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# Microplastics: The grand reach of our tiny plastics problem

by Whitney Pipkin

## Executive Summary

Tiny pieces of plastic are in our water, in our air, in our food, in our drinks, in our bodies, and, increasingly, in our headlines. Seemingly everywhere researchers have looked, they've found microplastics. They're floating in ostensibly unspoiled air over the Pyrenees Mountains and swirling in sediments taken from the remote Barents Sea, where bottom-living creatures also have been found with microplastics in their bellies. Scientists even found microplastics in Arctic snow this summer.[1] Yet researchers are only beginning to understand what that means for our health and that of our environment. Does the persistent presence of plastics necessarily mean they are causing harm?

Microplastics are loosely defined as plastic particles ranging from a microscopic 1 nanometer to 5 millimeters—about the length of a short grain of rice. Sometimes slightly larger particles or plastic fragments will be lumped into the microplastics category, too. Early evidence suggests that microplastics could be one of several environmental factors—coupled with others such as climate change—potentially shortening the lifespan of marine animals. So far, microplastics have been found in the guts of everything from seabirds and fish to oysters and shrimp. But research has barely begun to look at what that could mean for the health of humans living increasingly in urban areas where drinking water, seafood, and even the air we breathe could contain tiny plastic particles.

Even as scientists grapple with those overarching questions, decision-makers and consumers are revisiting the assumption that efforts to "reduce, reuse, and recycle" go far enough. Everyday activities such as washing clothes can release thousands of microplastic particles into local waters.[2] A recent report estimated that the average household in Canada and the U.S. releases 533 million microfibers from laundry into the wastewater treatment system every year.[3] Those releases equate to about 968 U.S. tons of microfibers that are estimated to make it through wastewater treatment facilities and into freshwater and ocean environments, said the report. That's not to mention the impact of human behaviors such as illegal dumping or littering. Such plastic trash can wash into the nearest stormwater drain and waterway, breaking into smaller and smaller particles over time.

Despite our best efforts—in a statistic that shocked scientists when they first tallied it in 2018—less than 10% of the 8.3 billion metric tons of plastic estimated to have been produced over the past six decades has actually been recycled.[4] The factors that make recycling difficult have only been exacerbated by China's 2018 ban on the import of most plastics to its recycling processors, which, for the previous quarter-century, had handled nearly half of the world's recyclable waste.[5]

Many of the plastics that haven't been recycled or incinerated are still around in one form or another. And, each year, between 5 and 13 million metric tons of plastic waste end up in our oceans,[6] where the pieces can be mistaken by animals for food or become vectors for harmful chemicals.[7] If nothing changes, by mid-century, the oceans will contain more plastic waste by weight than fish—an oft-quoted statistic that National Geographic said has become a "rallying cry to do something about it."

Meanwhile, a brand of innovation—not unlike what led to the development of durable plastics in the first place—has begun to filter into the milieu. While government leaders, business innovators, and individuals try to improve plastic production with the use of more biodegradable materials, the scientific community has zeroed in on microplastics as a less-understood—and equally urgent—consequence of our global plastics problem.

The National Science Foundation is offering $30 million to teams of researchers it has asked to dream up "a world without plastic waste," in which every "plastic" material would biodegrade rather than persist in the environment. Economists and leading retailers are rethinking raw materials and supply chains to see whether materials that are discarded today could instead be reintegrated into a "closed-loop" system of production. And some are in the early stages of considering a scientific solution to a seemingly impossible task: removing microplastics from the water column.

On the individual level, there is plenty to take away from a better understanding of plastics, microplastics, and their impact on the ecosystem and us. Understanding the endgame of our plastics habits equips us to better evaluate how we use plastics in the first place. It raises the stakes on daily decisions about how we purchase, deploy, and dispose of plastics.

## Introduction

The past decade has seen an exponential increase in the number of scientific research articles mentioning microplastics—from fewer than 500 publications per year in 2000 to more than 3,000 publications in 2018, and growing.[8]

In the Chesapeake Bay watershed, concerns about microplastics reached a crescendo in April 2019 as the research community convened a two-day conference to discuss what scientists still need to understand about the impact of these emerging pollutants. In October, they released a report calling for funding to research the ecological risks of plastics pollution in the bay watershed.

