and formula can linings, dental sealants and on the shiny side of paper cashier receipts (to stabilize the ink). Its estrogen-like activity makes it a hormone disruptor, like many other chemicals in plastics. Hormone disruptors can affect how estrogen and other hormones act in the body, by blocking them or mimicking them, which throws off the body's hormonal balance. Because estrogen can make hormone-receptor-positive breast cancer develop and grow, many women choose to limit their exposure to these chemicals that can act like estrogen.

BPA also seems to affect brain development in the womb. According to Breastcancer.org, a 2011 a study found that pregnant women with high levels of BPA in their urine were more likely to have daughters who showed signs of hyperactivity, anxiety and depression. The symptoms were seen in girls as young as three. It's not clear why boys aren't affected in the same way.

Vinyl Chloride

PVC or polyvinyl chloride, a type of plastic, is made with vinyl chloride, a known human carcinogen. *Journal of Carcinogenesis*, March, 2012. PVC is com-

monly used in packaging like bottle cap liners, safety seals, and labels on PET bottles. PVC is also found in clothing, furniture, gift cards, toys, sports equipment, medical devices, packaging, and building materials. Over the course of its life, PVC exposes us all to highly toxic chemicals, many of which are linked to an increased risk of breast cancer.

PVC is polymerized from vinyl chloride (VC) monomer, which is one of the highest production volume chemicals globally with a current annual worldwide demand of approximately 16 billion pounds. This production is increasing at an approximate 3% annual rate. Up to 98% of VC is used in the production of PVC. Brandt-Rauf PW, Li Y, Long C, Monaco R, Kovvali G, Marion MJ. Plastics and Carcinogenesis: The example of Vinyl Chloride. J Carcinog. 2012;11:5. doi: 10.4103/1477-3163.93700. Epub 2012 Mar 12. PMID: 22529741; PMCID: PMC3327051.

Unfortunately, VC is a well-established animal and human carcinogen. It is most strongly associated with liver cancer, in particular the rare, sentinel neoplasm of liver angiosarcoma (LAS), a malignant tumor of the endothelial cells of the liver. Vinyl Chloride has also been identified as a cause of hepatocellular carcinoma, the corresponding malignant tumor of the parenchymal cells of the liver It has also been associated with non-malignant health effects, including in the liver and other organs, as well as other malignancies (e.g., lung and brain), although these other carcinogenic associations remain much more

controversial. The most significant exposures to VC occur in the petrochemical and plastics' industries.

For example, National Institute for Occupational Safety and Health (NIOSH) has estimated that 81,000 workers employed in more than 3,700 worksites are potentially exposed to VC in the United States. Worldwide estimates are much higher with more than 2,200,000 workers probably exposed to VC.

General population exposures also occur primarily through the air and water. For example, elevated levels of VC have been found not only in the air near VC manufacturing and processing facilities but also in the vicinity of many hazardous waste sites and municipal landfills, either due to the direct disposal of VC or from the microbial degradation of other chlorinated solvents to form VC.

In some cases, dangerously high levels have been detected (up to 44 ppm; compared to a U.S. Environmental Protection Agency Reference Concentration of 0.04 ppm) in the air at some landfills. General population exposures may also occur from drinking water from PVC pipe, and food and beverages from PVC packaging and bottles, although probably at much lower levels. However, these are some of the reasons that authorities in the field of chemical safety have warned that VC is very much "still a cause of concern" in occupational and environmental health. Within the plastics' industry, VC is an also an excellent model for the study of chemical carcinogenesis via genotoxic mechanisms because it is a well-known DNA-reactive chemical, for which much has been

learned about the molecular biology of its pathways of action.

According to *Consumer Reports*, in the areas near plastic production facilities, researchers have documented increased risk for leukemia and lymphoma, lung cancer, asthma, stroke, premature birth and stillbirth. In January, 2024 *Consumer Reports* stated, "CR's findings are particularly worrisome because the issues with chemicals in plastic are not limited to phthalates and bisphenol-A (BPA). Those are just "poster children for a broken system," says Maricel Maffini, PhD, a chemical safety expert.

According to the *British Medical Journal Oncology*, "models based on global data predict that the number of early-onset cancer cases will increase by around 30% between 2019 and 2030". Zhao, J. et al. BMJ Oncol.

Annals of Global Health, 2023 found: "Plastics are comprised of a carbon-based polymer backbone and thousands of additional chemicals that are incorporated into polymers to convey specific properties such as color, flexibility, stability, water repellence, flame retardation, and ultraviolet resistance. Many of these added chemicals are highly toxic. They include carcinogens, neurotoxicants and endocrine disruptors such as phthalates, bisphenols, per- and poly-fluoroalkyl substances (PFAS), brominated flame retardants, and organophosphate flame retardants. They are integral components of plastic and are responsible for many of plastics' harms to human health and the environment." "Plastic production

workers are at increased risk of leukemia, lymphoma, hepatic angiosarcoma, brain cancer, breast cancer, mesothelioma, neurotoxic injury and decreased fertility." *Annals* at 3.

Lung Cancer

Studies from the last few decades have consistently shown plastic particles found in the lung specimens of patients with cancer and chronic lung disease. Workers exposed to plastic fibers can have lung problems and reduced lung capacity, perhaps due to damage caused by inflammation. A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health. Campanale C, Massarelli C, Savino I, Locaputo V, Uricchio VF. Int J Environ Res Public Health. 2020 February 13;17(4):1212. doi: 10.3390/ijerph17041212.

Heart Disease

The New England Journal of Medicine, one of the most respected medical journals in the world, has recently found both polyethylene, and polyvinyl chloride, in carotid artery placque. "Microplastics and Nanoplastics in Atheromas and Cardiovascular Events," March 6, 2024.

Polyethylene is a tough, light, flexible synthetic resin made by polymerizing ethylene, which is used chiefly for plastic bags, food containers and other

packaging. Polyvinyl Chloride (PVC) is a tough chemically resistant synthetic resin made by polymerizing vinyl chloride and used for a wide variety of products including plastic pipes, plastic flooring and plastic sheeting.

The *New England Journal of Medicine* recently noted, "A total of 304 patients were enrolled in the study, and 257 completed a mean (±SD) follow-up of 33.7±6.9 months. Polyethylene was detected in carotid artery plaque of 150 patients (58.4%), with a mean level of 21.7±24.5 μg per milligram of plaque; 31 patients (12.1%) also had measurable amounts of polyvinyl chloride, with a mean level of 5.2±2.4 μg per milligram of plaque."

The article concluded, "in this study, patients with carotid artery plaque in which MNPs (micro and nano plastic particles) were detected had a higher risk of a composite of myocardial infarction, stroke, or death from any cause at 34 months of follow-up than those in whom MNPs were not detected."

This groundbreaking new study found the presence of microplastics and nanoplastics in human arterial plaque.The presence of microplastics in plaque was associated with a 4.5 fold increase in the risk of heart attack, stroke and death. An earlier study, *Nature Reviews Cardiology*, Vol. 19, pages 69-70 (2021), pointed out the possible connection between plastic pollution and cardiovascular disease. This 2024 study

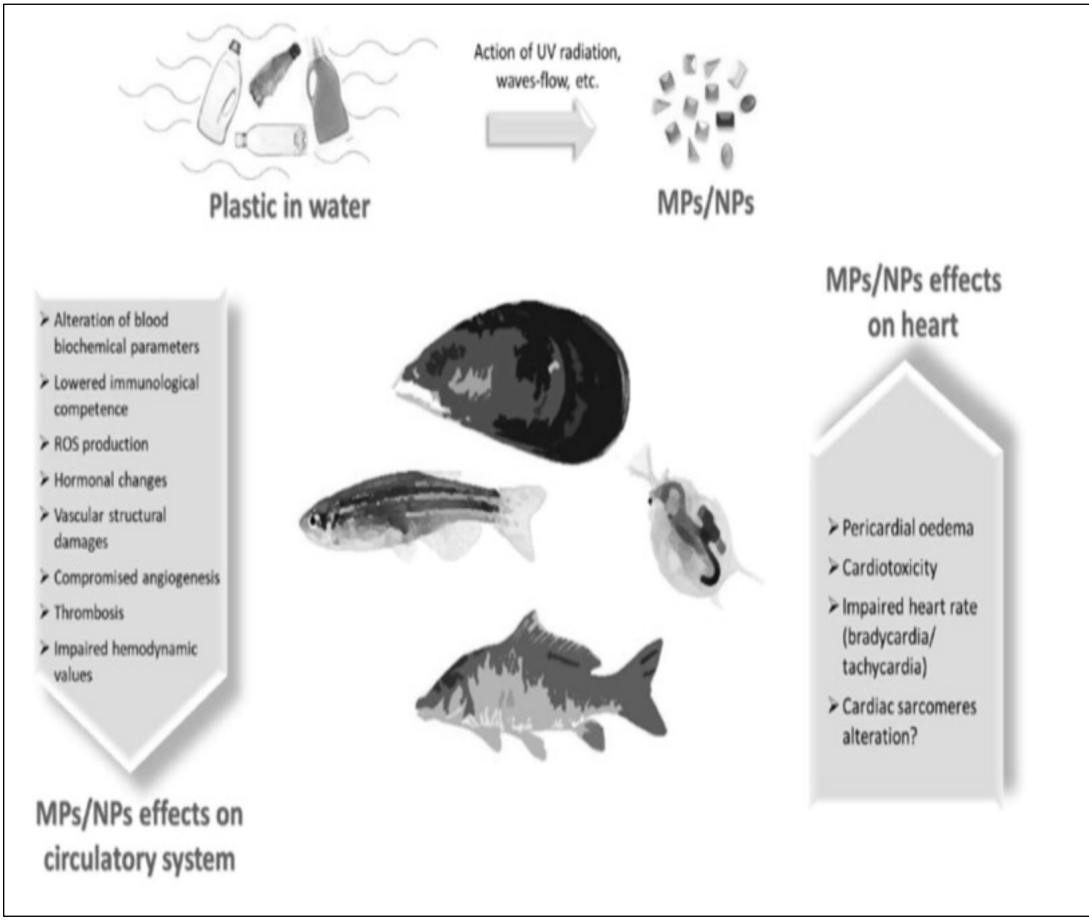
was more conclusive, showing that humans with plastic particles in their arterial placque had a significantly increased risk of heart attacks, stokes and death.

Julie Corliss, the Executive Editor of the *Harvard Heart Letter,* has warned its readers for many years of the risk to heart disease caused by plastic pollution

Another recent study, "Microplastics: A Matter of the Heart (and Vascular System), January 18, 2023, found that "the cardiovascular system, also if not the main target in terms of accumulation, is the main route of distribution for MPs (microplastics) and NPs (nanoplastics). Recent works presented in this review show the first detrimental effects of plastic pollution on cardiovascular function."

The study concluded, "MPs/NPs led to cardiotoxicity, pericardial oedema, and impaired heart rate in fish cardiac tissue. MPs/NPs effects on aquatic organisms pose serious health hazards and ecological consequences because they constitute the food chain for humans. Once present in the mammalian body, plastic particles can interact with circulating cells, eliciting an inflammatory response, with genotoxicity and cytotoxicity of immune cells, enhanced haemolysis, and endothelium adhesion. The interaction of MPs/NPs with plasma proteins allows their transport to distant organs, including the heart. As a consequence of plastic fragment internalisation into cardiomyocytes, oxidative stress was increased, and metabolic parameters were altered. In this scenario, myocardial damage, fibrosis and impaired electrophysiological values were observed. In

summary, MPs/NPs are an environmental stressor for cardiac function in living organisms, and a risk assessment of their influence on the cardiovascular system certainly merits further analysis."



What Consumers Can Do About It

Consumers can take many steps to protect their hearts from plastic pollution:

1. Don't drink or eat out of plastic containers. Ceramic and glass dishes are good. Metal drinking containers are also an alternative to plastic;
2. Don't store food or drinks in plastic containers. Use glass jars with metal tops.
3. Don't use plastic cutting boards. Wood and glass cutting boards are excellent choices.
4. Don't use plastic straws, plastic toothpicks. Use paper straws or biodegradable plastic straws and wood toothpicks.
5. Don't wrap leftovers in plastic wrap, use glass jars or aluminum foil; and

Risk to Infants and Young Children

"Infants in the womb and young children are two populations at particularly high risk of plastic-related health effects at every stage of the plastic life cycle. Because of the extreme sensitivity of early development to hazardous chemicals and children's unique patterns of exposure, plastic-associated exposures are linked to increased risks of prematurity, stillbirth, low birth weight, birth defects of the reproductive organs, neurodevelopmental impairment, impaired lung growth and childhood cancer. Early-life exposures to plastic-associated chemicals also increase the risk of

multiple noncommunicable diseases later in life." "Plastic production workers suffer high rates of cancer and lung disease." Annals at 71.

