PLASTIC OCEANS

Mr. McGuire: I want to say one word to you. Just one word.
Benjamin: Yes, sir.
Mr. McGuire: Are you listening?
Benjamin: Yes, I am.
Mr. McGuire: Plastics.
Benjamin: Exactly, how do you mean?
Mr. McGuire: There's a great future in plastics.
Think about it. Will you think about it?
Benjamin: Yes, I will.
– The Graduate, 1967

Marine debris – trash in our oceans –
is a symptom of our throw-away society and our approach
to how we use our natural resources.
– Achim Steiner

You're enjoying your day at the beach when suddenly a gust of wind blows your plastic bags and plates off of your blanket. You try and catch them as the various pieces lurch erratically across the sand. You recover a few items, but some of them get away and are carried by the breeze down the coast. At the end of the day, a plastic water bottle, a spoon, or two, maybe a shovel or Frisbee, get left behind in the sand.

Plastic products can escape from overflowing trash cans, piles of garbage at municipal and illegal dumps, and through many other circumstances. They make their way through streams, lakes, rivers, and stormwater to the ocean.[9] Styrofoam food containers, sunglasses, bottle caps, drinking straws, beach coolers, fishing lines, and a wide assortment of other consumer products gradually make their way to the ocean, where they are worn down by time and the elements. That bobbing plastic bottle will eventually disappear from view, but its ever smaller long-lived particles will still be in the environment.

Floating garbage off the shore of Manila Bay in the Philippines.

Some of these plastic objects may be picked up and thrown out, while some remain exposed to the environment. The sun, wind, and sand slowly do their work, making the plastics more brittle, breaking them down into smaller pieces. Some of these items and smaller fragmented parts make their way into the ocean, where sunlight and wave action continue to break them into smaller and smaller pieces. Through ocean currents, some of this plastic waste collects on distant shores. Many end up in one of the enormous ocean whirlpools where they accumulate and continue to break apart.

Rise of the plastics

Plastics are a man-made substance that has been incorporated into modern life over the last century. Plastic's characteristics of flexibility, durability, strength, versatility, light weight, and low production cost have contributed to its entering all aspects of everyday life. Many types of products use this synthetic material, which comes in many shapes, sizes, and colors. Some common types of plastic are polystyrene (PS, aka Styrofoam) used for take-out food containers; polyethylene terephthalate (PET) used for soda bottles; polyethylene (PE) used for plastic bags; high-density polyethylene (HDPE) used for detergent bottles; polyvinyl chloride (PVC) used for plumbing pipes; polypropylene (PP) used for drinking straws; polyamide (PA, aka nylon) used for toothbrushes; and polyester (PES) used for clothing.[10]

> *Plastics have become increasingly dominant in the consumer marketplace since their commercial development in the 1930s and 1940s… The largest market sector for plastic resins is packaging; that is, materials designed for immediate disposal. In 1960, plastics made up less than 1% of municipal solid waste by mass in the United States; by 2000, this proportion increased by an order of magnitude. By 2005, plastic made up at least 10% of solid waste.*[11]

Worldwide plastic production began just after World War II, increasing from 2.3 million tons in 1950 to 162 million tons in 1993[12] and 359 million tons by 2015.[13] Since the 1940s, a total of about 9.2 billion tons of plastic have been produced.[14] Of that amount, 6.9 billion tons have become waste, with only about 9% of discarded plastic having been recycled, leaving 6.3 billion tons sitting in landfills and in the environment[15,16] equal to the weight of over 17,200 Empire State Buildings.[17]

The Empire State Building, located in New York City, has a height of 443 meters (1,454 feet) and weighs 331,000 metric tons (365,000 tons), equal to over 220,000 midsize sedans.

Flooding our oceans

In 2010, the 6.4 billion people living in countries within 50 kilometers (31 miles) of an ocean coast produced an estimated 2.5 billion metric tons of garbage: Approximately 11% or 275 million metric tons of plastic. An estimated 1.7 to 4.6% (or 4.8 to 12.7 million metric tons) of plastic waste generated by those countries entered the ocean in 2010.[18] To put things into perspective, the largest living animal in the world is the blue whale, with an average adult weight of about 115 metric tons,[19] meaning that as much as 110,000 blue whales' weight equivalent of plastic enters our oceans each year. Another way to look at this, if the average midsize sedan weighs 3,300 pounds,[20] that plastic entering the ocean each year would equal the weight of over 8 million cars.

> It's hard to imagine the blue whale's size, which is the largest living animal in the world. They average 21 to 27 meters (70 to 90 feet) and weigh 90 to 136 metric tons (100 to 150 tons), equal to the weight of 75 midsize sedans. The blue whale is as long as three school buses, and their heart alone is as large as a small car.

According to the global risk consulting firm Verisk Maplecroft, Americans recycle just 35% of their municipal waste, while the most efficient country, Germany, recycles 68%. The firm estimates the United States produces about 106 kilograms (234 pounds) of plastic waste per person per year.

> *"The US is the only developed nation whose waste generation outstrips its ability to recycle, underscoring a shortage of political will and investment in infrastructure," the firm said. Will Nichols, the firm's head of environment, said the US had better recycling abilities than much of the world, "but the sheer amount of waste that is being generated is not being dealt with as well."*[21]

In the United States, the equivalent of 1,300 plastic grocery bags per person end up in places such as oceans and roadways.

A 2020 study in the journal Science Advances shows that in 2016 the United States generated 46.3 million tons of plastic waste, by far the most in the world.[22] Of that waste, between 2.7% and 5.3% (1.2 million and 2.5 million tons) was mismanaged. According to study co-author Jenna Jambeck, an environmental engineering professor at the University of Georgia,

> *If you took nearly 2.5 million tons of mismanaged plastic waste — bottles, wrappers, grocery bags and the like — and dumped it on the White House lawn, it would pile as high as the Empire State Building.*[23]

The plastic was dumped on land, rivers, lakes, or shipped abroad, where it was not properly disposed of. An estimated 560,000 to 1.6 million tons of United States plastic waste likely went into oceans. This makes the United States the largest plastic pollution generator globally and the third-worst ocean plastic polluter.[24]

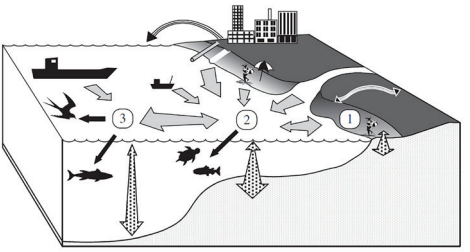


Diagram showing the main sources and movement pathways for plastics in the marine environment, with sinks occurring (1) on beaches, (2) in coastal waters and their sediments and (3) in the open ocean. Curved arrows depict wind-blown litter, grey arrows waterborne litter, stippled arrows vertical movement through the water column (including burial in sediments) and black arrows ingestion by marine organisms.

Recent work by researchers at The Ocean Cleanup, a Dutch foundation developing new technologies for ridding the oceans of plastic, found that two-thirds of oceanic plastic debris comes from the 20 most polluting rivers. The overwhelming majority of these rivers are in Asia. In China, the Yangtze River is the most significant culprit, dumping some 330,000 tons (the weight of over 200,000 cars) of plastic into the East China Sea every year.[25] It is perhaps unsurprising, with the United States and China leading the world in Gross Domestic Product (GDP), that they also lead in plastic production and pollution.