The report also asked watershed states to develop a strategy to curb sources of plastics pollution to local waters and for ongoing monitoring to continue to identify microplastic hotspots.[9]

Though microplastics are just coming onto the radar of some local officials, some advocates have already been chipping away at the problem for years. After founding Trash Free Maryland in 2010 to reduce trash pollution in the state, Julie Lawson wanted to quantify the

Small plastic particles collected from a Chesapeake Bay tributary this summer demonstrate how plastics break down over time. Photo by Whitney Pipkin

amount of plastic waste that was ending up in local waters. A 2014 survey had already concluded that microplastics are indeed ubiquitous in the Chesapeake Bay; they were found in all but one of 60 samples from four tidal tributaries at the time.[10] Lawson, who now directs the Mayor's Office of the Clean City in Washington, D.C., organized a more recent survey that trawled the Chesapeake Bay for microplastics and found them in every single sample collected. Samples taken near Baltimore's Inner Harbor contained the highest concentrations of microplastics. Other research has found the tiny pollutants accumulating in underwater grass beds that are key habitats for the estuary's iconic blue crabs, adding to concerns about microplastics' impact on local species.[11]

The region's scientific community has declared microplastics pollution in the bay waters to be an "urgent issue" that may affect the overall success of the Chesapeake Bay restoration effort.[12]

Meanwhile, national and international studies are bolstering concerns that microplastics are everywhere and that we still have much to learn about how our actions—from washing clothes to using throwaway plastics—could be contributing to the problem.

This report explains how microplastics have splashed onto our communal radar in recent years, raising the hackles of government officials, scientists, and consumers. Though there is still much to learn about where microplastics are, how they got there, and the impact they're having on human and environmental health, this report provides an overview of what we are learning in the harried hunt for information. Rather than causing additional alarm over the tiny plastics that are now part of life as we know it, this report aims to provide a foundation for making better individual and communal decisions—inspiring us all to be a little more flexible about our deeply rooted relationship with plastics.

## What are microplastics?

*From microfibers to microbeads, a growing category of tiny plastics*

Microplastics are loosely defined as plastic particles ranging from a microscopic 1 nanometer to 5 millimeters—about the length of a short grain of rice. Sometimes slightly larger particles or plastic fragments will be lumped into the microplastics category, too.

British marine biologist Richard Thompson first coined the term "microplastics" in a 2004 report, after finding microscopic plastic fragments to be "widespread" in oceans and accumulating in marine habitats near the United Kingdom.[13] His work also showed that organisms such as amphipods and barnacles could ingest the tiny plastic particles.

Today, microplastics research is fast becoming its own field of study. Scientists who regularly monitor or collect samples from marine environments are being asked to keep an eye out for the tiny particles we now know are ubiquitous. Eventually, field and laboratory protocols will allow for quantities of microplastics to be more accurately compared and quantified globally. According to the National Oceanic and Atmospheric Association's Marine Debris Program, nailing down the nitty-gritty details of how microplastics science is conducted is one of the first steps in determining how to curb the problem.[14]

Scientists have barely skimmed the surface of understanding an even smaller subset of microplastics—nanoplastics—which lab studies have shown can cross cellular membranes, impacting core processes such as respiration and gene expression. Studies have also shown that the presence of nanoplastics could be greatly underestimated because microplastics surveys in aquatic environments have not typically focused on particles smaller than 300 micrometers.[15]

"The scary thing is that it's everywhere," said Matt Robinson, an environmental protection specialist at the District of Columbia's Department of Energy and Environment who co-chaired the Chesapeake Bay meeting on microplastics. "And we don't know the effect plastic pollution has on the ecosystem in general."

It's helpful to think of these tiny plastics as either primary or secondary sources of pollution to the environment. Primary microplastics are any plastic fragments that measured less than 5 millimeters before they entered the environment. These include synthetic microfibers that clothing releases when washed; tire fragments washed off of bridges by rainwater; plastic pellets released by industrial facilities; and microbeads that can still be found in some cosmetics, dishwashing detergents, or sandblasting materials.[16]

Secondary microplastics are created when larger items of plastic debris break into smaller fragments in the environment. Fishing nets, soda bottles, and grocery bags—battered by wind, waves, and sunlight—can fracture over time into imperceptible fragments that remain in the environment for hundreds of years.