Risk to Men

"Men exposed to vinyl chloride monomer in liquid and vapor form in vinyl chloride polymerization plants have increased mortality from angiosarcoma of the liver, brain cancer, and connective and soft tissue cancers, with risks being highest in the most heavily exposed. *Annals* at 76. Creech JL, Johnson MN. Angiosarcoma of liver in the manufacture of polyvinyl chloride. J Occup Med Off Publ Ind Med Assoc. 1974; 16(3): 150–151. Mundt KA, Dell LD, Crawford L, Gallagher AE. Quantitative estimated exposure to vinyl chloride and risk of angiosarcoma of the liver and hepatocellular cancer in the U.S. industry-wide vinyl chloride cohort: mortality update through 2013. Occup Environ Med. 2017; 74(10): 709–716. DOI: https://doi.org/10.1136/oemed-2016-104051.

Lung Cancer and Leukemia

Leukemia risk was found to be 30% higher among 187,585 residents of "fenceline" communities compared to residents of more distant communities in a large meta-analysis. A fenceline community is located immediately adjacent to highly polluting facilities. Jephcote C, Brown D, Verbeek T, Mah A. A systematic review and meta-analysis of haematological malig-

nancies in residents living near petrochemical facilities. *Environ Health*. 2020; 19(1): 53. DOI: https://doi.org/10.1186/s12940-020-00582-1

Lung cancer risk has been reported to be 19% higher among residents of communities near petrochemical plants than in the general population. Lin CK, Hsu YT, Christiani DC, Hung HY, Lin RT. Risks and burden of lung cancer incidence for residential petrochemical industrial complexes: a meta-analysis and application. Environ Int. 2018; 121: 404–414. DOI: https://doi.org/10.1016/j.envint.2018.09.018.

Bioplastics

Based on degradation mechanisms, there are two main categories of biodegradable bioplastics, namely oxo-biodegradable and hydro-biodegradable. Iwata T. Biodegradable and bio-based polymers: future prospects of eco-friendly plastics. *Angew. Chem. Int. Ed.* 2015;54(11):3210–3215.

Oxo-biodegradable plastics are made of petroleum-based polymers mixed with a prodegradant additive that catalyzes the plastic's degradation process. Thomas N.L., Clarke J., McLauchlin A.R., Patrick S.G. Oxodegradable plastics: degradation, environmental impact and recycling. *Proc. Instit. Civil Eng. Waste Resour. Manag.* 2012;165(3):133–140. The additive is a metal salt (manganese or iron salts), which enhances the abiotic degradation process of the oxo-biodegradable plastic in the presence of oxygen.

Presently, oxo-biodegradable plastics are mainly produced from naphtha, a by-product of oil or natural gas. Otaigbe J., Goel H., Babcock T., Jane J-i. Processability and properties of biodegradable plastics made from agricultural biopolymers. *J. Elastomers Plastics.* 1999;31(1):56–71. Interestingly, the time taken by biodegradable oxo products to degrade can be 'programmed' at manufacture, like the methane or nitrous oxide industrial processes. The degradation of oxo-biodegradable plastics usually takes months to years. da Luz J.M.R., Paes S.A., Nunes M.D., da Silva MdCS., Kasuya M.C.M. Degradation of oxo-biodegradable plastic by Pleurotus ostreatus. *PloS One.* 2013;8(8).

On the other hand, hydro-biodegradable plastics decompose hydrolytically at a rate faster than oxo-degradable plastics. These plastics can be converted to synthetic fertilizers. Examples include bioplastics produced from plant sources (such as starch), and polylactic acid (PLA).

In order reduce cancers, plastic pollution must be controlled. We can do this in several ways. We can reduce plastic production and consumption. This can be done via increased recycling and increased reuse of plastics. Plastics derived from petroleum can be replaced with bioplastics. However, we must make sure that the bioplastics do not contain harmful additives like VC and BPA. It is not only the plastic that is harmful, it is the additives. In addition, individual consumers can reduce their exposure to plastics as shown below.

The Problem of Plastic Pollution Cannot Be Ignored

Since the 1950s, plastic products have been used in our daily lives. Because plastic takes hundreds of years to degrade, it has become one of the modern-day issues that threaten human health and survival.[40] Plastic pollution has now reached a level that urgently needs to be addressed. In the Pacific Ocean, between California and Hawaii, an island of plastic waste six-times the size of the United Kingdom has formed, known as the "eighth continent." This massive island of garbage is also known as the "Great Pacific Garbage Patch."[41] This garbage patch has grown over the past 60 years. At the same time, a 7- to 11-km long plastic deposit has been found in the deepest part of the world, the Marianas Trench.[42] The United Nations Environment Program (UNEP) estimates that by 2050, the amount of plastic in the oceans (by weight) will be higher than that of fish.[43]

The primary method of plastic disposal worldwide is in landfills, which does not effectively degrade plastics. Due to their physical and chemical properties, plastics in landfills will breakdown into

[40] Guzzetti et al., 2018.
[41] Lebreton et al., 2018.
[42] Peng et al., 2018.
[43] World Economic Forum, 2016.

microplastics smaller than 5 mm and enter the soil and the ocean.[44] In addition, we contact microplastics in our daily lives, in cosmetics, toothpaste, and detergents.[45] Microplastics are a growing global problem due to their considerable presence in the near future and their persistent toxicity to future generations.[46]

People routinely inhale microplastics. For example, human inhalation levels of 360 to 150,000 and 0.88 to 270 ng/kg/d polyethylene terephthalate microplastics and polycarbonate microplastic, respectively, have been reported in 12 countries.[47] Studies have estimated the inhalation of microplastics in China and reported that the median human inhalation of PET-MPs and PC-MPs was 6,500 to 89,700 and 0.5 to 7.37 ng/kg/d, respectively.[48]

Children are More at Risk

Studies have discovered significantly higher inhalation levels of microplastics in infants or children than in adults. Microplastic inhalation in children is at least five times higher than that in adults, implying a higher

[44] Rochman, 2018.
[45] Lassen et al., 2015.
[46] Shahul Hamid et al., 2018.
[47] Zhang et al., 2020.
[48] Liu et al., 2019.

potential risk of microplastic inhalation in infants or children than in adults.[49] A recent study using a breathing thermal manikin to simulate exposure to microplastics in indoor air showed that the manikin inhaled a total of 272 microparticles over 24 hours, with an average of 9.3 ± 5.8 particles per cubic meter.[50]

Food and Water Intake

Many studies have examined the occurrence of microplastics in food and water. One study has suggested that the annual intake of microplastics accounts for approximately 15% of Americans' caloric intake, at 39,000 to 52,000 particles. When inhalation is considered, the estimates of microplastic intake increase to 74,000 to 121,000 particles. In addition, people who drink only plastic bottled water may consume an additional 90,000 microplastics per year compared with those who drink only tap water, consuming an additional 4,000 microplastics per year[51] Cox et al., 2019. Microplastic intake can irreversibly accumulate to 6.4 micrograms per person by the age of 18 years and 40.7 micrograms per person by the age of 70 years.[52]

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[49] Abbasi et al., 2019.
[50] Vianello et al., 2019.
[51] *Environmental Science and Technology Journal,* July, 2019.
[52] Mohamed Nor et al., 2021.

Microplastics Can Enter the Human Body Through the Food Chain and Affect the Male Reproductive System

Because of their small size, microplastics can quickly enter an organism, adversely affect normal physiological functions, and be passed along the food chain, through which they are biologically enriched and amplified.[53] Humans are at the top of the food chain and thus are presumably the most affected. It is estimated that between five and 13 million tons of plastic waste enters the oceans each year, is subsequently ingested by aquatic organisms such as fish and crustaceans, and finally enters the human diet through the food chain.[54]

Direct contact with microplastic particles can have adverse effects at the cellular level.[55] The ingestion of microplastics can cause intestinal damage due to their small size and ability to absorb various toxic substances, heavy metals additives, and chemicals such as phthalate esters.[56]

In summary, ingestion of microplastics can cause mechanical damage to the intestines, reduce fertility, affect the growth rate of organisms, and have long-term adverse effects on the ecosystem.

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[53] van Raamsdonk et al., 2020.
[54] Jambeck et al., 2015.
[55] Hwang et al., 2020.
[56] C. Huang, Ge, et al., 2021; PAEs; Deng et al., 2021.

It is estimated that approximately 15% of child-bearing couples worldwide suffer from infertility; the incidence is increasing every year, nearly half of which is caused by male factors.[57] The quality of human semen has gradually decreased with modernization. For example, from 1940 to 1990, the concentration of male sperm dropped from 113 × 106/ml to 66 × 106/ml, a decline of fifty percent.[58]

In addition, the World Health Organization (WHO) has published six editions of the Laboratory Manual for the Examination and Processing of Human Semen (referred to as the Manual). In the first edition, published in 1980, the normal value for semen concentration was 60 × 106/ml (WHO, 1980), but by the publication of the fifth edition in 2010, this value was reduced to 15 × 106/ml (WHO, 2010), an incredible decline of 75 percent.

Ingestion of Microplastics Can Lead to Reduced Sperm Quality

The effects of microplastics on marine organisms and terrestrial mammals have been well documented.[59] In recent years, the effects of microplastics

[57] Inhorn & Patrizio, 2015.
[58] Carlsen et al., 1992.
[59] Sharma & Chatterjee, 2017; Xu et al., 2020; Yong et al., 2020) and mainly include impacts to the reproductive system

on the reproductive system have attracted increasing attention. Polystyrene microplastics (also known as styrofoam) exert significant toxic effects on the reproductive system of male mice. After 28 days of exposure to polystyrene microplastics, sperm quality and testosterone levels in mice decreased. A hematoxylin and eosin stain showed disorganized spermatogonia, multinucleated gonadotrophic cells in the germinal tubules, inflammation in the testes, and disruption of the blood–testis barrier. Polystyrene microplastics at sizes of 0.5, 4, and 10 μm were able to enter the three testicular cell types in vitro.[60]

Styrofoam exposure can lead to vas deferens damage, decreased sperm viability and concentration, increased sperm malformation, disruption of blood–testis barrier integrity, and spermatogenic cell apoptosis by activating the p38 MAPK-nuclear factor erythroid-2 related factor 2 (Nrf2) pathway.[61] A similar study reported that polystyrene microplastics induced reproductive toxicity in mice through oxidative stress and activation of the p38 MAPK signaling pathway, resulting in a significant decrease in sperm count and motility, a significant increase in sperm malformation

(Sharifinia et al., 2020), immune system and digestive system (Y. Jin et al., 2019; B. Li et al., 2020.

[60] H. Jin et al., 2021.

[61] S. Li et al., 2021.

in mice, and a substantial reduction in serum testosterone levels.[62]

Ingestion of Microplastics Can Lead to Increased Sperm DNA Fragmentation

The current primary clinical laboratory test for male sperm quality is semen analysis. While semen analysis can provide a general picture of the morphological aspects of sperm, it cannot evaluate the most critical material in sperm that determines the embryo's fate: sperm DNA. Half of the chromosomes of a fertilized egg originate from sperm, so genetic information is crucial for the offspring.

The DNA fragmentation index is an indicator of the integrity of sperm DNA. Studies in the literature have reported that conception rates are significantly reduced, and that infertility or miscarriage can occur, when the DNA Fragmentation Index (DFI) is greater than 27%.[63] Therefore, sperm DFI plays a crucial role in the process of normal pregnancy. The DFI is also a widely used indicator in clinical practice to assess male fertility. Exposure to nanoplastics with a mean diameter of 38.92 nm for 5 weeks at 1, 3, 6, and 10 mg/kg/day in rats resulted in different degrees of

[62] Xie et al., 2020.
[63] Corona et al., 2019.

increased sperm DFI.[64] Sperm prokaryotic DNA damage to globular star sea urchins caused by microplastics can be transmitted to offspring.[65]

In summary, semen quality in men has declined significantly over the last 80 years, with sperm concentration dropping to approximately one seventh of its original value. This timing coincides with the development of plastics. Of course, other factors may have also contributed to the decline in male fertility. Nevertheless, the most persistent threat to humanity by far is plastic pollution.

Honeybees are Accumulating Airborne Microplastics on their Bodies

Scientists discover a new way to monitor airborne plastic particles. But do they harm bees?

Bees lie at the heart of our survival. They pollinate 1 in 3 bites of food we eat and are essential to the health and prosperity of countless ecosystems.

However, bees are in peril. According to the Center for Biological Diversity, more than half of North America's 4,000 native bee species are in decline, with 1 in 4 species at risk of extinction.