Shore cleanups have been organized by the Ocean Conservancy since 1986. The organization has rallied communities together with the common goal of collecting and documenting the trash littering their coastlines. In 25 years, a total of 166,144,420 items were collected in 152 different countries and locations. Plastic items, such as plastic bags and bottles and six-pack holders, accounted for 11% of the total amount of collected waste. Over those 25 years, 957,975 six-pack holders alone were collected.[26]

By far, the largest single item collected was cigarette butts, at nearly 53,000,000. In fact, as many as 5.6 trillion cigarette butts or 766,571 metric tons (844,000 tons) of butts (the weight of over 6,500 blue whales or nearly half a million cars) are deposited into the environment worldwide every year.[27] Cigarette butts are made of compressed cellulose acetate, a plastic product wrapped in an external paper layer, and because of this, they degrade very slowly.[28] A typical cigarette butt can take 18 months to 10 years or more to decompose, slowly releasing trace amounts of toxic substances such as cadmium, arsenic, and lead into the environment.[29]

> *"Many people, even smokers, are not aware that the cigarette filter is comprised of thousands of little particles of plastic," says Nicolas Mallos, director of Trash Free Seas Program at the Ocean Conservancy in Washington DC. "One solid filter ends up being thousands of tiny fibres that can be released into the marine environment."*[30]

Cigarette filters are composed of about 12,000 fibers, and this material's fragments may be released during the inhalation of a cigarette. Threads can be inhaled and ingested, with these filter fibers reportedly found in the lung tissue of patients with lung cancer.[31] Ironically, a monograph published by the Public Health Service, National Institutes of Health, and the National Cancer Institute, concluded that filtered and low tar cigarettes have not provided any real benefit to public health, including any reduction in death from lung cancer.[32]

This enormous amount of plastic entering the environment is a considerable problem as plastics don't decompose like natural substances. Wood, grass, and food leftovers all undergo a process known as biodegradation. This means these natural substances are decomposed by bacteria and fungi into environmentally beneficial compounds. These same biological processes don't act on plastics or work very slowly, and so the net effect is that plastic products remain in the environment for a very long time.

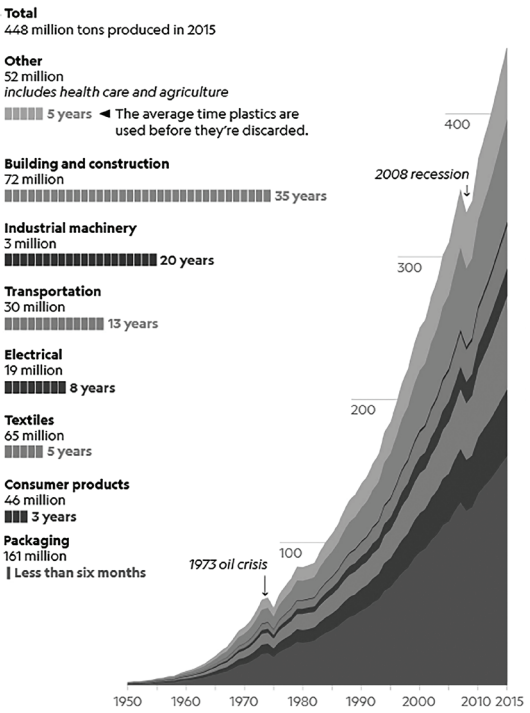
While there is no agreed figure for the time plastic takes to fully degrade, it could be hundreds of years.[33] In the marine environment, depending upon water conditions, ultraviolet light penetration, and the level of physical abrasion, plastics can last up to 600 years.[34] Plastic degeneration happens far faster in a hot, abrasive environment, like a beach, more so than in the ocean's colder water. However, objects eventually split up into tiny pieces of plastic. The main ways that plastics reach the sea are from beaches and land-based sources like rivers, stormwater runoff, wastewater discharges, or the transport of land litter by the wind.[35]

All of this plastic waste continues to accumulate in our oceans. By 2025 there will be an estimated 100 to 250 million metric tons of cumulative plastic debris.[36] Given that there are 10,000 to 25,000 blue whales in the world's oceans,[37] by 2025, there will be as much as 217 times more plastic by weight than blue whales. This is equal to as much as 750 times the weight of the Empire State Building or over 165 million cars.

Unless human behavior changes radically, plastic waste will continue to grow with increased population and increased per capita consumption associated with the current forms of economic growth, especially in urban areas and developing countries, with "peak waste" not expected to be reached before the year 2100.[38] According to a group of scientists who created a new computer model to track the flow of global plastic pollution, without widespread intervention, more than 1.3 billion tons of plastic waste will flow into the world's oceans and land from 2020 to 2040.[39] This increase in plastic will equal the weight of over 3,500 Empire State Buildings or more than 780 million cars.

A great deal of the recent explosion in plastic production is due to a technology known as ethane cracking. This byproduct of fracking is used to create the sorts of plastics used in packaging, often single-use plastic packaging. A new ethane cracking plant being built by petrochemical company Shell is expected to produce 1.6 million tons of polyethylene plastic each year.[40]

A million plastic bottles are bought around the world every minute. That number is projected to jump another 20% by 2021. This is all due to an insatiable desire for bottled water and the spread of a Western "on-the-go" culture. More than 480 billion plastic drinking bottles were sold in 2016 across the world, up about 60% from just 10 years earlier. If placed end-to-end, they would extend more than halfway to the sun.[41] Major drink brands produce the highest number of plastic bottles. Coca-Cola alone generates an estimated 110 billion throwaway plastic bottles every year, equating to an astounding 3,490 per second.[42]



Global plastic production by industry in millions of tons.

Other consumer products are also flooding the oceans. Scientists estimate that 437 million to 8.3 billion plastic straws are slowly disintegrating on all of the world's coastlines.[43] Each year, an estimated 500 billion to 1 trillion plastic bags are used worldwide. That is equal to as many as 32,000 plastic bags being used per second, with only about 1 in 200 being recycled.[44] Single-use coffee pods also create a staggering amount of waste. In 2014, the discarded K-Cups for the Keurig Single Serve Coffee Maker were enough to circle the earth more than 10 times.[45] Sachet style, tear-off packets that once held a single serving of shampoo, toothpaste, coffee, condiments, or other products are sold by the millions. Roughly 40% of the now more than 406 million metric tons (448 million tons) of plastic produced every year are disposable.[46]

According to a Global Alliance for Incinerator Alternatives (GAIA) study, in the Philippines alone, the population uses more than 163 million plastic sachet packets, 48 million shopping bags, and 45 million thin-film bags daily.

> *GAIA revealed that for plastic sachet packets alone, Filipinos produce enough waste each year to cover the entire land area of Metro Manila with one foot of plastic. And that's not counting the 17.5 billion pieces of plastic shopping bags and 16.5 billion pieces of plastic labo bags Filipinos use each year.*[47]

Once in the ocean, plastic products' environmental fate primarily depends on the plastic density, which influences buoyancy and its position in the water column. Plastics that are denser than seawater, like PVC, will sink, while those with a lower density like polyethylene (e.g., plastic bags) and polypropylene (e.g., drinking straws) will tend to float in the water column. Dr. Shoichi Oshima of the Japan Hydrographic Association noted an example of plastics floating in the water column by observing;

> *...a fleet of flimsy white plastic, supermarket shopping bags, up-ended and suspended at depths of 2000 metres [1.25 miles], and drifting like an assembly of ghosts.*[48]

One of the responses to the declared COVID-19 pandemic (a flu-like pandemic that began in 2019) was the use of facemasks in an attempt to reduce viral transmission. Despite several scientific articles showing a lack of or uncertainty of effectiveness,[49],[50],[51] many locations worldwide mandated the public wearing of facemasks, which helped create a massive increase in production and use.