Microbeads were once more common in everything from facewash to toothpaste—those sparkly, colorful dots were probably polypropylene—until the United States passed the Microbead-Free Waters Act of 2015, outlawing microbeads from rinse-off cosmetics by mid-2017. But critics say the legislation's narrow focus left a gaping loophole for manufacturers to continue to use microbeads in myriad products that aren't considered "rinse-off," including items such as cosmetics and dishwashing liquid that eventually make their way down the drain.[17] The processes used at wastewater treatment facilities filter out some but not all of these tiny beads and fibers before the water is discharged into local waterways.

A Chesapeake Bay-based scientific panel also analyzed the microbeads law and found that it fell short of its potential to rein in a significant source of plastics pollution.[18] The panel found that, while the federal legislation helped highlight the issue of microbeads, it only addressed a small subset of the overall problem and prevented future innovative solutions that could make use of biodegradable plastics.

Microplastics are, in many ways, a microcosm of the world's bigger plastics problem. As one of the first studies on the materials pointed out, they answer one question—where do all the plastics go?—while raising many others. Scientists are beginning to answer them, one by one.

## Plastics Proliferation: A brief history

Plastics, a word originally meaning "pliable and easily shaped," is now a name applied to a category of materials commonly made from synthetic, fossil fuel-derived polymers.[19]

The first synthetic polymer was invented in the 1860s and hailed as a success that would benefit nature by reducing reliance on its limited resources. The Philadelphia-based Science History Institute describes its monumental impact:

*"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 could protect the natural world from the destructive forces of human need."*

In 1909, the first fully synthetic plastic—meaning it contained no molecules found in nature—called Bakelite began being manufactured, making its way into telephone casings, electrical components, and now-collectable vintage bracelets. Rayon, made from cellulose, followed in 1910 and, in 1935, an attempt to make synthetic spider silk led to the invention of nylon.[20]

It wasn't until the 1960s, when newer, more inexpensive plastics made from petroleum became available, that plastics proliferated as a "symbol of the consumer society," in the words of the American Chemistry Council.

"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," Susan Freinkel writes in her book, "Plastics: A Toxic Love Story."[21]

It wasn't long after plastics flourished that their debris was first observed in the oceans in the 1960s, a decade synonymous with burgeoning American environmentalism.[22] It was then that consumers began to realize one of the paradoxes of plastics: While many products are "disposable"—advertised as items that can be used once and tossed—they actually last for centuries, whether in a landfill or floating around in the environment.

As plastics began to pile up, it was the industry that offered recycling as the solution in the 1980s, encouraging localities to offer it as part of their waste management programs. More than 10,000 American communities had some sort of public recycling collection program by 1990, and curbside recycling had begun to take off, too.[23] But, rather than absorbing the increasing amount of plastics, some critics say the recycling fervor merely justified skyrocketing consumption while actual recycling numbers remained subjected to the economic whims of an increasingly global industry.[24]

The U.S. Environmental Protection Agency's latest statistics from 2015 indicate that less than 10% of plastics generated that year were recycled, though rates were higher for some categories such as plastic bottles and jars (nearly 30%).[25]

Today, six times more plastic waste is burned than is recycled in the United States, a 2019 report found,[26] despite concerns that incinerators release cancer-causing pollutants and are more often than not located in poor communities.[27]




"A Specific Plastic for Every Purpose," 1941. Science History Institute. Philadelphia. https://digital.sciencehistory.org/works/8c97kq61x.

# A Day in the Life

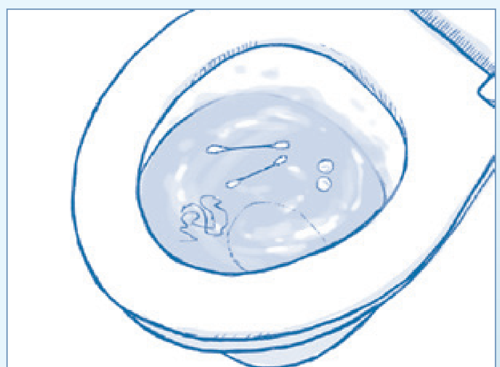
*A short story on our unconscious contributions to the microplastics problem*

Polly does not litter. She started recycling when the city provided a bin. While she doesn't always wash out her plastic containers, she does always put them in the recycling bin.