[64] Amereh et al., 2020.
[65] Trifuoggi et al., 2019.

As honeybees make their way through the world, they are ideally suited to pick up bits and pieces of plastic along the way. Bees are covered with hairs that have evolved to hold tiny particles that the bee collects intentionally or simply encounters in its daily travels. These hairs become electrostatically charged in flight, which helps attract the small plastic particles. Pollen is the most obvious substance that gets caught up in these hairs, but so do plant debris, wax, and even bits of other bees.

Now, another material has been added to that list: plastics. Specifically, 13 different synthetic polymers, according to a study of honeybees and microplastics in Denmark. The study was published in 2022 in *Science of the Total Environment*.

It's well established that microplastics are spread extensively around the planet. Yet scientists are still learning how they move through the atmosphere. Sampling them is difficult and most research of airborne microplastics to date has been conducted at ground level, scientists say.

It turns out that honeybees—and all those hairy legs and bodies—provide a viable means for better assessing the distribution of windborne plastic fibers and fragments. Thanks to their large numbers and

wide-ranging foraging, honeybees can be drafted as living probes of how microplastics are scattered around the world.

"This work demonstrates for the first time the possibility of using honeybees as a bioindicator for the presence of microplastics in the environment," according to Prof. Robert Rosal at the University Alcala in Madrid, Spain.[66]

Miniature Environmentalists

For decades, scientists have used bees as pollution sentinels, tracking heavy metals, pesticides, air pollution, and even radioactive fallout. But research into bees' interactions with plastics, which also dates to the 1970s, has focused more on macro plastics than micro.

Leafcutter bees, for example, which are similar in size to European honeybees but solitary and found all around the world, have been shown to use their huge mandibles to cut half-moon shaped pieces out of plastic, just as they do from leaves and petals.

Scientists in Chile, Argentina, and Canada, and the United States have observed leafcutter bees

[66] *National Geographic,* May 24, 2021.

collecting such bits from bags, packaging, and other plastic materials and lining their nests with them. In the United States U.S. a study suggested that the bees also cut nesting material from plastic flagging used for surveying or marking construction sites.

In the Denmark study, scientists gathered thousands of worker bees, which are all female, from 19 apiaries—nine in the center of Copenhagen and 10 in suburban and rural areas beyond the city. The researchers collected bees directly from the interior of their hives in the spring, when colonies were building up. Because bees interact with plants, water, soil, and air—all areas where microplastics accumulate—they had abundant opportunity to encounter plastics. The collection team wore clothing made of natural fibers and took other precautions to avoid contaminating the sample bees.

The bees were frozen to euthanize them, then washed and scrubbed to remove the particles attached to their legs and bodies. Using a microscope and infrared light, the particles were then sorted by size, shape, and material type.

Fifteen percent of the particles recovered were microplastics. Of those, 52 percent were fragments and 38 percent were fibers. Polyester was the dom-

inant fiber, followed by polyethylene and polyvinyl chloride. The bees also picked up natural cotton fibers.[67]

The city bees presented the highest counts of microplastics, as expected, since it's known that urban areas contain the highest densities of microplastics. The surprise was that the counts of microplastics on suburban and rural bees were not much lower. That suggests that wind dispersion evens out the concentration of microplastics over large areas, the scientists say.

"I would have expected more 'clean' bees in the countryside than in central Copenhagen," Roberto Rosal, a professor of chemical engineering at the University of Alcalá in Madrid and a co-author of the study, said in an email. "But the high mobility of small microplastics offers an explanation for it."

Is Plastic Pollution Harming Bees?

In a study published in 2021 in the *Journal of Hazardous Materials*, scientists in China sought to assess the potential risks that microplastics pose to honeybees. They fed honeybees polystyrene microplastics for two weeks and found it did not change

[67] *National Geographic,* May 24, 2021.

their mortality rate. It did, however, alter the bees' microbiome—the assemblage of gut bacteria essential to basic biological functions—in a way that the Chinese team concluded presents "substantial health risks."

In particular, the team found that the bees' death rate shot up from less than 20 percent to around 55 percent when the bees consumed a combination of polystyrene and tetracycline, a common antibiotic used in beekeeping to prevent a larval disease. "In isolation, microplastics might not be the most toxic contaminant, but the existence of other chemicals might increase their toxicity," the Chinese researchers concluded.

Illaria Negri, a researcher at the Università Cattolica del Sacuro Cuore in Italy, who was not involved with either the Denmark or China studies, expressed similar concerns. The toxic effects of microplastics "could be magnified when they occur in combination with other pollutants, such as pesticides, veterinary drugs, plastic additives," she said in an email.

Certain pesticides can be absorbed by plastic debris, Negri said, and could have "devastating

effects" on the health of bees and other wildlife and insects if ingested.

Wild bees, nesting in Argentinian crop fields, were recently found constructing nests entirely made of the flimsy plastic packaging material left on farms.

From 2017 to 2018, researchers at Argentina's National Agricultural Technology Institute crafted wooden, artificial nests for wild bees. Unlike bee species that have a large hive with queens and workers, wild bees burrow into nests to individually lay larvae. The constructed nests fit together like long rectangles with a narrow, hollow opening that allowed wild bees to crawl inside and fill it with cut leaves, twigs, and mud.

Sixty-three wooden nests were constructed, and three were found lined entirely with plastic. Similar in size and shape to a fingernail, the bits of plastic had been carefully cut by bees and arranged in an overlapping pattern in their nests. Based on the material, researchers think the plastic may have come from a plastic bag or film, which has a similar texture to the leaves bees typically use to line their nests.

Of the three plastic nests, one had not been finished, meaning the bee did not use it to lay her

larvae, *Science Alert* reported. In the remaining two nests, one larva died and the other was not found, leading the researchers to believe it survived.

What does it Mean for the Future of Bees?

This research, published in the journal *Apidologie*, documents the first-time bees have been seen making nests only out of plastic, but for years scientists have known bees were incorporating plastic into their building materials.[68]

In 2013, a paper published in *Ecosphere* outlined how bees were using plastic films and foams to line nests in urban areas throughout Toronto, Canada. Similar to the bees in Argentina, the wild bees observed in Canada cut pieces of plastic that resembled the leaves they commonly use.

Notably, the Canadian study found it wasn't just flaps of plastic bags the bees were using. Plant resins, which can be fashioned into anything from gum to latex, often bind a bee's building materials together. But some individuals, they observed, were hauling a plastic-based caulk back to their nests to use instead.

[68] *Smithsonian Magazine,* June 7, 2019.

Both studies noted that more research needs to be done before scientists can outline the potential impact plastic might have on bees, but the nest building shows that bees are highly adaptive to changing environments. In both places, leaves were readily available as a building material.

“It would demonstrate the adaptive flexibility that certain species of bees would have in the face of changes in environmental conditions,” the study’s lead author Mariana Allasino wrote in a press release translated from Spanish.

Plastic Dangers to Bees

Hollis Woodard, an entomologist who studies bees at the University of California at Riversides Woodard Lab, isn’t surprised to see bees hauling plastic to their nests.“ I think it’s really sad,” she says. “It’s another example of the rampant use of materials that end up in places we don’t intend them to.”

Plastic often presents a threat to wildlife in the form of microplastics, the incredibly tiny bits of plastic that form as larger plastic trash breaks down. Microplastics are a danger to the animals that mistake them for food, which many do, especially in marine environments. If the bees are in fact choosing plastic

over natural materials, it wouldn't be the first time animals have used trash to their advantage.

Sparrows and finches line their nests with cigarette butts to ward off parasitic mites, and black kites in the Italian Alps collect bright strips of plastic to decorate their nests and attract mates.

"It would take a lot more research to know what this means for the bees themselves," says Woodard. "Sure it's possible it might afford some benefits, but that hasn't been shown yet. I think it's equally likely to have things that are harmful."

Researchers are calling for human intervention to deal with the extent of plastic ingestion in wildlife, with 1557 species worldwide now documented to have eaten plastic.

Massey University's Cetacean Ecology Research Group (CERG) Research Associate Dr. Gabriel Machovsky-Capuska says the new numbers are alarmingly widespread throughout terrestrial and freshwater species, not just marine life. "It demonstrates wide contamination across numerous branches of the tree of life; including eight phyla and more than half of the vertebrate orders," Dr. Machovsky-Capuska said.

Published in the journal *Science*, the recent article is the most up to date comprehensive report of plastic ingestion of species worldwide including terrestrial, freshwater and marine environments. Co-author of the review, Dr. Machovsky-Capuska says for many years the main explanation for plastic ingestion was that plastics were confused with prey that animals consumed, however the review shows it's much more complicated than that.

"There are many factors to be considered including the availability of plastic in the environment, the nutritional status of the animal, and their foraging strategy.These characteristics or traits play an important role for understanding the risk of plastic ingestion in each species," Dr. Machovsky-Capuska added.

Plastics can be considered "evolutionary traps" because animals face the challenge of distinguishing plastics as non-prey items despite extremely similar physical and chemical characteristics.

Dr. Machovsky-Capuska says there is a very small chance that species could start to evolve and adapt in response to plastic pollution.

"This could potentially take place over multiple lineages across different evolutionary time scales, therefore, human intervention is desperately needed."

New Zealand's phasing out more single-use plastics by 2025 is exactly the human intervention that Dr. Machovsky-Capuska wants to see more of.

"It will certainly reduce plastic availability in the environment and hopefully decrease the chances of wildlife encountering and ingesting plastic. While there is still plenty more that needs to be done, it's a step in the right direction," she said.

CERG Research Director, Professor Karen Stockin added "The significance of plastics in the environment is certainly recognized by the New Zealand government and for good reason, as this new study demonstrates."

Conclusions

The disappearance of bees and the drastic decline in sperm counts are flashing warning signs that we must stop the spread of plastic pollution. We must take strong steps to significantly reduce plastic waste that is overtaking our oceans.

Disposable plastic bags, bottles, straws, cigarette filters and other wasteful use of plastics must be banned worldwide. There are many alternatives to these uses of plastics.

Chapter Three

Lack of Regulation

"A nation that destroys its soils destroys itself."

—Franklin D. Roosevelt

"It does seem really hard to get consumers to do the right thing. It's stupid that we put water in plastic bottles in Fiji and ship it here."

—John Doerr, chairman of venture capital firm Kleiner Perkins

"One of my big pet peeves is single-use plastic bags. I think it's one of the stupidest ideas in the world."

—Philippe Cousteau, Jr. (son of Jacque Cousteau), French diver and environmentalist.

We are all guinea pigs. All humans, plants and animals on this planet are part of a giant experiment. Most countries to not regulate plastics at all. We just keep producing more and more plastics, most of which winds up in landfills and in the ocean. Most plastic waste is packaging.

For example, Costco sells a 24 pack of Gillette razor blade refills in massive amounts of plastic packaging:

The package has more plastic than blades. This is unnecessary. The blade refills could be packaged in cardboard. No government agency in the United States regulates product packaging. I am not aware of any government on Earth that regulates packaging.

When you go to the grocery store, the store often provides single-use plastic bags in which to put your

vegetables. These bags should either be biodegradable plastic or paper. Trader Joe's, a national grocery chain in the United States, uses Crown Poly biodegradable plastic bags. The Crown Poly Compostable Bags are made from 100% vegetable starches which make them fully biodegradable and compostable. These bags are certified for both commercial and home composting and will biodegrade within 180 days. Trader Joe's uses these bags without being forced to buy a government agency. But a government agency should compel stores to use biodegradable bags and ban the use of regular plastic bags. Trader Joe's would not voluntarily use biodegradable plastic bags if they were significantly more expensive than ordinary plastic bags.

Plastic may be necessary for certain medical applications, such as syringes or saline bags. But single-use plastic bags, plastics knives and forks, straws and stirrers are not necessary. Plastic packaging is not necessary. We lived without plastic packaging for thousands of years. Paper, cardboard and wood work just fine. If plastic is really necessary, then it should be biodegradable plastic.

Chapter Four

Bottle Deposit Laws

"We do not inherit the Earth from our ancestors; we borrow it from our children."

–Native American Proverb

"If it can't be reduced, reused, repaired, rebuilt, refurbished, refinished, resold, recycled, or composted, then it should be restricted, designed or removed from production."

– Pete Seeger, Folk Singer & Social Activist

I only feel angry when I see waste. When I see people throwing away things we could use.

–Mother Teresa

Years ago, we all talked about recycling and not dumping things down your drain and all of that, but talking doesn't help much. Basically, it's going to have to be legislation because the impact is so huge and diversified.