In 2020, facemask manufacturing increased to an estimated 52 billion masks.[52] According to a report by marine conservation NGO Oceans Asia, this massive increase in the number of masks being used resulted in an estimated 1.56 billion of them ending up in our oceans in 2020. This amounts to between 4,680 and 6,240 metric tons or the weight of as much as 4,100 cars. Disposable facemasks are now another major contributor to our oceans' ongoing plastic pollution crisis. Facemasks take as long as 450 years to break down, providing a source of microplastics for centuries. Dr. Teale Phelps Bondaroff, OceansAsia's director of research, noted,

> *The fact that we are starting to find masks that are breaking up indicates that this is a real problem that microplastics are being produced by masks.*[53]

Also, because of COVID-19, single-use plastic use has escalated, and many places rolled back efforts to reduce the use of single-use plastics. Some locations banned reusable options, and people turned to items wrapped in more plastic under the impression that it is safer. Companies removed bulk bins placing those items in plastic containers. People increased their takeaway food consumption where the packaging is often in styrofoam or other plastic containers. As a result, this has caused an estimated increase of 30% in plastic waste entering the oceans in 2020 than in 2019.[54] In 2021 a study found that 8 million tons (more than 4.8 million cars worth) of pandemic-related plastic waste were generated globally, of which 25,000 tons (equal to over 15,000 cars) entered the ocean.[55]

Many of these facemasks and other plastic items made it into our rivers and oceans, causing further damage to the environment and sealife. Early in

2020, facemasks were already washing up on the shores of beaches, adding to the already existing staggering amount flooding our oceans.

> *"The 1.56 billion face masks that will likely enter our oceans in 2020 are just the tip of the iceberg," says Dr. Teale Phelps Bondaroff, Director of Research for OceansAsia, and lead author of the report. "The 4,680 to 6,240 metric tonnes of face masks are just a small fraction of the estimated 8 to 12 million metric tonnes of plastic that enter our oceans each year."*[56]

Jason Ulset with the Chattahoochee Riverkeeper has seen an increase in Personal Protective Equipment (PPE), gloves, masks, and little plastic bottles of hand sanitizer, some of which end up in the Chattahoochee River.[57] That's a worry as the river supplies drinking water for 5 million people and eventually empties into the Gulf of Mexico. Kim Cobb, a Georgia Tech professor who studies oceans and climate, indicated this massive influx of COVID-19 related waste could be disastrous.

> *"The fact that these kinds of influxes are headed the way of these ecosystems that are already so stressed by existing failures in our handling of plastics globally, really, could be the nail in the coffin."*[58]

Microplastics

Because plastics don't decompose, they simply get smashed into smaller and smaller pieces. Pieces shorter than 5 millimeters (just under two-tenths of an inch) or about a pencil eraser's size have been termed microplastics.

A 2016 study estimates that there are already 245,000 metric tons (270,000 tons) of microplastics made of 5.25 trillion particles in our oceans.[59] Another study in the journal Nature estimated that there could be up to 51 trillion pieces of microplastics floating in the oceans.[60] That's roughly 7,000 plastic particles for every person on the planet. While most microplastics are due to the wearing down of larger products like water bottles, there are direct microplastic pollution sources.

> *The majority of microplastics in the oceans are secondary products derived from degradation and fragmentation of mesoplastics or larger fragments; primary microplastics, introduced directly into the oceans via runoff, are manufactured as micron-sized particles typically used as exfoliants for cosmetic formulations, in industrial abrasives and 'sand-blasting' media, in textile applications and synthetic clothes.*[61]

Microbeads made of various plastic particles are used in hundreds of products designed to be discarded down the drain. They are often used as abrasive scrubbers in face washes, body washes, cosmetics, cleaning supplies, and even in kinds of toothpaste.[62] A single bottle of facial cleanser can contain 350,000 microbeads.[63] The massive scope of the microbead problem has led some countries to outlaw the manufacture of products containing microbeads.[64]

An estimated 800+ trillion of these particles are to be washed down US pipes every day.[65] Many of these are recovered in wastewater treatment, ending up as sediment that accumulates at the bottom of settling tanks. These wastes are often applied to land as mulches or fertilizers that may eventually enter aquatic habitats via runoff or become airborne and distributed throughout the environment as the sludge dries out and decomposes. The airborne microplastics can then be inhaled by anitmals and people, accumulating in and potentially delivering chemicals to the lower parts of their lungs. These toxins may even cross into the circulatory system.[66]

More than 10 million metric tons (11 million tons) of sewage sludge was produced in wastewater treatment plants in the European Union (EU) in 2010. Every kilogram of this sludge has been found to contain thousands of microplastic particles, most of which are plastic fibers. The microplastic-laden sewage sludge that is then spread on fields and forests as mulch or fertilizer will undoubtedly cause further accumulation of microplastics in the environment.[67] Not all microplastics are separated via wastewater treatment. As many as 8 trillion of these particles escape into the Earth's waterways daily just in the United States. That's enough to cover more than 300 tennis courts daily or over 21.4 square kilometers (8.3 square miles) yearly.

Exposure to wind, waves and sun degrades plastic trash into tiny plastic particles that soak up pollutants. These 'microplastics' made up 80% of total plastic samples collected in a recent survey of Lake Erie.

In 2001, a high concentration of plastic debris was first observed in the North Pacific central gyre or whirlpool. It was christened an "ocean garbage patch." There are currently five ocean garbage patches that have been identified in the North Atlantic, South Atlantic, South Indian, North Pacific, and South Pacific. The total estimated combined surface size of these patches is 15,916,000 square kilometers (or 6,145,000 square miles), or roughly double the size of Australia.[68] The Great Pacific Garbage Patch alone is comprised up of an estimated 1.8 trillion pieces of plastic, with 94% being microplastics.[69] Julia Reisser, a researcher based at The University of Western Australia, noted that traversing the giant rubbish-strewn whirlpools in a boat was like sailing through "plastic soup."

> *"You put a net through it for half an hour, and there's more plastic than marine life there," she said. "It's hard to visualise the sheer amount, but the weight of it is more than the entire biomass of humans. It's quite an alarming problem that's likely to get worse. Bigger fish eat the little fish, and then they end up on our plates. It's hard to tell how much pollution is being ingested, but certainly, plastics are providing some of it."*[70]

Even the remote and the once pristine Arctic Ocean is being infiltrated by plastic. The first survey of this region in 2013 found roughly 300 billion pieces of floating plastic. Most of these pieces are tiny but visible to the naked eye.

> *"Our data demonstrate that the marine plastic pollution has reached a global scale after only a few decades using plastic materials," said Andrés Cózar Cabañas, a biologist at the University of Cádiz [Spain]. It is, he said, "clear evidence of the human capacity to change our planet. This plastic accumulation is likely to grow further."*[71]

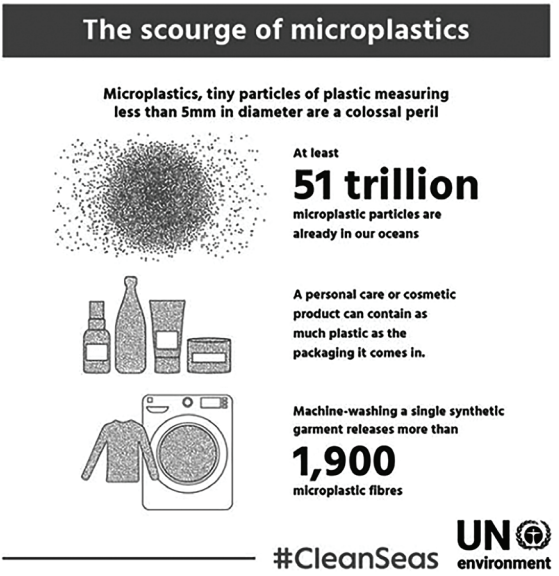
Besides floating particles, microplastics also accumulate on the seafloor, posing additional risk to those ecosystems. Some plastic flakes drift like "marine snow" down the water column where fish can consume them. Other bits fall farther to the muddy bottom, where they are gobbled up by grass shrimp and other sediment feeders. Other plastic pieces wash up onto beaches and salt marshes to become food for burrowing worms and filter-feeding oysters. On some beaches on the Big Island of Hawaii, as much as 15% of the sand is composed of microplastics.[72]