But Polly, like most of us, has no idea how her everyday actions are contributing to a facet of the plastics pollution problem that goes entirely unnoticed: Polly's clothes, her food, her cosmetics, and her mode of transportation are each contributing microplastics pollution to the environment.

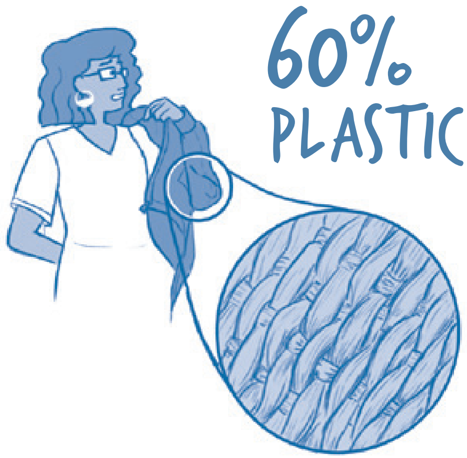
Polly wakes up, washes her face, brushes her teeth, and applies lotion first thing in the morning. While her preferred facial scrub recently replaced polypropylene with peach pits for exfoliation, her toothbrush bristles are breaking down and releasing tiny plastic particles to be washed down her sink.

Her lotion—and the makeup she'll put on later—are not considered "rinse-off" cosmetics, so they weren't covered by the Microbead-Free Waters Act of 2015. They may still contain tiny plastic particles that will wash down the sink when she washes her face.



After Polly uses a cotton swab, she tosses it into the nearby toilet. She does the same with the floss she uses and the contact lenses she forgot to take out the night before—then she flushes. Plastics in each of those items are now on their way to the water.

Polly wears her favorite yoga pants during a quick workout and then tosses them in the washer. The fabrics used to make yoga pants (polyester, nylon, and acrylic) will release hundreds of thousands of microfibers into the water during the wash cycle, which eventually make their way into the Chesapeake Bay.




Polly puts on a fleece jacket as she prepares to leave for work. Plastic fibers are what give many clothes their stretch, and in the case of microfleece, its warmth. Today, 60% of our clothes are made from synthetic fibers, which are forms of plastic.

Polly doesn't have time for breakfast, so she grabs a plastic container of yogurt to eat on her walk to work. The trash bin outside her office is nearly full, but she jams her used to-go cup in anyway. Later, the container rolls out of the bin and into a nearby stormwater drain, which will convey it to the nearby harbor. It will break into smaller pieces of plastic over time.

Polly is meeting a friend in a nearby city for dinner, so she runs home and jumps in her car. On her way across the bridge that spans the Patapsco River, her car tires release tiny black particles that are part-plastic, part-rubber onto the pavement. The next rain will wash those particles directly into the river below.

## Where are they?

Seemingly everywhere researchers have looked, they've found microplastics. They're floating in ostensibly unspoiled air over the Pyrenees Mountains and swirling in sediments taken from the remote Barents Sea, where bottom-living creatures also have been found with microplastics in their bellies. Scientists even found microplastics in Arctic snow this summer.[28] They're also in our food supply: Avid mussel eaters could be consuming up to 11,000 microplastics a year, one study found. Tea lovers should be wary, too.[29] A study published in late September found brewing methods caused a single plastic teabag to release about 11.6 billion microplastic and 3.1 billion nanoplastic particles into the water.[30]

Meanwhile, as many as nine out of 10 of the world's seabirds are thought to have consumed pieces of plastic,[31] and one study found that each of 50 large marine mammals that washed up on the shores of the United Kingdom had microplastics in their digestive tracts.[32]

Closer to home, Chesapeake Bay researchers have only recently begun to measure the ubiquity of plastics, primarily in local waterways. A 2014 report on the presence of microplastics in four Chesapeake rivers was the first of its kind in the region.[33] The study confirmed that microplastics are more plentiful in surface waters near urban and suburban centers and after heavy rains—and they were found in all but one of 60 samples collected in the Corsica, Magothy, Patapsco, and Rhode rivers during sampling in 2011. University of Maryland researcher and author of the report Lance Yonkos said at the workshop in April 2019 that his study generated as many questions as answers for him.