–Ted Danson

According to the Container Recycling Institute (CRI) beverage containers make up a large portion of litter in the United States, and deposit laws are known for achieving a high recycling rate for beverage containers and reducing litter where other recycling systems have failed. CRI found that states with bottle bills have a beverage container recycling rate of around 60%, while non-deposit states only reach about 24%. In addition, the higher the deposit, the more bottles and cans that get recycled. Michigan uses a 10-cent deposit to achieve a return rate around 90%.

In 2019, the European Union adopted the Single-Use Plastics Directive, mandating that its member states collect 90% of plastic beverage containers by 2029.[69]

Jim Jeffords, who served as a U.S. senator from Vermont from 1989 to 2006, first as a Republican and then as an Independent, introduced and co-sponsored legislation for a nationwide bottle bill more than half a dozen times in his career. His final attempt, the *National Beverage Producer Responsibility Act* of 2002, would have established a 10-cent deposit on a wide range of containers across the country. The bill was referred to the Senate Committee on Environment

[69] June 5, 2019, EU Directive 2019/904.

and Public Works and never received a vote. A national bottle bill was introduced to the House in 2009 but also failed to gain traction.

In the United States only ten states have bottle deposit laws: California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon and Vermont. Michigan and Oregon have the highest deposit fee of ten cents.

Container deposit legislation mandates a refundable deposit on certain types of recyclable beverage containers. Studies show that the recycling rate for beverage containers is vastly increased with a bottle bill. The United States' overall beverage container recycling rate is approximately 33%, while states with container deposit laws have a 70% average rate of beverage container recycling. Michigan's recycling rate of 97% from 1990 to 2008 was the highest in the nation, as is its ten-cent deposit.[70] Studies also show that beverage container legislation has reduced total roadside litter by between 30% and 64% in the states with bottle bills.[71]

[70] Gitlitz, Jenny & Franklin, Pat (2006). "The 10 Cent Incentive to Recycle". Container Recycling Institute.
[71] Bottle Bills Prevent Litter." www.BottleBill.org.

Americas

There are voluntary deposit-refund schemes for glass containers in Barbados, Bolivia, Brazil, Chile, Colombia, Ecuador, Jamaica, Mexico and Venezuela.

Canada

In 1970, British Columbia became the first Canadian province to establish a mandatory deposit-return system for soft drinks and beer containers. As of 2021, all provinces in Canada have passed deposit laws. In Ontario, only containers of alcoholic beverages come with deposits. In Manitoba only beer containers are included in the deposit scheme.

Deposits range from CAD$0.05 to CAD$0.40 per bottle, depending on the material and size of the container and whether the container contains an alcoholic or non-alcoholic beverage.

Israel

In Israel, there is a 0.30 shekel deposit on beverage containers over 100 mL and under 5 L, except for dairy products. The system is operated by the ELA Recycling Corporation, a private non-profit organization owned by Israel's beverage manufacturers. Businesses are required to accept bottles if they sold them, or if they

are over 28 square meters and sell beverages from the same manufacturer or importer. Businesses are not required to accept more than 50 bottles per customer per day.

South Korea

By 1997, South Korea had introduced a deposit-refund system for beverage containers.[72] South Korea has one of the highest recycling rates in the world.

Taiwan

By 1997, Taiwan had introduced a deposit-refund scheme for polyethylene terephthalate (PET) soft drink bottles.

Turkey

In 2021, the Turkish government decided to introduce deposit return system (DRS) by January 1, 2022, to protect Turkey's 8,000 kilometers (4,800 miles) of coastline. The upcoming deposit refund scheme is expected to help reduce different types of litter, such as land and marine litter, and prohibit packaging waste from damaging landfills within the country. One of the main reasons the Turkish government has implemented DRS is that it will increase the recycling of plastic and glass containers by

[72] Stavins, R. N. (2003). *Handbook of Environmental Economics: Environmental Degradation and Institutional Responses*. Amsterdam: Elsevier. p. 376.

250 percent and help turn the 811,000 tons of glass and plastic containers thrown into landfills each year into secondary raw materials.

Australia

All Australian states have implemented or will introduce a state-based container deposit scheme operating by 2023, with Victoria the final jurisdiction to support such a scheme.[73] With eight billion beverage containers landfilled or littered every year in Australia, proponents argue that it is the most effective method to reduce litter and improve recycling.

Europe

Most European countries have mandatory bottle deposit laws. Germany was noted in 2012 as one of the few countries that included plastic bottles in its schemes. Ireland is introducing a Deposit Return Scheme for plastic bottles and aluminium cans on February 1, 2024.[74]

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[73] A*BC News*. February 24, 2020.
[74] https://www.gov.ie/en/press-release/b3f2f-minister-smyth-launches-irelands-deposit-return-scheme/

Who Has the Highest Recycling Rate in the World?

During the past few decades, there has been a tremendous push to increase recycling rates all over the world, and Europe does a better job than most other parts of the world. For example, Germany is the country that has the highest recycling rate in the world. Even though there are different ways to calculate the total recycling rate, Germany appears to recycle about 56 percent of all of the waste that it produces.[75]

Germany was not always the leader in world recycling. In 1990, Germany conducted a comprehensive audit of its waste and recycling management systems, and it completed a comprehensive overhaul of its waste and recycling management system to increase the percentage of waste it recycles.

Austria also has a very high recycling rate. It takes second place in the world, with approximately 54 percent of its waste being recycled.[76] Austria increased the percentage of waste it recycles by putting a blanket ban on certain products ending up in landfills. In general, any product that has a total organic carbon emission rate that is higher than five percent is not

[75] Resource.co.
[76] Resource.co.

allowed to go into a landfill. It has to be recycled in some way. This type of strict legislation has led to a significant increase in the recycling rate in Austria during the past few years. There are several other countries in Europe that have followed suit.

Does the United States Recycle a Lot of Waste?

The United States does not recycle nearly as much waste as the other countries in the world. It can be difficult to estimate the total amount of waste that is recycled in the United States because it is controlled at the state level. There are not a lot of rules and regulations at the federal level. Therefore, there are some states that do a much better job of recycling than others. Furthermore, just because someone in the United States puts something in the recycle bin doesn't necessarily mean it is going to get recycled. The recycling plant may decide that some waste might not be recyclable, so it might end up in the landfill anyway.

The United States has a recycling rate of 23%.[77] The U.S. has one of the lowest recycling rates for advanced nations.

Even though Europe is closely associated with recycling, there are a few Asian countries that do a good job as well. For example, South Korea does a great job

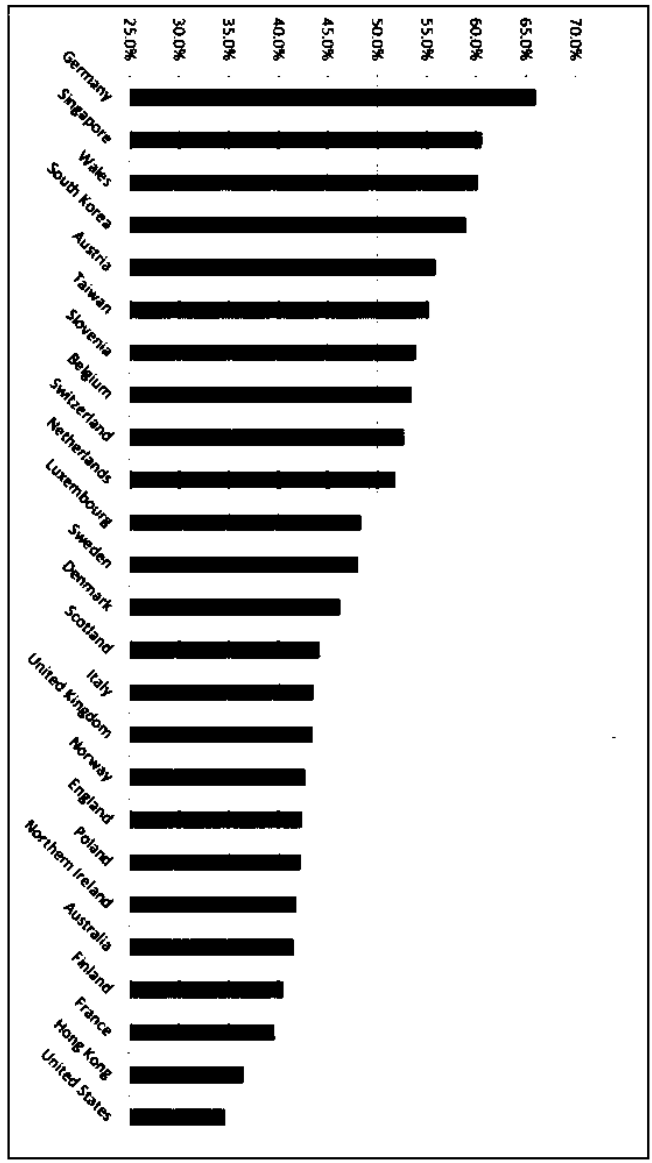
77 "Biomass Explained." *eia.gov. November 2020.*

competing with some of the European countries on the list. South Korea has a recycling rate of approximately 53.7 percent.[78] It has a number of very successful private companies that collect the waste, recycle it, and sell it for a profit.

Slovenia and Germany had the highest municipal solid waste recycling rates (including composting) among OECD countries in 2020, at 75 and 67 percent, respectively. Of the 10 highest ranked recycling rates worldwide, nine were for European countries.[79]

[78] Resource.co.
[79] Resource.co.

Recycling Rates by Country 2017 (Resource.co)



Chapter Five

Alternatives to Plastic

"If it can't be reduced, reused, repaired, rebuilt, refurbished, refurbished, resold, recycled, or composted, then it should be restricted, redesigned or removed from production."

–Pete Seeger, from the song *Garbage,*
late American singer and social activist.

"Waste is a design flaw."

—Kate Kreba, Closed Loop Beverage Fund

"My obsession is plastic packaging. It makes me sick, all the waste. Everything about it disappoints me."

—Theo James, British Actor

"I'll tell you what scares me is plastic. Plastic bags and plastic bottles. Why does my water have to be in a bloody plastic bottle?"

—Helen Mirren, actress

There are many alternatives to plastic. Humans existed for hundreds of thousands of years without plastic. Here are some of the alternatives to plastic:

- Stainless steel. Tough and easy to clean, stainless steel options for reusable food and beverage storage have multiplied in recent years.
- Aluminum.
- Glass.
- Platinum silicone.
- Beeswax-coated cloth.
- Natural fiber cloth.
- Wood.
- Bamboo.
- Pottery and Other Ceramics.
- Cardboard.

Best Alternatives to Plastic

Here are some long-lasting plastic alternatives available right now.

Stainless steel

Tough and easy to clean, stainless steel options for reusable food and beverage storage have multiplied in recent years. You can replace single-use cups, kitchen storage, lunch boxes, and more with this durable metal.

Glass

While not biodegradable, glass is inert, inexpensive and infinitely recyclable. And since many food items come packaged in glass, upcycling glass jars into food storage is a no-cost way to give your food packaging new life. Jars from jam, honey, pickles, nut butters, and so much more can be added to your no-waste toolkit for shopping from the bulk bins. They can also be repurposed to store leftovers and homemade drinks, or decorated and turned into homemade gifts.

Platinum Silicone

Made primarily of sand, food grade platinum silicone is flexible and durable. It's also heat tolerant, so you can boil, bake, and cook in these products without danger of denaturing.

Beeswax-coated cloth

Used primarily as a replacement for plastic wrap and plastic bags, beeswax-coated fabric is easy to use and easy to clean. It also smells great.

Natural fiber cloth

Natural cloth can replace plastic bags. Sustainable clothing made from organic cotton, wool, hemp, or bamboo won't shed plastic fibers when washed. Felted or recycled wool is a versatile, safe, and compostable material for children's toys, household containers, and

more. Cloth bags, and paper bags, keep mushrooms fresher than plastic does.

Wood

A renewable resource, wood from sustainably-managed forests can replace plastic in household items like cleaning brushes, kitchen utensils, and cutting boards.

Bamboo

This fast-growing renewable resource can replace plastic in items like tableware and drinking straws. It is lightweight, durable, and compostable.

Pottery and Other Ceramics

Around for millennia, pottery and other fired ceramics offer a stable, waterproof alternative that's good for food storage and tableware. Look for non-toxic glazes.

Paper

In days gone by, many things were packaged in plain paper. And while better than plastic, paper can't be recycled infinitely because every time it's reused, the fibres get shorter, limiting its use. Luckily all paper except the glossy kind is safe to put in your home compost pile.

Cardboard

Cardboard is fully compostable at home as long as it's not coated, you guessed it, with plastic. Many companies are now packaging their products in plain cardboard to cut down on waste. You can also use cardboard boxes to replace plastic storage containers in your home.