Some may find it surprising because of plastic's buoyancy, but a significant amount reaches the deep seafloor, which is the largest marine habitat on the planet. Once in the deep sea, plastic can persist for thousands of years.[73] Microplastics in the form of microfibers made from modified acrylic, polypropylene, viscose (rayon), and polyester have been found in deep-sea organisms.[74] A recent study "shocked" scientists when they found up to 1.9 million pieces of microplastics in just one square meter of the seafloor.[75]

It has been shown that microplastics are ingested by large marine organisms, such as whales.[76] Plastic debris and fibers from textiles have also been found in hundreds of species globally, including many fish species.[77] These include swordfish and tuna, and bivalves,[78] such as mussels and oysters.

In 2015 scientists examining rivers found as many as 111 microscopic pieces of plastic in a single fish.[79] That result would later seem minuscule when a 2018 study of the River Tame, the main river of the West Midlands of England, found more than 500,000 microplastic particles per square meter in the top 10 centimeters of the river bed.[80] That is a concerning 5,000,000 particles per cubic meter (6,000,000 per cubic yard) buried in the river's bottom.

> *More than 1,000 small pieces of plastic per litre were found in the River Tame... The River Thames in London was found to have about 80 microplastic particles per litre, as was the River Cegin in North Wales. The Blackwater River in Essex had 15. Ullswater has 30 and the Llyn Cefni reservoir on Anglesey 40.*[81]



The scourge of microplastics.

A 2018 study in Frontiers in Marine Science found microplastics, particularly plastic fibers such as those used in textiles, in the stomachs of 73% of mesopelagic fish caught in the Northwest Atlantic.[82] The mesopelagic is an ocean zone at a depth of 200 to 1000 meters (660 to 3,300 feet), with the fish from that zone serving as a food source for a large variety of marine animals, including tuna, swordfish, dolphins, seals, and seabirds.

Studies have demonstrated that quantities of microscopic plastic fragments found in surface water plankton have significantly increased since the 1960s.[83] Their widely distributed occurrences suggest environmental impacts whose magnitude and significance have yet to be fully understood. Through environmental exposure, fragmentation turns larger plastics into fine powders that pass from view and are soaked up by the environment. More microplastics and their associated toxins continue to accumulate in the oceans, and ultimately in the entire environment causing irreversible harm. Their tiny size makes it exceptionally difficult, if not impossible, to remove them from the vast open ocean and other environments.

Killing life

Over 630 species have been recorded interacting with plastic debris.[84] Seabirds, sea snakes, sea turtles, penguins, seals, sea lions, manatees, sea otters, fish, crustaceans, and half of all marine mammals are the most impacted by macro debris.[85] They can choke on grocery bags and become entangled in six-pack rings and fishing nets. Studies have shown that fish and other marine life, such as birds, eat these plastics, damaging their digestive systems. Plastics that stay in the gut make the animal feel full, leading to malnutrition or even starvation. In one experiment, grass shrimp were fed a brine shrimp diet mixed in with polypropylene plastic beads. After six days, all of the shrimp were dead. They stopped eating because their guts were blocked with plastic, which caused them to starve to death.[86]

Each year, an estimated 1 million seabirds, 100,000 sea mammals, and countless fish are killed due to plastic pollution.[87] An autopsy of a young male sperm whale that had washed up dead on the southeastern coast of Spain was found to have 29 kilograms (65 pounds)

> *…of plastic trash crammed into the dead whale's stomach and intestines, including dozens of plastic bags, chunks of mangled rope and glass, a large water container and several 'sacks of raffia [a fiber derived from palm trees].*[88]

The whale died because its digestive system had become lethally impacted or infected. A young whale washed up in the Philippines, which died of dehydration and starvation after eating 40 kilograms (88 pounds) of plastic bags made up of "40 kilos of rice sacks, grocery bags, banana plantation bags, and general plastic bags. Sixteen rice sacks in total."[89] Around the world, sightings are being made of dead whales washed ashore killed by eating plastic.[90],[91] Most of the endangered sperm whales that have been found dead in the eastern Mediterranean have been killed by plastic debris. According to an article in The Times,

> *Post-mortem examinations on nine of 24 [sperm whale] carcasses found in Greek waters revealed that the animals experienced slow and painful deaths after their stomachs were blocked by the large amounts of plastic they had ingested.*[92]

A baby albatross chick can have an ounce of plastic in its belly and remain healthy; the dead chicks have twice as much.

By being entangled in or eating macro plastics, large organisms, such as birds, can be killed or experience sublethal effects. These include a compromised ability to capture and digest food, sense hunger and/or escape from predators, decrease body condition, and impaired locomotion, including migration. In 1960, plastic was found in the stomachs of fewer than 5% of seabirds. By 1980 that number had jumped to 80%, and by 2015 it was 90%.[93] According to one estimate, by 2050, almost all seabirds will have ingested plastic.[94]

Recent studies show that fish that hatched in waters with high quantities of microplastics were "smaller, slower, and more stupid" than those hatched in clean waters, making them easier targets for predator fish. Disturbingly, the fish actually choose to eat plastic instead of their typical food.

> *"They all had access to zooplankton, and yet they decided to just eat plastic in that treatment. It seems to be a chemical or physical cue that the plastic has, that triggers a feeding response in fish," Dr. Lonnstedt told BBC News. "They are basically fooled into thinking it's a high-energy resource that they need to eat a lot of. I think of it as unhealthy fast food for teenagers, and they are just stuffing themselves."*[95]

In another study, perch, still in their larval state, were shown to take in plastics and prefer it over their real food. Larval perch with access to microplastic particles ate only the plastics, ignoring their natural food source of plankton.

> *"This is the first time an animal has been found to preferentially feed on plastic particles and is cause for concern," said Peter Eklöv, co-author of the study. "Larvae exposed to microplastic particles during development also displayed changed behaviours and were much less active than fish that had been reared in water that contained no microplastic particles."*[96]

A 2017 study published in the journal Marine Pollution Bulletin shows that corals are also gobbling up plastics.[97] Corals, which are sightless symbiotic animals and plant organisms, find something about plastics appealing enough that they want to eat it. This is a threat to corals because, like other animals, corals can't digest plastic. The ingested plastic can lead to intestinal blockages, which create a false sense of fullness, impacting coral health.

Some insects appear to be consuming microplastics from their environment as well. Research published in 2018 showed that mosquitoes that ate microplastics as mosquito larva developing in their aquatic environment still contained some plastic as they became airborne adults.[98] Later as they are eaten by spiders, bats, birds, and other creatures, they could be dispersing those plastic bits throughout the food chain. Other winged insects have similar life cycles, making them another possible way of spreading microplastics throughout the food web. Other work has already shown that mayflies and caddisfly larvae also contain microplastics.[99]

Ghost Fishing

Knotted masses of lost but relatively intact nets and fishing lines can retain the ability to trap fish and other species for long periods. This unintentional capture of sea life has been termed "ghost fishing." Hundreds of kilometers of nets and lines estimated at 580,000 metric tons (640,000 tons or the weight of over 375,000 cars) are lost in the ocean every year.[100]

> *Fishing gear can be lost by accident or abandoned at sea deliberately. Once there, nets and lines can pose a threat to wildlife for years or decades, ensnaring everything from small fish and crustaceans to endangered turtles, seabirds and even whales. Spreading throughout the ocean on tides and currents, lost and discarded fishing gear is now drifting to Arctic coastlines, washing up on remote Pacific Islands, entangled on coral reefs and littering the deep sea floor.*[101]

About half the weight of the Great Pacific Garbage Patch is made up of fishing nets and other fishing industry gear, including ropes, oyster spacers, eel traps, crates, and baskets.[102] Due to the resilient nature of the materials used to produce this fishing gear, they can and will keep ghost fishing for multiple decades or even centuries.