"Just because we found [microplastics] doesn't mean they came from there," Yonkos said. "We need to... understand the source."

Researchers also are beginning to get results from a batch of samples collected from the bay in 2015 by Trash Free Maryland. The nonprofit group worked with a lab at the University of Toronto and renowned microplastics researcher Chelsea Rochman to quantify and classify microplastics gathered from the water in 30 locations.

Out of 30 sites sampled in the bay, the survey found the highest concentrations of

A plastic Easter egg is seen floating in a Chesapeake Bay tributary in May 2019, along with other detritus that could include plastic particles.

Photo by Whitney Pipkin

microplastics in samples taken near Baltimore from the Back River and the Patapsco River near the Inner Harbor. The majority of the debris was categorized as fragments from larger plastics, followed by microfibers and plastic films.

Rochman's work has since shown that the microplastics that scientists had recorded in the ocean also are plentiful in freshwater systems closer to cities and could be having unique impacts in those ecosystems.

Amid a growing concern that microplastics could be as present in the Anacostia River, which flows from Maryland's Montgomery and Prince George's counties and through the District, the Anacostia Riverkeeper staff recently took a closer look, collecting samples at four locations in the river on May 15, 2019.[34]

Under a microscope, each of the samples contained more than 400 pieces of microplastics per liter of river water. And the vast majority of those particles measured between 10 and 100 micrometers. For reference, good eyes can just distinguish items that are 40 micrometers wide—the width of a fine human hair—but not objects that are 20 micrometers.[35]

The majority of plastics in these water samples were, therefore, "on the smaller (end) of the microplastic spectrum—an issue not to be taken lightly given their size and availability to aquatic life," wrote Robbie O'Donnell, project coordinator for the Anacostia Riverkeeper, in the report.[36]

One of the Anacostia's samples contained nearly 700 microplastic particles per liter. Similar studies have been conducted in rivers across the U.S. and the world, including one that found about 84 microplastic particles per liter in the River Thames in London.

There are many pathways for microplastics to make it to the nearest body of water, but there are a few that appear to be ripe for the next round of innovation and behavior changes among consumers. We'll look at two of them: the clothes we wash and the way we throw things away.

## Washed away?

The scientific community has only recently realized just how many microplastics are released by a system that is already heavily regulated and could be considered a major source of these tiny pollutants: wastewater

A plastic water bottle floats in the Anacostia River during a rainy-day paddle on September 30, 2019.

Photo by Whitney Pipkin

treatment facilities. For all their sophistication, these facilities are ill-equipped to remove the tiny plastic particles consumers send them every day when they wash their clothes, which are increasingly made from plastic materials such as acrylic, polyester, or nylon.[37]

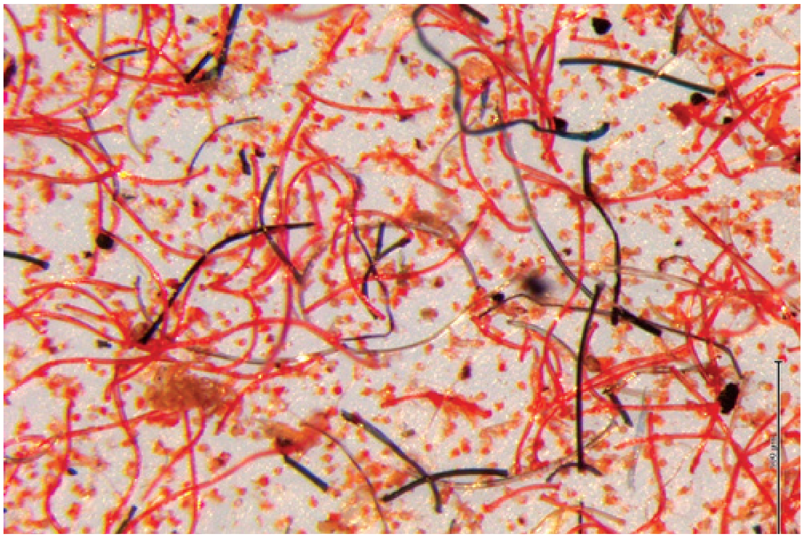
Though the exact number of particles regular clothes-washing contributes to the cycle is difficult to pin down—estimates range from thousands of particles per wash to millions, depending on the fabric's construction, the washing machine, and a half-dozen other variables—the "shedding of textiles in home laundry" is now considered a major source of plastics to local rivers and the oceans.[38] A recent report estimated that the average household in Canada and the U.S. releases 533 million microfibers from laundry into the wastewater treatment system every year.