Keep in mind that anything you buy has an environmental footprint. Though longer lasting than plastic, things made from glass, metal, and so on still take energy to make and transport. For these swaps to make sense, you need to use them over and over *and over again*. Buying well-made, durable products will help ensure you get the most use from whatever you choose.

Plant-Based Packaging

Mushroom packaging: A combination of agricultural waste and mycelium (mushroom) root, this home compostable product is "grown" on a hemp-flour mixture, and then dried to halt the growth process. It's most commonly used to replace Styrofoam packaging.

Seaweed-based packaging that comes in edible and biodegradable grades.

Pressed hay is being used as egg cartons in Poland.

Banana Leaves are being used in Thailand, where the plastic problem is reaching crisis proportions, One Thai supermarket has opted to go plastic-free in favor of banana leaf-and-bamboo packaging. And while banana leaves may only be practical where they're readily available, this reinforces the idea of using local, compostable materials.

Chapter Six

Biodegradable Plastics

"Plastic pollution free world is not a choice but a commitment to life – a commitment to the next generation."

–Amit Ray, Indian author and spiritual master.

"It cannot be right to manufacture billions of objects that are used for a matter of minutes, and then are with us for centuries."

–Rosalind Savage, English ocean rower and environmental advocate.

Each year approximately 500 billion to one trillion plastic bags are used worldwide.[80]

Most plastics are made from petroleum. However, functionally similar materials can be made from poly-

[80] "Store offers biodegradable bags." Aiken Standard (Aiken, South Carolina (February 17, 2009).

lactic acid (PLA), which is typically made from plant starch. The other main type of bioplastic is made from polyhydroxyalkanoates (PHAs). PHAs are long-chain polyesters produced by microorganisms and plants. Both types of material are called bioplastics. You will also see them referred to as biodegradable plastics and compostable plastics. Despite the name, not all bioplastic products biodegrade naturally or break down in a compost bin.

One product category where biodegradability makes the most sense is plastic bags. Even when they are made of a recyclable polymer, plastic bags can't go in the regular recycling in most communities. A few curbside programs accept plastic bags, but more often, they must be delivered to special collection bins– which are not available everywhere.

Biodegradable Plastic Bags

Trader Joe's, a national grocery chain in the United States, uses Crown Poly biodegradable plastic bags. The Crown Poly Compostable Bags are made from 100% vegetable starches which make them fully biodegradable and compostable. These bags are certified for both commercial and home composting and will biodegrade within 180 days. Trader Joe's uses these bags without being forced to buy a government agency. But a government agency should compel stores

to use biodegradable bags and ban the use of regular plastic bags. Trader Joe's would not voluntarily use biodegradable plastic bags if they were significantly more expensive than ordinary plastic bags.

Bioplastics, or specifically bioplastic resins, are understood as plastic resins that are combined from starch (wheat starch, corn, potatoes, etc.) and ordinary plastic resins (derived from petroleum) that have been broken. polymer bonding. Depending on the type of product produced, the mixing ratio between coffee grounds and ordinary plastic granules is regulated, up to a maximum of 50% starch. The most commonly used bioplastic is PLA, polylactic acid.

Bioplastic, also known as organic plastic, is defined as a plastic derived from living organisms and formed from renewable materials from nature such as corn flour, rice flour, potatoes, cassava ... or by a variable microorganisms that have the potential to have a positive impact on the environment. Biodegradable bioplastics are plastics that, under the influence of microorganisms, will be completely transformed into CO2, H20, biomass... Common types of biodegradable bioplastics are:

- PLA (polylactic acid) is a biological raw material for the production of plant starches such as corn, potatoes, cassava, etc.

- PHAs (polyhydroxyalkanoates)–these plastics can be made from microbial origin, applied in some cases in the medical field.

- Coffee Bio-composite: Bioplastic derived from 60% natural coffee.

The popularity of PLA bioplastics is much higher than that of PHAs, typically due to the application and field of application of the two different types.

Great features of PLA plastic:

PLA plastic looks and acts like polyethylene terephthalate (PET) and polypropylene, so it is difficult to distinguish PLA from traditional plastic by the eye.

Degradability: The decomposition time of PLA plastic is quite short, only a few months or a few years.

When affected by microorganisms, this bioplastic will completely decompose into carbon dioxide (CO_2) and water (H_2O), beneficial humus for the soil. This is

the main factor that has created a lot of positive effects on the environment.

Environmental Benefits

According to NatureWorks, a company specializing in the production of bioplastics in the U.S., producing PLA bioplastics will save two-thirds of the energy compared to producing conventional plastics.

Unlike traditional plastic, when decomposed, PLA bioplastic does not increase the amount of CO^2 in the air very much. In particular, if buried (composted), when decomposed, they will produce 70% fewer greenhouse gases.

Currently, people are very interested in the use of products related to bioplastics, so biodegradable plastic beads are applied in many fields in life and production. The main aim is to reduce dependence on fossil fuels and be friendly to the environment and human health:

- **Packaging and Coating films:** They are often used in the production of bags or shopping bags, shading films for sun or rain in agriculture;
- **Packaging Industry:** Bags for food.

- **Disposable Plastic Products:** disposable knives, spoons, forks, bowls.
- **Medical Industry:** Syringes, tubes, saline bags.

Chapter Seven

Ban Certain Plastics: Styrofoam, Plastic Straws, Plastic in Cigarettes and Single-Use Plastic Bags

"Cigarette filters are the deadliest fraud in the history of human civilization. They are put on cigarettes to save on the cost of tobacco and to fool people. They don't filter at all. In the U.S., 400,000 people a year die from cigarettes–and those cigarettes almost all have filters."

–Robert Proctor, Professor, history of science
Stanford University

"Of all the waste we generate, plastic bags are perhaps the greatest symbol of our throwaway society. They are used, then forgotten, and they leave a terrible legacy."

–Zac Goldsmith U.K. Minister of State for Overseas Territories, Commonwealth, Energy, Climate and Environment

"Plastics in all its forms – Straws, bottles, packaging, bags, etc. – Are all choking our planet… We must find ways to reduce and eventually eliminate single-use plastic products."

–Former California Governor Jerry Brown

Certain plastics are unnecessary because they are easily replaced with biodegradable materials or because they are not easily recyclable. These materials include Styrofoam, plastic straws, plastic in cigarette filters and single-use plastic bags. Styrofoam is a trademarked brand of closed-cell extruded polystyrene foam. The first polystyrene ban was implemented in Berkeley, California, in 1987.[81]

Microplastics are bits of synthetic material measuring 5 mm or less–about the size of a sesame seed.[82] They're too small to clean up – and they're everywhere.

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[81] *Los Angeles Times,* September 24, 1987.

[82] National Ocean Service. What are microplastics? oceanservice.noaa.gov. https://oceanservice.noaa.gov/facts/microplastics.html.

Cigarette Filters

The tobacco industry produces[83] an estimated six trillion filtered cigarettes a year,[84] making them a top contributor to a global plastic crisis. The tobacco industry's cigarette filters fraud could put us all in danger. The industry makes filters from microplastic fibers, which filter practically nothing.[85] Microplastics contaminate our soil, food, and water, and new studies suggest links to mutations in DNA.[86,87]

They're destroying our environment–and may wind up inside you and the ones you love.

Styrofoam

Styrofoam is a trademarked brand of closed-cell extruded polystyrene foam (XPS), commonly called "Blue Board," manufactured as foam building

[83] Zafeiridou M, Hopkinson NS, Voulvoulis N. Cigarette Smoking: An Assessment of Tobacco's Global Environmental Footprint Across Its Entire Supply Chain. Environmental Science & Technology. 2018.
[84] Novotny TE, Slaughter E. Tobacco Product Waste: An Environmental Approach to Reduce Tobacco Consumption. Curr Environ Health Rep. 2014;1(3):208-216.
[85] Proctor RN. Golden Holocaust: Origins of the Cigarette Catastrophe and the Case for Abolition. Berkeley, CA: University of California Press. 2011.
[86] Oliveri Conti G, Ferrante M, Banni M, et al. Micro- and nano-plastics in edible fruit and vegetables. The first diet risks assessment for the general population. Environ Res. 2020.
[87] Poma A, Vecchiotti G, Colafarina S, et al. In Vitro Genotoxicity of Polystyrene Nanoparticles on the Human Fibroblast Hs27 Cell Line. Nanomaterials (Basel) 2019.

insulation board used in walls, roofs, and foundations as thermal insulation and water barrier. This material is light blue in color and is owned and manufactured by DuPont. DuPont also has produced a line of green and white foam shapes for use in crafts and floral arrangements.

The EPA reported evidence that styrene is carcinogenic for humans and experimental animals, meaning that there is a positive association between exposure and cancer and that causality is credible.[88]

Polystyrene is slow to degrade, and if disposed of improperly, the foam can leach chemicals into the environment harming water sources. Polystyrene manufacturing is an enormous creator of hazardous waste. Furthermore, polystyrene manufacturing greatly contributes to global warming.

Styrofoam is non-biodegradable and appears to last forever. It's resistant to photolysis, or the breaking down of materials by photons originating from light. This, combined with the fact that Styrofoam floats, means that large amounts of polystyrene have accumulated along coastlines and waterways around the world. It is a main component of marine debris.

[88] (Styrene) Fact Sheet: Support Document (CAS No. 100-42-5) "(PDF). EPA. *December 1994.*

Styrofoam can be recycled, but the market for recycled Styrofoam is diminishing. Many companies no longer will accept polystyrene products. Those that are recycled can be remanufactured into things like cafeteria trays or packaging filler.

Along with the health risks associated with the manufacture of polystyrene, air pollution is another concern. The National Bureau of Standards Center for Fire Research has found 57 chemical byproducts released during the creation of Styrofoam.[89] This not only pollutes the air, but also results in liquid and solid toxic waste that requires proper disposal. Another cause for concern are the brominated flame retardants that are used on Styrofoam products.

Research suggests that these chemicals may have negative environmental and health effects.

Styrofoam manufacture also uses hydrofluorocarbons (HFCs), which negatively impact the ozone layer and climate change. HFCs are less detrimental to the ozone than chlorofluorocarbons (CFCs), which were used in the manufacturing of Styrofoam in the past, but it is thought that the impact of HFCs on climate change is much more serious.

[89] https://rucore.libraries.rutgers.edu/rutgers-lib/38329/PDF/1/play/

Styrofoam is made from petroleum, which is a non-sustainable resource, the production of which creates heavy pollution and accelerates climate change.

Alternatives to Styrofoam

According to the EPA, Americans throw out approximately 25 billion styrofoam cups and take-out containers every year. Compostable food service packaging is very available now. Compostable containers are made using corn starch, palm fiber, peat fiber and wheat stocks; and they're able to break down into soil-enriching compost.

Scientists are developing a suitable replacement for styrofoam. A company named Ecovative Design has created a line of products made from fungi and agricultural waste that are styrofoam-like and aspire to be a more environmentally friendly replacement.[90]

Already, a number of independent restaurants and food service brands worldwide, such as Dunkin' Donuts, have shown how compostable containers can be used as a practical alternative. Several years ago, coffee retailer Tully's began serving its popular beverages in compostable cups.

[90] www.ecovativedesign.com.

New York City; Washington, D.C.; Seattle; San Francisco and many more municipalities have announced that food service establishments, stores and manufacturers may not possess, sell, or offer for use single-service Expanded Polystyrene (EPS) foam articles or polystyrene loose fill packaging, such as “packing peanuts.”

You, too, can make eco-friendly choices to eliminate the use of Styrofoam. Send a letter to your state representative demanding a statewide ban on polystyrene products.

Plastic Straws, Plastic Stirrers

- Plastic straws, plastic stirrers and plastic Q-tips are unnessary uses of plastic. The United States uses millions of single-use plastic straws a day.
- Plastic straws are among the top 10 contributors to plastic marine debris across the globe.
- Nearly 7.5 million plastic straws were found on U.S. shorelines during a five-year cleanup research project. Extrapolated globally, that is 437 million to 8.3 billion plastic straws on the world's coastlines.
- Currently, plastic straws make up about 99% of the $3 billion global drinking-straw market.
- Most recycling machines aren’t capable of recycling straws, given their size.

As of November 1, 2021, New York City food service establishments may no longer provide single-use plastic beverage straws, except upon request.[91] Additionally, food service establishments may no longer provide single-use beverage splash sticks or stirrers made of plastic.