> *Prior to the 1950s, rope, and cordage used in all marine activities, including fisheries, was made of natural fibres—typically Indian or Manila hemp and cotton, and it was often strengthened with a coating of tar or strips of worn canvas. These materials lose their resilience in usage, and if lost or discarded at sea tend to disintegrate quickly... over the past 50+ years, these natural fibres have been replaced by nylon and other synthetic materials that are generally buoyant and far more endurable.*[103]

It's virtually impossible to know how many marine animals are killed each year by "ghost fishing." However, various reports suggest staggering numbers—many of them of commercially valuable or endangered species. Off the coast of Washington state in Puget Sound, lost fishing gear is thought to kill more than 3.5 million animals a year, including nearly 25 seals, porpoises, and other marine mammals every week.[104]

Toxins and microbes

The chemical ingredients in 50% of plastics are listed as hazardous by the United Nations Globally Harmonized System of Classification and Labeling of Chemicals.[105] Bisphenol-A, commonly known as BPA, and phthalates are called "everywhere chemicals" because they are widely used in making countless plastic products. Plasticizers are frequently added to increase plastic's flexibility, flame retardants to reduce the spread of combustion, and colorants and other materials to modify basic plastic properties. Plastics may contain ingredients such as oxybenzone used as an ultraviolet light absorber and stabilizer.[106]

BPA has been recognized since the 1940s as an endocrine-disrupting chemical that interferes with normal hormonal function.[107] Researchers have linked phthalates, which are used as plasticizers, to asthma, attention-deficit hyperactivity disorder, breast cancer, obesity and type II diabetes, low IQ, neurodevelopmental issues, behavioral issues, autism spectrum disorders, altered reproductive development, and male fertility issues.[108] These plastic additives and pollutants might be released when eaten by a wide variety of marine organisms. In 2018, "surprising levels" of phthalates were found in wild bottlenose dolphins, which are high up on the food chain.[109]

> *Commonly used additives, including phthalates, bisphenol A (BPA), alkylphenols, [and] polybrominated diphenyl ethers are hazardous to biota [ocean animal and plant life] acting as endocrine-disrupting chemicals that can mimic, compete with, or disrupt the synthesis of endogenous [growing within the body] hormones. These compounds have been measured at high concentrations in plastic fragments sampled both at remote and urban beaches, as well as in those floating in the open ocean.*[110]

PCBs (polychlorinated biphenyls) and PBDEs (polybrominated diphenyl ethers) were once commonly used as electrical insulators and flame retardants. Although they were banned in the United States in 1979, these substances' global production is estimated to have been about

1.3 million metric tons. They have been found in high concentrations in crustaceans in the deep ocean.[111] The surface area of microplastics allows them to absorb these pollutants from the surrounding ocean water. Plastic debris accumulates pollutants such as PCBs up to 100,000 to 1,000,000 times the levels found in seawater.[112]

Japanese scientist Yukie Mato demonstrated that plastics bind to chemicals in seawater and concentrates them. DDE (a breakdown product from the insecticide DDT), PCBs, and other endocrine-disrupting chemicals were each found to be one million times more concentrated on plastic beads than the seawater they were placed into.[113] Seabirds that ingested microplastics have been found to have elevated amounts of PCBs and other persistent organic contaminants.[114]

Bacteria and other microbes have been found to also live on microplastic particles. The plastic fragments help to disperse these organisms throughout the environment while the organisms simultaneously influence contaminants leaching from these plastics. A researcher from the National University of Singapore found more than 400 types of bacteria on 275 pieces of microplastic collected from local beaches. They included microbes linked to coral reefs' bleaching and that cause wound infections and gastroenteritis in humans.[115]

Contaminated food and drink

The dangerous cocktail of pollutants associated with plastics can be transferred to fish and other sea life. When mammals, such as seals or people, eat marine animals that have consumed this marine debris, there is the potential to increase their own burden of these hazardous chemicals.[116] This raises important questions regarding the bioaccumulation and biomagnification of chemicals and the consequences for human health. Recent studies show that humans are ingesting microplastics from seafood, with 100% of mussels sampled from UK coastlines and supermarkets containing microplastics or other debris like cotton and rayon.[117] Scientists believe microplastic consumption by people eating seafood in Britain was likely "common and widespread."

> *When consuming an average portion of mussels (250 g wet weight), one consumes around 90 particles. An average portion of 6 oysters (100 g wet weight) contains around 50 particles... European top consumers will ingest up to 11,000 microplastics per year, while minor mollusc consumers still have a dietary exposure of 1,800 microplastics per year. Once inside the human digestive tract, intestinal uptake of the ingested particles may occur.*[118]

> *"This is a wake-up call to the fact that our waste management systems are not as tight and advanced as they should be, and that might be coming back to haunt us through the food chain," said Chelsea Rochman, a postdoctoral fellow at the University of California, Davis.*[119]

As might be expected, plastic contamination is already being found in other places besides seafood. Analysis of a variety of consumer sea salt brands showed they also contain plastics.[120] While the particle amounts found are currently low, smaller particles, which probably will be in even higher concentrations, were not measured due to study limitations. Also, the low detected quantities of plastic are likely to increase significantly over time as ocean plastic loads continue to accumulate and plastics continue to splinter and spread. Microplastics have also been found in 90% of the table salt brands worldwide, with Asian brands having exceptionally high amounts.[121] Through salt alone, the average adult consumes approximately 2,000 microplastic particles per year. Erik van Sebille, an oceanographer at Utrecht University in the Netherlands who studies global ocean circulation and plastic pollution, noted that,

> *"Over the last few years, whenever scientists have gone out to look for plastic in the ocean, they have almost always found it. Whether on the remote ocean floor, in the ice in the Arctic, in the stomachs of seabirds and fish, or now in sea salt. Plastic in the ocean is an atrocity, a testament to humanity's filthy habits."*[122]

Sea salt was not only contaminated with plastics but was also tainted with pigments associated with plastics. Examples of pigments found in table salt include victoria blue, commonly used as a coloring agent

in polyacrylic fibers, and lead chromate (yellow) dye, a toxic compound with extensive applications in paints and plastic industries. Lead chromate pigment has been associated with cancers, cerebrovascular (brain blood vessels) disease, and nephritis (inflammation of the kidneys) in humans. Researchers recently found microplastic particles in the placentas of unborn babies of healthy women who had normal pregnancies and births.[123] The researchers said was that this was "a matter of great concern." Elizabeth Salter Green, at the chemicals charity Chem Trust, noted,

> *Babies are being born pre-polluted. The study was very small but nevertheless flags a very worrying concern.*[124]

Dr. Sherri Mason collaborated with researchers at the University of Minnesota to examine microplastics in drinking water. Dr. Mason found that Americans could be ingesting upwards of 660 particles of plastic every year. It is thought that the majority of this plastic contamination comes from microfibers and single-use plastics such as water bottles.[125] A small study in 2018 found that microplastics have already been detected in human waste, suggesting they are widespread in the food chain.[126]