Those releases equate to about 968 U.S. tons of microfibers that are estimated to make it through wastewater treatment facilities and into freshwater and ocean environments, said the report. Despite advanced filtration methods that remove several other contaminants, plants' treated discharge is estimated to release an average of 4 million microparticles per facility per day.[39] And there are 516 major wastewater treatment plants discharging into the Chesapeake Bay watershed, making the source "a significant concern" for the ecosystem.[40]

The only wastewater treatment facility in the region that has specifically surveyed its effluent for the presence of microplastics is the Hampton Roads Sanitation District (HRSD), which manages 16 treatment plants in 18 counties and cities in Virginia. Its findings, however, are relevant to the entire region.

The plant worked with a doctoral student at Virginia Institute of Marine Science to analyze water samples for the presence of microplastics to see which, if any, stages of its existing treatment process helped remove them. Each stage seemed to remove some microplastic particles. But, in the end, between 500 and 2,000 particles per liter remained in the discharge, ranging in size between 1 and 10 micrometers (the length of a single bacterium).[41]

These treatments produce a secondary waste-turned-nutrient called biosolids, which are used by farmers in the region as fertilizer.



A photo under a microscope of microfibers released by clothes-washing.

Photo provided by Ocean Wise

Chris Burbage, an environmental scientist at HRSD, hypothesizes—and others have, too—that much of the microplastics are being captured in the biosolids, which are then spread on fields where they could be a future source of additional microplastics pollution to nearby waterways.

Another caveat Burbage points out is that the HRSD facilities, unlike the District of Columbia, for example, do not treat any combined sewer effluent. A combination of sewage and often trash-laden stormwater coming to such systems could mean they must handle a much heavier burden of plastics and microplastics for removal—and that a lot more makes it into local waters.

The world's largest wastewater treatment facilities are often hotbeds of innovation as they have adapted over the years to remove emerging pollutants from their waste streams. But facilities have said so far that filtering tiny plastics through an additional process would be too costly and inefficient.

## Is litter still the low-hanging fruit?

Unless water-bound litter—the majority of it plastic—is scooped up by trash-reduction technologies such as Baltimore's trash wheels or trash traps, it eventually becomes a source of microplastics that persist in the environment. Though such litter is far from the only source of this particular type of pollution, it is the low-hanging fruit of the microplastics problem.

In Baltimore, litter remains an intractable problem for a Solid Waste Bureau that, according to reporting this summer by The Baltimore Sun, "does not have enough resources to effectively clean up behind more than 600,000 city residents."[42] Still, reducing litter has emerged as a policy priority at both the city and state levels.

This year the Maryland General Assembly approved a ban on polystyrene foam food containers, a common source of litter that easily breaks down into smaller beads in local waters. Baltimore had already passed its own ban that went into effect in October.

Ashley Van Stone, former executive director of Trash Free Maryland, which helped lead the push for the ban, said part of the argument against polystyrene was its propensity to break down into smaller beads and to remain in marine environments.

Even a small amount of plastics collecting near a storm drain could make its way to the nearest waterway and eventually become microplastics.

Photo by Whitney Pipkin

> "Right now, there is a lot of appetite for trash and litter reduction," said Van Stone. "We're seeing the challenges to the recycling system and its limitations. Pollution keeps ending up in our waterways."

Baltimore's Sustainability Plan,[43] published in 2019, outlines a strategy to inch the city closer to "zero waste," a term that describes communities diverting 90% of their discarded materials from landfills, incinerators, and the environment, though the plan states no concrete timeline for such a strategy.[44]

Meanwhile, trash-free advocates like Stone are eyeing the next goal: local and state legislation that would curb the use of plastic bags, which remain among the top five types of litter found in cleanups, according to Van Stone.[45]

One study of plastic bag regulations in California found their impact to be a bit of a mixed bag if they increase paper bag use or the use of plastic garbage bags for things like lining small trash cans at home.[46] But the study found that fees seem to work better than bans, overall, and that bag regulations do at least one thing well: reduce nonbiodegradable litter in the environment.