Establishments May Provide:

- Beverage straws that are compostable and not made of plastic (for example. compostable paper)
- Beverage splash sticks and stirrers that are compostable and not made of plastic (for example, wood)

Urban Bans on Plastic Straws and Stirrers

Cities including Washington, D.C., New York City, Charleston, South Carolina, and Miami Beach, Florida all have enacted their own bans on plastic straws and stirrers.[92] In September 2019, the Norwalk, Connecticut Common Council unanimously passed a law that prohibit the selling and distribution of single-use plastic straws, single-use plastic stirrers, and

[91] New York City Executive Order No. 54 February 6, 2020.
[92] www.nbcwashington.com/news/local/1-year-in-most-dc-business-complying-with-plastic-straw-ban/2195059. www. https://www.charleston-sc.gov/plastic. www.miamiherald.com/news/local/community/miami-dade/article230127759.html

polystyrene, more commonly referred to as Styrofoam. These ordinances took effect on April 22, 2020.[93]

After a local 2nd grade student successfully petitioned the Portland City Council in 2018 to mitigate plastic straw use in city-owned buildings, the Maine Chapter took it to the next level with Council interest to pass a citywide ordinance becoming the first municipality in Maine to ban single-use plastic straws, stirrers and splash sticks![94]

The days of getting a plastic straw automatically with any drink are over in New Jersey.[95] In a bid to cut down on plastic pollution in the state, all coffee shops, restaurants, convenience stores and any other business that sells food can only give out plastic straws to customers who request them.

The new regulation is the first of several measures that are among the nation's most wide-ranging ban on disposable plastic products. On May 4, 2022, all carry-

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[93] https://www.norwalkct.org/1902/Plastic-Straw-Styrofoam-Ordinances#:~:text=In%20September%202019%2C%20the%20Common%20Council%20unanimously%20passed,These%20ordinances%20take%20effect%20on%20April%2022%2C%202020.

[94] https://www.newscentermaine.com/article/news/local/portland/portland-city-council-votes-to-ban-plastic-straws/97-820a9186-d72b-4aa0-91a2-fdbdfd5607fc.

[95] www.dailyprincetonian.com/article/2021/11/plastic-straws-ban-new-jersey.

out plastic bags were banned along with poly-styrene cups, plates, takeout cartons and other food containers made of the material often called Styrofoam.

The U.S. Microbeads Ban

In 2015, the U.S. banned plastic microbeads in cosmetics and personal care products. Several other countries including the UK, Canada, Taiwan, and New Zealand have also banned microbeads from rinse-off products.

There are many natural alternatives to microbeads in cosmetic products. Some companies have switched to using natural exfoliates such as oatmeal, sea salt, apricot pits, and coconut husks.

Canada's Single-Use Plastic Ban

In Canada, infrastructure is being introduced nationally to reduce plastic waste. Canadian Prime Minister Justin Trudeau announced last year that the country will aim to ban "harmful" single-use plastics by 2021. Trudeau said in a statement: *"As parents, we're at a point when we take our kids to the beach and we have to search out a patch of sand that isn't littered with straws, Styrofoam, or bottles."*[96]

[96] https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/reduce-plastic-waste/single-use-plastic-overview.html.

California's Ban on Straws and Bags

California was the first state to ban single-use plastic bags in 2014 and the first to implement a partial ban on plastic straws in 2018. But California's plastic law is weak and not comprehensive. Ralphs grocery stores, and many other stores, use only plastic bags and claim that they are not single use. Both IKEA and Costco have stopped providing plastic bags at cash registers.

The EU's Single-Use Plastics Ban

In 2018 the EU banned ten throwaway plastics including Styrofoam and single-use straws. Manufacturers of other plastic products—including water bottles and cups—have also seen more strict regulation and all plastic water bottles will need to contain 30 percent recycled content by 2030. The ban will come into force in 2021.[97]

Britain's Straw Ban

In 2015, England joined Wales and Northern Ireland by adding a 5p charge for carrier bags in large

[97] https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics_en#:~:text=The%20EU%20is%20acting%20against,of%20the%20EU%20Member%20States.

supermarkets and stores.[98] Further legislation on lightweight carrier bags and disposable food containers will be clarified and implemented by December 2024. In the next five years, policy on single-use plastics will begin to take effect.[99]

A ban on plastic straws, cotton buds, and stirrers was first announced in April 2018. These restrictions are expected to take effect in April 2020. The Welsh government has said Wales aims to be zero-waste by 2050. The country will also phase out all single-use plastics and plans to become the world leader in recycling.

Australia's Plastic Bag Bans

Victoria is the most recent Australian state to ban the sale of plastic bags. From November, all retailers in Victoria will be subject to heavy fines for providing plastic carrier bags. New South Wales is now the only state in Australia yet to outlaw the bags.[100]

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[98] https://www.gov.uk/guidance/carrier-bag-charges-retailers-responsibilities#:~:text=From%2021%20May%202021%20retailers,bags%20they%20sell%20in%20England.
[99] https://www.gov.uk/government/news/far-reaching-ban-on-single-use-plastics-in-england
[100] https://www.cleanup.org.au/single-use-plasticbags?

Mexico City's Plastic Bag Ban

Mexico City launched its plastic bag ban on January 1, 2021.[101] The law, which was passed in May, 2020, now restricts all businesses excluding perishable food vendors. Companies that produce plastic bags outside of the area will also be prohibited from selling them to Mexico City businesses.

Kenya's Single-Use Bag Ban

Tens of millions of plastic bags were distributed to supermarket customers every year in Kenya before the ban in 2017.[102] Discarded bags polluted the local environment and contributed to floods by blocking drains. The African continent is where most countries have introduced a ban on both the production and use of plastic bags.

Rwanda's Bag Ban

As part of Rwanda's recovery from genocide in the 1990s, the government emphasized environmental protection–including a ban on single-use plastic bags. Rwanda's ban is particularly notable as it prohibits the manufacture, use, importation, and sale of single-use

[101] https://www.dw.com/en/mexico-city-begins-2021-with-ban-on-single-use-plastics/a-56113859.
[102] https://www.unep.org/news-and-stories/story/kenya-bans-single-use-plastics-protected-areas.

carrier bags. Violations are met with fines and in some cases even prison sentences.[103]

Thailand's Plastic Bag Ban

Thailand has kicked off the year with a ban on single-use plastic bags at major stores and supermarkets.[104] A national campaign orchestrated by the gov-ernment and retailers aims for a total ban by the year 2021. Several animals were found last year with plastic in their digestive systems, which increased the coun-try's determination to reduce waste.

Bangladesh Plastic Bag Ban

The government of Bangladesh was the first to introduce a total ban on lightweight plastic bags in 2002.[105] This followed extreme flood damage caused by littered plastic bags that submerged more than two-thirds of the country.

Bangladesh has also created a lucrative and natural alternative to plastic. A scientist has found a way to turn jute—the plant fiber used to create burlap sacks—

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[103] https://www.visitrwanda.com/facts/plastic-ban/
[104] https://www.reuters.com/article/us-thailand-environment-plastic/thailand-kicks-off-2020-with-plastic-bag-ban-idUSKBN1Z01TR.
[105] https://www.reuters.com/article/us-bangladesh-environment-plastic/bangladesh-to-ban-use-of-single-use-plastic-in-hotels-and-restaurants-idUSKBN1Z51BK.

into a plastic-like material. The new bags are biodegradable and recyclable.

Chapter Eight

British Single-Use Plastic Law

"Of all the waste we generate, plastic bags are perhaps the greatest symbol of our throwaway society. They are used, then forgotten, and they leave a terrible legacy."

–Zac Goldsmith, the British Minister of State for Pacific and the Environment.

"Industrial pollution and the discarding of plastic waste must be tackled for the sake of all life in the ocean."

–Sir David Attenborough, renowned British naturalist and documentary filmmaker.

A range of polluting single-use plastics will be banned in Great Britain starting October, 2023.[106] The ban will include single-use plastic plates, trays, bowls,

[106] https://www.gov.uk/guidance/carrier-bag-charges-retailers-responsibilities#:~:text=From%2021%20May%202021%20retailers,bags%20they%20sell%20in%20England.

cutlery, balloon sticks, and certain types of polystyrene cups and food containers. This ban will be introduced from October 2023, allowing businesses time to prepare.

According to estimates, England uses 2.7 billion items of single-use cutlery—most of which are plastic—and 721 million single-use plates per year, but only 10% are recycled. If 2.7 billion pieces of cutlery were lined up they would go round the world over eight and a half times (based on a 15 cm piece of cutlery).

Starting October, 2023 people won't be able to buy these products from any business–this includes retailers, takeaways, food vendors and the hospitality industry. Over 95% of those who responded to the survey were in favor of the bans.

Plastic pollution takes hundreds of years to break down and inflicts serious damage to our oceans, rivers and land. It is also a major source of greenhouse gas emissions, from the production and manufacture of the plastic itself to the way it is disposed.

Environment Secretary Thérèse Coffey said:

> We all know the absolutely devastating impacts that plastic can have on

our environment and wildlife. We have listened to the public and these new single-use plastics bans will continue our vital work to protect the environment for future generations.

I am proud of our efforts in this area: we have banned microbeads, restricted the use of straws, stirrers and cotton buds and our carrier bag charge has successfully cut sales by over 97% in the main supermarkets.

Environment Minister Rebecca Pow said:

Plastic is a scourge which blights our streets and beautiful countryside and I am determined that we shift away from a single-use culture.

By introducing a ban later this year we are doubling down on our commitment to eliminate all avoidable plastic waste. We will also be pressing ahead with our ambitious plans for a deposit return scheme for drinks containers and consistent recycling collections in England.

It is expected that banning these items will have a significant impact in reducing plastic waste and littering in the U.K.. Plastic cutlery, for instance, was in the top 15 most littered items in the country by count in 2020. The ban includes plastic straws, stirrers and cotton buds (Qtips).

The Rt. Hon. George Eustice MP said:

> The ban on supplying plastic straws and stirrers and plastic-stemmed cotton buds has come into force in England marking yet another major step in the Government's fight against single-use plastic waste to protect our environment and clean up our oceans.
>
> Just one month after ministers confirmed the single-use plastic bag charge would be increased to 10p and extended to all retailers, today's commencement of the ban will further ensure the country builds back greener.
>
> It is estimated we use 4.7 billion plastic straws, 316 million plastic stirrers, and 1.8 billion plastic-stemmed cotton buds in England every year, many

> of which find their way into our ocean. By banning the supply of these items, we can further protect our marine wildlife and move one step closer to our ambition of eliminating all avoidable plastic waste, as set out in our 25 Year Environment Plan.

Dr Laura Foster, Head of Clean Seas at the Marine Conservation Society, said:

> It's fantastic news that the ban on plastic cotton bud sticks, stirrers and straws is now in place. The results of our annual Great British Beach Clean have shown a decrease in cotton bud sticks littering British beaches.
>
> In 2017 we found an average of 31 cotton bud sticks per 100 metres of beach, and in 2019 we found just eight on beaches in England. This reflects that many companies have already made the switch away from plastic, in cotton buds and other items, something we need to see more companies doing.

The ban will not apply to plates, trays, and bowls that are used as packaging in shelf-ready pre-packaged

food items, as these will be included in a plan for an Extended Producer Responsibility Scheme–which will incentivize producers to use packaging that can be recycled and meet higher recycling targets. For example, this would include pre-packaged salad bowls and bowls filled with food at the counter of a takeaway.

The U.K. also enacted the Plastic Packaging Tax in April, 2022–a tax of £200 per ton on plastic packaging manufactured in, or imported into the UK, that does not contain at least 30% recycled plastic.

Through the Environment Act, the U.K. government is bringing in further measures to tackle plastic pollution and litter. This includes a Deposit Return Scheme for drinks containers to recycle billions more plastic bottles and stop them being landfilled, incinerated, or littered via a small deposit on drinks products to incentivize people to recycle, and plans for Consistent Recycling Collections for every household and business in the United Kingdom.

Chapter Nine

Other Nation's Plastic Laws

Since December 20, 2022, the manufacture and import for sale in Canada of checkout bags, cutlery, foodservice ware, stir sticks and straws as defined in the Regulations, are prohibited.[107] The law bans six items, plastic grocery bags, straws, stir sticks, six-pack rings, plastic cutlery and plastic take-out containers.

Indonesia is dealing with a serious plastic pollution problem It is home to the world's largest archipelago with more than 17,000 islands, 81,000 kilometers (50,000 miles) of coastline and a rich abundance of biodiverse marine life. Within a few years Indonesia projected that 800,000 tons of plastic waste would be dumped into its waters.

Indonesia plans to cut its plastic pollution by 70% within the next five years and aims to achieve a plasti-free Indonesia by 2040. Domestically, since the Solid

[107] www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/reduce-plastic-waste/single-use-plastic-overview.html.

Waste Management Act (NO.18/2008), there have been many waste management laws and regulation rules introduced at national, regional, and city levels, with some addressing plastic pollution as part of the broader issue.