A 2017 study found 83% of the world's tap water is already contaminated with microscopic plastic fibers.[127] The United States had the highest level of contamination at 94% of samples collected at various sites.[128] Another study found that 93% of leading brands of bottled water were contaminated with plastic debris, including nylon, polyethylene terephthalate, and polypropylene, which are used to make bottle caps.[129] Other studies have shown that plastics have spread throughout the aquatic environment and end up in products such as honey[130] and beer.[131]

Other plastic pollution sources

Sources of environmental and aquatic plastic contamination have expanded as more products use plastics. Products like wet wipes, marketed as flushable, add to the load in sewer systems, costing billions of dollars in worldwide maintenance. Because they don't biodegrade quickly, they can end up among all of the accumulating refuse on beaches.[132] These wet wipes are also made from plastics, which once flushed, break apart into microplastics and add to the world's environmental plastic burden.[133]

Production of synthetic diapers began in the 1960s. They gained popularity over the following decades, replacing traditional cloth diapers. In 2018, Americans generated an estimated 4,100,000 tons of waste from disposable diapers, accounting for 1.4% of municipal waste.[134]

> *In the United States, there are about four million babies born every year. During their first year of life, the average newborn uses about 2500 diapers. This means that from babies under one year old, Americans dispose of around a trillion diapers a year.*[135]

Worldwide, disposable diapers represent about 4% of solid waste and are the third-largest single consumer item in landfills discarded after a single use.[136] These synthetic diapers take hundreds of years to break down, meaning that the diapers you wore as a baby are likely still intact, sitting in a landfill. In addition to the enormous waste generated, disposable diapers contain substances that are harmful to human health and the environment.

Diaper ingredients include tributyltin (TBT) – a biocide used to prevent the growth of bacteria, which is considered highly toxic and poisonous to marine life and humans; dioxins – a group of persistent, highly toxic organic pollutants that are carcinogenic and linked to long-term health problems.

> *Dioxin is carcinogenic, and had been listed by EPA as the most toxic of all cancer-linked chemicals. Dioxin, in very small quantities (parts*

> *per trillion), causes birth defects, skin diseases, liver disease, immune system suppression and genetic damage in laboratory animals consequently, dioxin was banned in many countries of the world... While one may believe that the tiny amount of dioxin exposure from diapers is insignificant, it is however of much concern that a substance reputed as the most carcinogenic chemical known, is found in a baby care product.*[137]

Phthalates are synthetic plastic materials that act as liquid absorbents to improve the functionality and softness of diapers and many other products, such as women's sanitary pads. Some of these plastic materials release volatile organic compounds (VOCs) and endocrine-disrupting chemicals, potentially posing health risks to children who wear them. Phthalates and VOCs are absorbed directly through the skin, so there is an increased public health concern about whether these substances may adversely influence children's health.[138] Where phthalates are released into the environment, they can create reproductive toxicity in humans and animals.

Synthetic rubber, a variant of plastic, makes up about 60% of the rubber used in car tires. As tires wear down, they emit small dust particles into the air, landing on adjoining surfaces, with an unknown amount carried out to the sea.[139] The total amount of microplastics generated from the wear of automotive tires in the EU alone is estimated at 503,500 metric tons (555,000 tons) per year or over 4,300 blue whales' worth.[140] Microplastics from tires and roads were found to make up 89% of the ultrafine particles found in the air around busy motorways.[141] A 2019 study found an estimated 7 trillion pieces of microplastics flow into the San Francisco Bay via stormwater drains alone.[142] Nearly half of these particles found in stormwater looked suspiciously like tiny fragments of car tires, which rainfall washes off the streets and into waterways.

Another primary source of plastic pollution is nurdles. Nurdles are tiny pellets of plastic resin that manufacturers use to create plastic packaging and products. Billions are lost every year, ending up in waterways. They are the second-largest source of microplastic pollution in water after

the amount generated from vehicle tires.[143] A 2018 study estimated that between 3 million to 36 million pellets may escape every year from just one small industrial area in Sweden. When smaller particles were considered, the number of particles released is a hundred times greater.[144]

Synthetic textiles, such as polyester and acrylic, also slowly break down while washing and drying clothes. A Plymouth University study showed that more than 700,000 microscopic fibers could be released into wastewater during each use of a domestic washing machine. Many of these are likely to pass through sewage treatment and into the environment.[145] A study in California found that in 2019 an estimated 13.3 quadrillion fibers (4,000 metric tons equal to the weight of 2,600 cars) were released into California's natural environment.[146] The 13.3 quadrillion figure is 130,000 times as many fibers as stars in the Milky Way galaxy. These fibers are primarily shed when articles such as yoga pants, stretchy jeans, and fleece jackets are repeatedly washed. Up to 40% of these microfibers pass through wastewater treatment plants and end up in rivers, lakes, and oceans, with 85% of the world's plastic debris containing some percentage of this waste.[147]

Nanoplastics

As plastics break down into smaller pieces, their fate in the marine environment is poorly understood, but they potentially become the most hazardous form – nanoplastics. Nanoplastics are particles less than 100 nanometers (nm) or about the size of a typical virus such as the influenza A virus.[148] These ultra-small plastics could enter living cells, causing inflammation and possible disruption of cellular functions.[149] Rachel Hurley from the University of Manchester noted:

> *"It is the really small stuff we get worried about, as they can get through the membranes in the gut and in the bloodstream – that is the real fear."*[150]

Studies have shown that these particles can be transported through the aquatic food chain via algae into fish, affecting lipid metabolism and fish behavior.[151] A recent study found that these nano-sized particles can cross the blood-brain barrier accumulating inside fish brains, creating behavioral disorders through what researchers believe is brain damage.[152] The study also found that animal plankton (zooplankton) died when exposed to plastic nanoparticles, while larger plastic particles did not appear to affect them. According to Tommy Cedervall, a chemistry researcher at Lund University in Sweden,

> *It is important to study how plastics affect ecosystems and that nanoplastic particles likely have a more dangerous impact on aquatic ecosystems than larger pieces of plastics.*[153]

Breakdown of plastics into nanoplastics may actually take a long time on the order of decades or centuries. However, the direct use of nanoparticles in cosmetics, detergents, food, dental, and other commercial products is rapidly increasing despite very little knowledge of their effect on the environment, particularly on organism metabolism. One product, 3D printers, has been found to emit 200 billion ultra-fine particles (UFP) per minute, having potentially serious health consequences.

> *Inhaling UFPs is potentially harmful, as the particles' deposit efficiently in both the pulmonary and alveolar regions of the lung, as well as in head airways.' The particles could also enter the brain through the olfactory nerve. Symptoms of UFP inhalation include shortness of breath, stroke, cardiac arrest, and even death.*[154]

These nano-sized products can easily bypass any sewage treatment system, with these potentially potent particles ending up in freshwater and marine habitats. If the magnitude of adverse effects on wildlife is severe enough, such as population-level declines, world food security could be affected. Heidi Taylor, director of the marine debris organization Tangaroa Blue, recently noted that,

> *This is the next climate change, and nobody's thinking that it's going to be as bad as it is. If we start looking at communities like the islands here, that rely so heavily on seafood, and that [seafood] is contaminated by plastics and chemicals that are in the ocean, this is going to be not an issue about saving turtles, this is going to be a human health issue, and that will be a game changer.*[155]

Greenhouse gases

As countries turn from fossil fuels to renewable energy, plastic production is a way for petrochemical companies to continue to make big profits. By 2030, plastic-linked emissions of production are expected to equal nearly 300 coal power plants.[156]

Once plastic waste enters the environment, it continues to affect the atmosphere. Dumping, incinerating, recycling, and composting of certain types of plastics all release carbon dioxide. The total emissions from plastics in 2015 were equivalent to nearly 1.8 billion metric tons of CO_2 (the weight of over 1.2 billion cars).[157]

Once the plastic waste enters the environment, it continues to affect the air, as most conventional plastics have also been found to discharge the greenhouse gases methane and ethylene when exposed to sunlight.[158] Polyethylene, used in shopping bags, was found to be the most prolific emitter of both gases. David Karl, the senior author of a study that examined this phenomenon, noted,

> *Plastic represents a source of climate-relevant trace gases that is expected to increase as more plastic is produced and accumulated in the environment. This source is not yet budgeted for when assessing global methane and ethylene cycles, and may be significant.*[159]

Recycling illusion

A 20-foot long shipping container has a volume of 33.2 cubic meters (42.3 cubic yards).