President Regulation No. 97/2017 is a roadmap towards the 2025 Clean-from-Waste Indonesia (Indonesia Bersih Sampah 2025). It sets a target of 30% waste reduction and 70% waste handling by 2025 (Figure 3). Indicators for waste reduction include decreasing waste generation per capita, reducing waste at source (e.g., plastic bag restriction), and reducing waste leakage to the environment (Figure 4). For the "70% handling" target mentioned above, the indicators include increasing waste to be treated (recycling, composting, biogas, thermal recovery, etc.) and reducing waste to be landfilled (MoEF 2020). Through these targets, the Ministry of Environment and Forestry aims to reduce 70% marine plastic by 2025.

The regulation No. P.75/2019 on Extended Producer Responsibility (EPR) is designed to guide and facilitate the producers (brand owners, manufacturers, importers, retailers, and the food and beverage service industry, etc.) to implement their EPR on reducing the waste generated from their goods, packaging, and services in plastics, paper, aluminum cans, and glass (MoEF 2020). The regulation contains three components (direct translation from IGES 2021):

(1) To prevent and limit the potential of waste generation as much as possible by implementing design for sustainability in the form of redesigned products and packaging, by phasing out single-use plastics, eliminating unnecessary and excessive packaging, making packaging more recyclable and reusable, creating packaging out of more recycled content, and producing more durable, returnable, rechargeable, and refillable goods; (2) To take back post-consumer products and packaging for reuse; and (3) To take back post-consumer products and packaging for recycling.

Chapter Ten

U.S. Plastic Law Proposal

The California Association for Recycling All Trash (CARAT) is proposing the Plastic Limitation and Environmental Action Strategy Endeavor Act (PLEASE). The proposed legislation is simple, clear and powerful:

Plastic Limitation and Environmental Action Strategy Endeavor Act

1. **Name of Law.** This law shall be known as the Plastic Limitation and Environmental Action Strategy Endeavor Act (PLEASE).
2. **Regulations.** The U.S. Environmental Protection agency shall implement this legislation with regulations and enforcement.
3. **Definitions.**
    a. Plastics made from petrochemicals: Plastic made from petroleum or petroleum byproducts.

b. Biodegradable plastics: Plastics made from plants with no petrochemicals.
c. Compostable: Products that degrade in soil and/or water within 90 days.

4. **Ban on Certain Plastics.** It shall be unlawful to manufacture and sell plastics made from petrochemicals into the following products:
   a. Straws;
   b. Toothpicks;
   c. Coffee stirrers;
   d. Single-use bags;
   e. Packaging;
   f. Wrap for wrapping food leftovers;
   g. Eating utensils;
   h. Plastic tops for beverages;
   i. Food containers;

j. Styrofoam and polystyrene foam;

k. Cigarette filters; and

l. Dental picks;

m. Drycleaner's use of plastic to cover clothing and to hold clothing in place;

n. Balloons.

5. **Biodegradable Plastics.** It shall be lawful to manufacture and sell plastic that is biodegradable and compostable, including the items banned under section 4.

6. **Plastic bottles.** Plastic bottles can be legally manufactured and sold so long as they are recyclable and a deposit is paid when purchased. The deposit is refundable at stores where the products are sold. This requirement

is for all plastic bottles, including beverages, food and drug products.

7. **Electronic Products.** All electronic products containing plastic, including computers, televisions, radios, telephones and other electronic devices must have a deposit paid when purchased of not less than $10. Stores selling these products must accept them for recycling and repay the deposit when the product is returned.

8. **Medical Products.** Medical products, including syringes, tubing, intravenous devices and other medical products, must be stored in red bags at hospitals and disposed of in landfills that are lined with material that prevent leaching.

9. **Toys.** Plastic toys made out of petroleum-based plastics shall be made of recyclable materials. A deposit on these toys shall be no less than $1 and shall be redeemed when toys are returned to stores selling these toys. Toy stores are required to accept the return of these products and to repay the deposit to the consumer.

10. **Plastic Containers.** Plastic containers can be manufactured and sold so long as they have a deposit of at least $1 that is redeemable at the store where plastic containers are sold.

11. **Other Plastic Products.** Plastic products must either be biodegradable plastic or have a deposit for its redemption.

12. **Enforcement.** The U.S. Environmental Protection Agency has the right to enforce this legislation administratively and by seeking court orders. This legislation creates standing and a cause of action for any consumer or non-profit organization to bring an action against a manufacturer or a retail store not in compliance with this law. The consumer shall recover not less than $1,000 no more than $25,000 in statutory damages, plus attorneys' fees and court costs. The court shall order the manufacturer or the retail store to implement the law within 30 days. Attorneys' fees shall not be awarded against a plaintiff.

13. **Effective Date**. This law shall go into effect on January 1, 2024.

Chapter Eleven

Proposed International Treaty

"Plastic waste is now found in the most remote areas of the planet. It kills marine life and is doing major harm to communities that depend on fishing and tourism."

–António Guterres, UN secretary general

The first round of discussion for a Global Plastics Treaty were held in Punta del Este, Uruguary in November, 2022. The UN Environmental Assembly in March, 2022 agreed on the adoption of a mandate for an International Negotiating Committee to develop a legally-binding UN Treaty on Plastic Pollution. The goal is to complete negotiations by the end of 2024.

The Draft Resolution

- Includes explicit references to the circular economy, full life cycle and sustainable production and consumption.
- Underlines the importance of promoting a circular design of products and materials so that they can be reused, remanufactured or recycled and therefore retained in the economy for as long as

possible along with the resources they are made of, as well as minimising the generation of waste.

- Encourages action by all stakeholders, including the private sector, and calls upon all UN member states to continue and step up their activities, whilst also recognising the significant contribution made by workers under informal and cooperative settings to collecting, sorting and recycling plastics in many countries.
- Promotes cooperation at the global, regional, national and local levels, recognizing the need to strengthen global coordination and governance to take immediate actions.

This new treaty should:

- Include legally binding elements to prevent a patchwork of disconnected solutions, create a level playing field, and set the right enabling conditions to scale up circular economy solutions worldwide.
- Address the full life cycle of plastics, including product design, aiming to keep plastics in the economy and out of the environment, reduce virgin plastic production and use, and decouple plastic production from the consumption of finite resources.
- Provide a global common vision and harmonized standards that strengthen global coordination, and align stakeholders behind a common under-

standing and a shared approach to address plastic pollution.

- Recognize the significant contribution made by workers under informal and cooperative settings to collecting, sorting and recycling plastics in many countries, and that they must be included as key stakeholders in the negotiation of the UN treaty on plastic pollution.

Realizing a circular economy for plastics (and beyond) is also crucial to address climate change and biodiversity loss. In view of the key international meetings on climate and biodiversity policy this year,2 it is the right time to acknowledge the important contribution of a global transition towards a circular economy, for plastics and beyond, to achieve the goals and commitments under the Paris Agreement and Convention on Biological Diversity.

A new UN treaty to address plastic pollution would provide the framework for building the relevant capabilities and institutional mechanisms for increased international coordination and cooperation to solve this crisis.

Important work has already been carried out under the 2018 Canadian G7 presidency on the Ocean Plastics Charter,3 as well as under the 2019 Japanese G20 presidency on the Osaka Blue Ocean Vision and the G20 Implementation Framework for Actions on

Marine Plastic Litter. In 2021 the G20 agreed to engage fully in upcoming UN discussions on how to take further decisive steps, including the possibility of a new global agreement or instrument to address marine plastic litter. Such a global policy framework could include binding targets and setting out the scope for sectoral, regional and national action plans as well as support for implementation. Relevant initiatives should be brought together to ensure that progress and impact monitoring will be based on consistent definitions and measurement towards a global goal, such as preventing all plastic leakage into the environ-ment by a certain target date. A comprehensive policy framework supporting the global transition to a circular economy would:

• Enable circular design solutions for plastics in the relevant sectors, including agriculture and fishery, medical, hygiene and cosmetic products, textiles and wearing apparel, construction materials, transporttation, food and beverage packaging

• Promote better resource management capabilities to eliminate waste and pollution, keeping plastics in use for longer and re-circulating them after their useful life

• Review the setup of financial incentives and regulations to shape the right economic conditions for a circular economy, including for reuse models and recycled plastics

• Facilitate investments to scale relevant innovations, infrastructures and skills in countries and industries most in need of international support

• Foster public-private collaboration across value chains and governance structures A growing number of leading businesses from the corporate and the financial sectors, are calling on national governments to commit to the development of a new UN treaty addressing plastic pollution and enabling circular economy solutions to scale globally. In this regard, governments, industry, and civil society stakeholders should work together towards creating a common understanding and direction of travel on the main building blocks for a new UN treaty on plastic pollution.

In July 2020, The Pew Charitable Trusts and SYSTEMIQ released Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution-one of the most analytically robust studies ever produced on ocean plastics. Thought partners were the University of Oxford, University of Leeds, Common Seas, and the Ellen MacArthur Foundation. The key findings from this report show that a comprehensive circular economy approach is needed, rethinking what is put on the market, whilst also rapidly increasing our ability to keep it in the economy after it has been used.12 The circular economy considers every stage of a product's life cycle–before and after it reaches the customer.

This approach is not only vital to stop plastic pollution, but as the study shows, it offers the strongest economic, social, and climate benefits. In contrast, business-as-usual is driven by four main cumulative trends: population growth, rising per capita plastic use, shifts to low-value and hard-to-recycle materials, and disproportionate growth in markets with low plastic collection rates.13 In this context, an opportunity beckons for the plastics value chain to deliver better systemwide economic and environmental outcomes: First, in a circular economy we must eliminate the plastics that we do not need. Secondly, we must circulate the plastics that we do need. Deploying all known solutions at maximum speed and scale would still result in more than 150 million tonnes of plastic waste being incinerated, landfilled, or mismanaged every year by 2040. So we must also innovate at unprecedented speed and scale towards new business models, product designs, materials, technologies, and collection systems. For example, converting 20% of global plastic packaging into reuse models offers a USD 10 billion business opportunity. Material Economics (2018): The Circular Economy: a Powerful Force for Climate Mitigation The Pew Charitable Trusts and SYSTEMIQ (2020): Breaking the Plastic Wave. A comprehensive assessment of pathways towards stopping ocean plastic pollution. 10 Global Resources

Outlook (2019): Natural resources for the future we want 11 Ellen MacArthur Foundation (2016):

The New Plastics Economy initiative has brought together key stakeholders to rethink and redesign the future of plastics, starting with packaging. Today, more than 1,000 organizations are aligned behind a common vision on a circular economy for plastics, which has six key points:

1. Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority

2. Reuse models are applied where relevant, reducing the need for single-use packaging

3. All plastic packaging is 100% reusable, recyclable, or compostable

4. All plastic packaging is reused, recycled, or composted in practice

5. The use of plastic is fully decoupled from the consumption of finite resources

6. All plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected European Union. Today, the

Charter brings together 26 national governments and 9 global partners from businesses and civil society organizations who are committed to implementing a more resource efficient and lifecycle management approach to plastics on land and at sea within their respective jurisdictions and areas of influence. The Ocean Plastics Charter recognizes key areas for action at national level including: 1. Sustainable design, production, and after-use markets 2. Collection, management, and other systems and infrastructure 3. Sustainable lifestyles and education 4. Research, innovation, and new technologies 5. Coastal and shoreline action While upstream measures in the plastic value chain have been defined as a distinct area for policy action, the Charter lacks an institutionalized mechanism to provide international coordination, technical and financial support where most needed, as well as binding rules on monitoring and reporting. In sum, current efforts do not aggregate to deliver the desired global change: preventing all plastic leakage into the environment by a certain target date.

There is an opportunity to strengthen policy coordination and collaboration beyond exchange of information and best practices, but this requires a more binding and comprehensive international framework. Working towards a new UN treaty to address plastic

pollution will accelerate progress and convergence under existing initiatives, even before such a treaty is adopted and comes into force.

Over the last two years, the political momentum and support for starting international negotiations on a comprehensive global policy framework to address plastic pollution has been growing:

• More than 70 leading companies support a call for a new UN treaty on plastic pollution20 to address the fragmented landscape of regulation and complement existing voluntary measures.

• A majority of all UN member states from across the world have already officially declared that they are open to considering a new global agreement. As of August 2021, more than 100 national governments have already taken an explicit decision to support establishing an international negotiating committee at UNEA 5.2 in February 2022.21

• More than two million people have signed the online petition on the WWF website, supporting a global legally binding agreement that involves every country in ending the plastics crisis.