For decades the United States and other industrialized countries have counted plastic waste as "recycled" if exported. While this avoids disposal costs and local environmental impacts, this waste problem is often shifted to countries with poor waste management.[160] In 2018, the United States sent 157,000 twenty-foot-long shipping containers (430 per day) to such countries. This equals 5.2 million cubic meters (6.6 million cubic yards) or enough to fill over 2,000 Olympic-sized swimming pools.[161] Malaysia has become a "dumping ground" for Western plastics. In 2017, Malaysia imported approximately 550,000 metric tons of plastic (the weight of over 4,500 blue whales or over 330,000 cars). There the plastics are manually broken down by workers earning $10 a day. Large amounts of low-grade scrap, such as single-use plastic bags, end up in massive dump-sites where it eventually is buried in landfills or incinerated in the open, further releasing toxins into the environment.[162]

Exporting plastics to countries ill-equipped to manage it creates a comfortable illusion that predominantly Asian countries are to blame for the world's ocean plastic pollution. While this plastic pollution sleight of hand may make citizens and businesses in the Western world more comfortable with their plastic addiction, the end result is that the increasing plastic disaster is still impacting the planet as a whole. According to Kara Lavender Law, an oceanography professor at the Sea Education Association in Cape Cod, Massachusetts,

> *We're putting this in the blue bin and then it's getting trucked to Boston. And then it's getting put on a ship that's sailing most of the way around the world for somebody to unpack it and pick through it and cut labels off it in hopes that some portion of that material will be turned into (plastic) pellets and into a children's toy or whatever.*[163]

When recycling started in the 1980s, it was a noble and well-intentioned idea that provided a closed-loop for products and packaging. Unfortunately, the notion of recycling has given the manufacturers of disposable items the ability to essentially market overconsumption as environmentalism.[164] The system cannot keep up with massively escalating consumer consumption, and many things that consumers throw in the blue bins thinking they will be recycled are simply not.

> *Every year, reports come out touting rising recycling rates and neglecting to mention the soaring consumption that goes along with them. American consumers assuage any guilt they might feel about consuming mass quantities of unnecessary, disposable goods by dutifully tossing those items into their recycling bins and hauling them out to the curb each week.*[165]

Reports from September 2020 showed how the plastic industry-funded ads in the 1980s promoted recycling to solve our growing waste problem.[166] These makers of virgin plastics were the major proponents and financial sponsors of plastic recycling programs because they created the illusion of a sustainable, closed-cycle while actually promoting the continued use of raw materials for new single-use plastics. According to Judith Enck, a visiting professor at Bennington College in Vermont and president of Beyond Plastics, a nonprofit focused on ending plastics pollution,

> *The reason the public thinks recycling is the answer is that the plastic industry has spent 30 years on multimillion-dollar campaigns saying that. That was absolutely the wrong message. The message should have been: Don't use so much plastic.*[167]

In the United States, about 76% of plastic garbage goes into landfills, 16% is burned at very high temperatures releasing greenhouse gases, 1% ends up in the oceans.

Unfortunately, most plastic can't and won't be recycled. For example, the EPA reported that plastic generated in 2018 was 35.7 million tons, accounting for 12.2 percent of municipal solid waste that year.[168] Of this total, only 3 million tons, less than 9%, were recycled. The vast majority – 27 million tons – ended up in landfills, and the rest was combusted. The environmental agency also estimated that less than 10% of plastic thrown in bins in the last 40 years has been recycled. According to David Biderman, CEO and executive director of the Solid Waste Association of North America,

> *Most people have the attitude that if they just put it in the blue bin, it will get taken away and somebody will figure out what to do with it, but putting something in the blue bin and actually recycling it are two very different things.*[169]

Why isn't more plastic recycled? Most products are made up of mixtures of various plastics and chemicals, which can make recycling impossible. The two recycling codes, 1 and 2, which are considered the most recyclable, are usually "downcycled," which means they're turned into lower-quality products that will eventually end up in a landfill because those materials can't be recycled again. Often consumer products utilize virgin plastic because the cost of new plastic is lower than recycled plastic.

Ultimately, recycling is mostly an illusion that allows for continued rampant consumerism. According to Professor Enck and others, recycling doesn't work if you continue to increase new plastic manufacturing. According to Enck,

> *We can't recycle our way out of the problem. The only solution is reducing the generation and use of plastic.*[170]

Plastic Armageddon

Although the plastic garbage patches and marine debris are not precisely quantifiable in all aspects, they are a symptom of a root problem, which is plastic end-of-life use. The microplastic endgame is not the ocean garbage patches, but ultimately it is the interaction with the entire ocean ecosystem. Los Angeles Captain Charles Moore, an environmental advocate, credited with bringing attention to the Great Pacific Garbage Patch, noted that,

> *The ocean is like a plastic soup, bulked up with the croutons of these larger items. It's like a toilet bowl that swirls but doesn't flush.*[171]

With global plastic production doubling every 11 years, during those 11 years, people will make as much plastic as has been produced since plastic was invented. [172] A 2017 Ellen MacArthur Foundation report shows that by 2050 plastics will consume 20% of all oil production, up from 5% today. One out of every five barrels of oil will not fuel or lubricate our machines but will be used to make plastic. The report states that at least 8 million metric tons of plastic waste enter the oceans each year. If action is not taken by 2050, there will be more plastic in the sea than fish, weighing 850 million metric tons (937 million tons)[173] or equal to over 2,500 Empire State Buildings or over 550 million cars. Those 550 million cars placed bumper to bumper would wrap around the Earth over 66 times.

> *Each year, at least 8 million tonnes of plastics leak into the ocean — which is equivalent to dumping the contents of one garbage truck into the ocean every minute. If no action is taken, this is expected to increase to two per minute by 2030 and four per minute by 2050. Estimates suggest that plastic packaging represents the major share of this leakage. In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025, and by 2050, more plastics than fish (by weight).*[174]

We are facing an ever-swelling tsunami of plastic waste that is difficult to imagine. Measurements from the most contaminated regions of the world's oceans show that the mass of plastics already exceeds that of plankton sixfold.[175] The potential for biomagnification of plastic particulates in the environment is of significant concern for life all the way up on the food chain, biosecurity, and, ultimately, human health. Dr. Lisa Emelia Svensson, the former executive director of the oceans branch at UNEP, the UN Environment Programme, said plastics are "ruining the ecosystem of the ocean" and are nothing short of a "planetary crisis."[176] Erik Solheim, the former head of the UN's environment program, stated that "we're facing an ocean Armageddon."[177]

Despite numerous laws, regulations, and cleanup efforts, plastic-dominated marine debris appears to be ever expanding, and hence, so is the magnitude of the resulting problems. This plastic load of pollution not only reaches our oceans, but a large portion of this debris ends up on, or buried in, the seafloor. The potential is there for an unseen pervasive impact on deep-marine ecosystems.

The looming plastic catastrophe is something we need to tackle in a globally comprehensive way. Even if 100% of plastics in the Western world were truly recycled, the number of plastics flooding the oceans from the developing world would still be overwhelming. Globally, there are almost 2.8 billion people without access to waste collection services, of which 1.9 billion live in rural areas, generating large amounts of uncollected household waste ending up in surrounding water bodies, open dumps, or burnt in open-fire activities.[178] We need to work together as one human community to solve this massive mismanagement of waste materials across the planet. What is needed is a global plan to properly collect trash, recycle whatever can be, and keep it from inundating the environment.

With the sea covering over 73% of our world, it is not physically practical to remove all the existing plastic debris. With more than 90% of plastics in the ocean being less than 10 millimeters long,[179] it really becomes an impossible task. So instead, we must find ways to change our continuing impact because we can't significantly alter the enormous damage that has already been done.

Because of our modern obsession with convenient single-use items, we will be eating, drinking, and breathing in plastic product remnants and their toxins for decades and centuries to come. We must substantially decrease plastics use, especially these single-use types, which is nearly half of all plastics manufactured today. We must also think of better ways to intercept and capture all plastics before they infiltrate the marine environment. *If we don't take action, the problems will persist, continue to escalate, and become increasingly hopeless, with potentially disastrous consequences for all life on this planet.*

What you can do!

Plastic pollution is a worldwide crisis. If we work together, we can really make a difference and solve this problem. Here are some simple steps that you can take at a personal level to make a difference.

Switch from bottled water – Use glass or stainless steel bottles and refill from a filtered tap water source. According to a 2009 article in Environmental Research Letters, bottled water takes as much as 2,000 times the energy cost of producing tap water. In 2007, in the United States, about 33 billion liters of bottled water were consumed "equivalent to between 32 and 54 million barrels of oil or a third of a percent of total US primary energy consumption."[180]

Switch from other drinks that come in plastic bottles – Make your own drinks at home, such as fruit smoothies or juices, which are also much healthier alternatives than sodas, and place them into your reusable bottle. According to the Harvard School of Public Health, sugary drinks are calorie-rich and devoid of nutrition. "Beyond weight gain, routinely drinking these sugar-loaded beverages can increase the risk of type 2 diabetes, heart disease, and other chronic diseases. Furthermore, higher consumption of sugary beverages has been linked with an increased risk of premature death."[181]

Switch to a reusable travel mug for hot drinks – According to the Environmental Protection Agency (EPA), 25 billion Styrofoam cups are thrown out each year. Styrofoam cups are not biodegradable and cannot be recycled, and they will still be sitting in landfills in 500 years.[182] The plastic cup lids and stirrers are also not recycled. Paper cups are lined with a plastic coating, so they don't leak, which also means they can't be recycled. Billions of them ending up in landfills each year. Instead, use a stainless steel travel mug. Better yet, break free of the "on-the-go" culture and consider having your coffee or tea at home or at a sit-down café instead of taking it with you.

Switch from plastic straws – A plastic straw – It's something that comes with most beverages we order, from soft drinks to even a glass of water. In the United States, Americans use them at an average rate of 1.6 straws per person per day, which equals 175 billion straws a year used once and thrown out.[183] Most of us can simply do without this frill, but there are plenty of alternatives for those that need them – straws made of metal, paper, and even actual straw.

Use reusable utensils – An estimated 40 billion individual plastic utensils are produced each year. With low reuse and recycling rates, most of them end up in our landfills, beaches, and oceans.[184] Instead of plastic forks, spoons, and knives, carry one of the many sets of reusable utensils made from bamboo or stainless steel.

Use reusable shopping and produce bags – Plastic bags are an eyesore as they end up as litter in our parks, forests, and beaches. These single-use bags are made from fossil fuels and end up as deadly waste in landfills and the ocean. It only takes about 14 plastic bags to equal the amount of gas required to drive one mile.[185] Instead, use reusable hemp, cotton, or other cloth bags for groceries and other shopping. For produce, leave it loose for items like avocadoes and onions. For other things, use reusable mesh produce bags.

Purchase products in bulk – Many products such as fresh meat, grains, and condiments can be purchased from providers that offer their prod-

ucts in bulk. This takes a little more planning to provide your own containers and pantry for freezer storage space at home, but once the habit develops, it is remarkable how much plastic packaging can be avoided this way.

Use your own take-out food containers – Pack lunches and bring containers to restaurants so you can pack your own leftovers into reusable containers made from stainless steel or glass with snap-on lids.

Switch to bars of shampoo and conditioner – Shampoo and conditioner bars eliminate the need for plastic bottles. Most bars come wrapped in recycled paper or in paper boxes. Most bottled shampoos are 80% water, and conditioners can be up to 95% water. Shampoo and conditioner bars are concentrated and generally last longer than bottled versions. On average, a shampoo bar will outlast two to three bottles of liquid shampoo.[186]

Switch from using toothpaste tubes – Toothpaste tubes are, for the most part, not recycled, with more than a billion of them ending up in landfills every year. Use toothpaste tablets that come in glass jars, or you can also make your own tooth powder out of natural ingredients such as baking soda.

Switch to natural fibers for clothing – We often don't think of our clothing as plastic, but polyester, made from petroleum, is now used in about 60% of our clothes.[187] When synthetic fabrics are washed, they release tiny strands called microfibers, which end up everywhere in the environment. Switch to organic cotton, hemp, and linen, which are natural materials used to make clothing for thousands of years.

Avoid seafood – Over a ton of lost plastic fishing gear, also known as "ghost gear," ends up in the ocean every minute, which is destroying sea life on a massive scale. According to the Independent, "the world's biggest seafood firms are all contributing to the deaths of more than 100,000 whales, dolphins, seals, turtles, and seabirds that are killed in agony every year by discarded fishing equipment."[188] Moving away from eating seafood will reduce demand and lessen the damage caused by

highly destructive industrial fishing practices.

Breastfeed – Plastic bottles release microplastics and nanoplastics. Although the impact on health isn't clear, to avoid any problems, breastfeed when possible. Breastfeeding provides the best nutrition for a baby and is the most widely recommended way to feed a newborn.[189] When breastfeeding is not possible, consider using glass bottles.

Use modern cloth diapers –Disposable baby diapers have primarily replaced older cloth diapers mainly due to perceived advantages, principally convenience. However, very little attention is given to the product after its use and its potential adverse health effects. Modern cloth diapers are washable and reusable. All diapers impact the environment; however, using cloth diapers and washing a full load and line drying is the most sustainable option. Cloth diapers can have flushable liners that can still add to landfills. Diaper liners are used to make diaper changes easier but are not essential. Cloth diapers are free of harmful chemicals and plastics for a healthier baby. If you need to use disposable diapers, there are biodegradable options available.

Quit smoking – This helps cut down on the massive amount of toxic cigarette butts entering the environment and eliminates a significant cause of lung cancer. Also, the discarded cigarette filters are of dubious benefit in actually reducing diseases in smokers. According to a 2009 article in the International Journal of Environmental Research and Public Health, "cigarette filters are primarily a marketing tool to help sell 'safe' cigarettes" which have little "scientific evidence, including patterns of mortality from smoking-caused diseases, does not indicate a benefit to public health from changes in cigarette design and manufacturing over the last fifty years." [190]

Innovate! – For every problem, there are many solutions. Human ingenuity and creativity are boundless when it comes to almost any situation. You may have a great idea to tackle this serious issue. Let your ideas blossom and work with others to make them a reality. Every positive change makes a difference.