A new UN treaty would allow governments to tackle plastic pollution in a way that the Paris Agreement has done for climate change and the Montreal Protocol has done for ozone depletion. Indeed, for most other pressing environmental challenges that entail growing negative transboundary impacts and

require problem drivers to be addressed internationally, there is already a global policy framework in place. In the case of the Montreal Protocol for example, it took only 18 months to reach a binding global agreement to protect the earth's ozone layer, once there was a clear understanding of the problem and consensus between governments about the scope and timeframe for political action. As a result, the ozone hole in Antarctica is slowly recovering, and projections indicate that the ozone layer will return to 1980 levels between 2050 and 2070.

A more recent example is the so-called Minamata Convention to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. It was signed in 2013 after three years of meetings and negotiations. In support of its objective, it includes provisions that relate to the entire life cycle of mercury, including controls and reductions across a range of products, processes, and industries where mercury is used, released or emitted. This approach could be well suited to be adapted to plastics. The political reasoning for a UN treaty on plastics is well supported

World Wildlife Fund's Global Plastic Navigator petition at the G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth, held in 2019 in Japan, the G20 Implementation Framework for Actions on Marine Plastic

Litter was established. It was endorsed by the G20 Leaders at the subsequent G20 Osaka Summit together with a common global vision to address plastic pollution: the 'Osaka Blue Ocean Vision'.

As of July 2021, the number of countries and regions sharing the Osaka Blue Ocean Vision has risen to 87. These countries, which include the G20 members, also share and update information through annual reports on relevant policies, plans and measures, and promote peer learning from best practices. The Osaka Blue Ocean Vision signalled for the first time the international support for an overarching goal of stopping plastic leakage into the ocean by a certain target date. Working towards this goal, the G20 countries committed to implement and report on relevant solutions in their own jurisdictions, as well as to enhance international cooperation and capacity building. The G20 Implementation Framework for Actions on Marine Plastic Litter acknowledges and is expected to complement the work carried out under the UN Environmental Assembly.

A pathway to negotiating such a treaty is in sight The United Nations Environment Assembly (UNEA) has adopted successive resolutions, leading to an increased focus on the effectiveness of policy response and governance options relating to plastic pollution. At UNEA-3 in 2017, governments established an Ad Hoc Open-Ended Expert Group (AHEG) to review different

governance options for combating marine plastic litter and microplastics from all sources, especially land-based. It considered existing agreements and frameworks and identified where gaps remained, in addition to analyzing the effectiveness of existing and potential response options to address plastic pollution.23 At UNEA-4 in 2019, member states called for more rigorous monitoring of the status of the global plastic pollution problem and efforts to address it, including existing activities and actions by governments covering the whole life cycle of plastics. A Plastics Policy Inventory24 was created to support such monitoring. The expert group's mandate was extended to continue its work on scoping possible governance options which was concluded in November 2020 with a view to taking a decision at UNEA-5 in February 2022.25 In the meantime, a majority of UN member states had already stated that they are open to consider starting negotiations on a new international treaty to address plastic pollution.

The World Wildlife Fund has proposed five points of action:

1. Production.

Cutting or limiting production of plastic is the first step. Underscoring how out of control production is,

the production of virgin plastic has increased 200-fold since 1950 and has grown 4% a year since 2000. The facts are alarming. Today, single-use plastic covers the Earth, and its consumption is on track to skyrocket – from 460 million tons in 2019 to 1.23 billion tons in 2060, threatening our ecosystems.

2. Usage

Currently 40% of plastic is single-use, like plastic bags, straws, coffee stirrers, bottles, packaging and cigarette filters.

3. Waste Collection

Poor sorting of trash and low recycling rates must be addressed.

4. Treatment

In 2016 less than 20% of plastic waste was recycled worldwide.

5. Secondary Markets

We must expand secondary markets for recycled materials.

The California Association for Recycling All Trash (CARAT) is proposing the Plastic Limitation and Environmental Action Strategy Endeavor Treaty (PLEASE).

This treaty is consistent with the proposals of the World Wildlife Federation and the United Nation's resolution. The proposed treaty is simple, clear and powerful:

Plastic Limitation and Environmental Action Stategy Endeavor Treaty (PLEASE)

1. **Name of Treaty.** This law shall be known as the Plastic Limitation and Environmental Action Strategy Endeavor Treaty (PLEASE).
2. **Definitions.**
    a. Plastics made from petrochemicals: Plastic made from petroleum or petroleum byproducts.
    b. Biodegradable plastics: Plastics made from plants with no petrochemicals.
    c. Compostable: Products that degrade in soil and/or water within 90 days.

3. **Ban on Certain Plastics.** It shall be unlawful to manufacture and sell plastics made from petrochemicals into the following products:
    a. Straws;
    b. Toothpicks;
    c. Coffee stirrers;
    d. Single-use bags;
    e. Packaging;
    f. Wrap for wrapping food leftovers;
    g. Eating utensils;
    h. Plastic tops for beverages;
    i. Food containers;
    j. Styrofoam and polystyrene foam;
    k. Cigarette filters;
    l. Dental picks;
    m. Drycleaner's use of plastic to cover clothing and to hold clothing in place; and

n. Balloons.

4. **Biodegradable Plastics.** It shall be lawful to manufacture and sell plastic that is biodegradable and compostable, including the items banned under section 3.
5. **Plastic bottles.** Plastic bottles can be legally manufactured and sold so long as they are recyclable and a deposit is paid when purchased. The deposit is refundable at stores where the products are sold. This requirement is for all plastic bottles, including beverages, food and drug products.

6. **Electronic Products.** All electronic products containing plastic, including computers, televisions, radios, telephones and other electronic devices must have a deposit paid

when purchased. Stores selling these products must accept them for recycling and repay the deposit when the product is returned.

7. **Medical Products.** Medical products, including syringes, tubing, intravenous devices and other medical products, must be stored in red bags at hospitals and disposed of in landfills that are lined with material that prevent leaching.

8. **Toys.** Plastic toys made out of petroleum-based plastics shall be made of recyclable materials. A deposit on these toys shall be redeemed when toys are returned to stores selling these toys. Toy stores are required to accept the return of these products and to repay the deposit to the consumer.

9. **Plastic Containers.** Plastic containers can be manufactured and sold so long as they have a deposit of that is redeemable at the store where plastic containers are sold.

10. **Other Plastic Products.** Plastic products must either be biodegradable plastic or have a deposit for its redemption.

11. **Effective Date**. This treaty shall go into effect on January 1, 2025.

Chapter Twelve

Cleanup of the Oceans

"Never doubt that a small group of committed citizens can change the world; indeed, it is the only thing that ever has."

— Margaret Mead, Cultural Anthropoligist

"It is our collective and individual responsibility to preserve and tend to the world in which we all live."

—Dalai Lama, Spiritual Leader of Tibet

At 16 years of age, Boyan Slat saw more plastic bags than fish when scuba diving in Greece. He thought: "Why can't we just clean this up?" This question led him to research the plastic pollution problem for a school project. He learned about plastic accumulating in five large oceanic gyres, the largest one being the Great Pacific Garbage Patch. In 2012, Boyan Slat held a TEDx talk about how to rid the world's oceans of plastic using technology. The video went viral, and the

momentum that followed allowed him to drop out of school and found The Ocean Cleanup.

After many years of research, development, testing, and iteration, The Ocean Cleanup now has technologies to intercept plastic in rivers before it reaches the ocean, and technologies to remove the plastic that is already out there—debris that has been building up for decades.

Ocean Systems

Plastic, once trapped in a gyre, will slowly break down, fragmenting into pieces called microplastics. Microplastic debris (< 5mm) is not only more challenging to clean up but is also easily mistaken for food by marine life.

The ocean garbage patches are massive. To effectively clean an area of such magnitude, a calculated and energy-efficient solution is required. With a relative speed difference maintained between the cleanup system and the plastic, we can concentrate the plastic for extraction.

The harvested plastic is brought back to shore for recycling. Ocean Systems first product– The Ocean Cleanup Sunglasses – using the catch of System 001/B in 2019. Going forward, Ocean Systems plans to part-

ner with companies who will use ocean plastic in their products.

Interceptors

1,000 rivers, or one percent of the world's rivers, account for 80% of the plastic flowing into the oceans from land. Ocean Systems has developed a toolkit of Interceptors to tackle these rivers. Together with corporations, governments and individuals globally, Ocean Systems plans on tackling 1,000 of the most polluted rivers with it technology, knowledge, experience and network.

The Ocean Cleanup is a project; Ocean System's goal is to reach a 90% reduction of floating ocean plastic by 2040.

Mechanical systems, such as Mr. Trash Wheel, a litter interceptor in Maryland's Baltimore Harbor, can be effective at picking up large pieces of plastic, such as foam cups and food containers, from inland waters.

4 Ocean

4ocean was founded on the belief that business can be a force for good and that the small choices we make every day, collectively, have the power to change the world.

4Ocean has pulled 27,589,117 pounds of trash from the world's oceans, rivers, and coastlines. 4ocean manufactures bracelets and other products from plastic that it pulls from streams and oceans.

Global Plastic Innovation Network

In June 2021, the Global Plastic Action Partnership and UpLink launched the Global Plastic Innovation Network (GPIN). GPIN is building a community of innovators to tackle plastic pollution at the national and global level, from redesigning packaging to implementing new recycling technologies.

Siklus

Siklus is reinventing the future of retail in Indonesia by delivering refills of everyday needs to people's doors without plastic waste. It offers refill stations that allow consumers to buy household products without plastic packaging.

gCycle and Other Compostable Diapers

gCycle in Australia is tacking sustainability in the disposable diaper (nappy) industry. The newest invention is the world's first patented fully compostable disposable diaper.

Dyper bamboo diapers are compostable.

Andy Pandy Bamboo Disposable Diapers

Eco by Naty Baby Diapers is made from wood chips.

Bamboo Nature Baby Diapers.

Freestyle Absorbent Diapers.

Pampers Pure Protection Disposable Diapers.

Coterie Ultra Soft Diapers.

Plastic Fischer

Plastic Fischer has developed a low-tech plastic collection systems for rivers and have already deployed several systems in the Citarum River in Bali. Thanks to their low-tech system, their solution is designed to be easily scaled around the world.

Diwanna provides a hardware and software solution to waste-sorting facilities. The technology uses AI-based image recognition software that automates waste analysis.

River Recycle offers disruptive methods to alter waste management systems. The solution seeks to stem

the tide of plastic pollution in rivers by collecting and recycling plastic waste and floating debris while providing a livelihood for local communities.

Waste Bazaar is a clean-tech providing waste collection and recycling services in Nigeria. They have developed a mobile-phone app that uses geolocation functionalities to connect users to the nearest recycling station, where recyclable waste can be exchanged for green credits.

Wasser 3.0 has developed a solution that is quick, efficient and cost-effective to remove microplastic and micropollutants from different types of water. The solution uses agglomeration fixation for microplastics and chelation for inorganic compounds.

TONTONTON is building a system in which the communities play a key role in cleaning their own environment while earning a livelihood through a certified plastic credit system. They work closely and empower local waste pickers to address plastic pollution in Vietnam and Cambodia.

Microscopic Plastic Removal from Wastewater

The Norwegian Institute for Water Research demonstrated that plastic particles could be removed from wastewater with sand filtration.[108] A laboratory-scale sand-filter was highly efficient in removing all types and sizes of microplastic particles, from both wastewater samples, i.e., untreated and the facility's sand-filtered samples. Very few particles were found in the wastewater filtered using the laboratory-scale sand-filter, and a significant improvement in color was also observed. This study demonstrates the effectiveness of a correctly designed sand-filter for the removal of a wide range of microplastic particles from wastewater. The final filtration step (sand-filter or other filtration processes) should therefore be optimized for both the removal of microplastics, and other contaminants of concern, including micropollutants.

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About the Author

Joel D. Joseph is the author of eighteen books, mostly on law, including *Black Mondays: Worst Decisions of the Supreme Court*. Now in its fifth edition, Justice Thurgood Marshall wrote the foreword.

Joseph is a former law professor and graduate of Georgetown University Law Center in Washington, D.C. He has represented environmental organizations, including the Sierra Club, in Clean Air Act and National Environmental Policy Act cases up to and including the United States Supreme Court.

Joseph formed the California Association for Recycling All Trash (CARAT) in 2020. CARAT is a nonprofit, tax-exempt, 501(c)(3) organization. He is its Chief Executive Officer. CARAT has forced, through litigation and persuasion, thousands of grocery stores in California to accept the return of bottles and cans for recycling. California is one of only ten states that mandates bottle and can recycling deposits. In these ten states the recycling rate is significantly higher than in the other 40 states. Joseph has also proposed a nationwide recycling law in the United States to increase recycling nationwide.