## What's the impact?

We know microplastics are ubiquitous, but the looming question to which researchers are now pivoting is, "So what?" What, exactly, does their presence mean for all the fish in the sea and the broader ecosystems that support them?

"That's something we still need to get a handle on," said Matt Robinson, who helped write the report on microplastics in the Chesapeake Bay. "That's the most important thing we can probably research right now."

One of the report's unanimously supported recommendations was that the region conduct an "ecological risk assessment" for the Chesapeake Bay ecosystem. Imagine a graphical depiction of the way a tiny piece of plastic travels into the ecosystem (from washing machine to wastewater treatment plant to water) and then up the food chain (from macroinvertebrates to feeder fish to larger fish or marine mammals).[47]

Such a big-picture study would help the scientific community understand more holistically the impact that plastics pollution has on the entire environmental system, from wildlife and humans to economic assets.

Internationally, animal studies have demonstrated that "ingested microplastic particles can physically damage organs and leach hazardous chemicals—from the hormone-disrupting bisphenol A (BPA) to pesticides—that can compromise immune function and stymie growth and reproduction," an article in Scientific American stated, synthesizing the latest research.[48] Once eaten by the smallest species, these plastics can then travel up the food chain and into the human diet. But researchers are now working feverishly to understand what exactly that means for the species—and for us.

### *The impact on critters*

A growing body of evidence suggests that several species in the bay and its rivers are ingesting microplastics from the water column or in their respective habitats. One of

"I always get [asked] the question of whether [the beads] are actually inside the larvae," Knauss said, showing a video of the plastics, marked with fluorescent dye, swirling inside a tiny oyster. "They do eat them, and they do get into the gut."

the first corners of the bay where researchers began to look for microplastics—and found them in droves—was in underwater beds of bay grasses, also called subaquatic vegetation or SAV.

A study in the tidal Potomac River found microplastics accumulating in grass beds in significantly higher concentrations than in the adjacent open water column. The spindly grasses not only are workhorses of ecological life where baby crabs get their start, but they also appear to function like combs, inadvertently pulling microplastic particles out of the water column.[49]

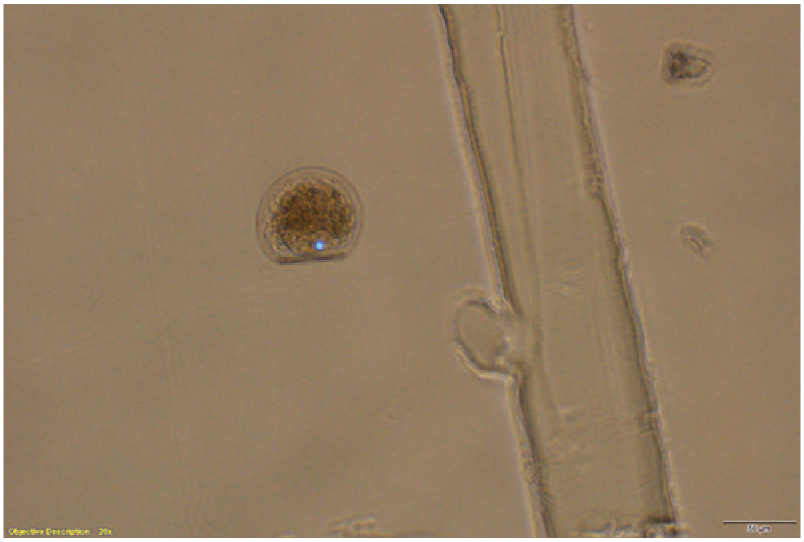
The beds "may serve as these filters for microplastics, just as they do for suspended sediments," explained Brooke Landry, chair of the Chesapeake Bay Program's SAV Workgroup and a biologist at the Maryland Department of Natural Resources. "But once microplastics accumulate in SAV beds, they could also serve as a source to small grazers that eat detritus and could be consuming microplastics at the same time. Then that travels up the food chain."

That finding was one of the triggers for the bay community to begin further studying the impact of these tiny plastics.

## OYSTERS

Christine Knauss, a doctoral student at the University of Maryland Center for Environmental Science at Horn Point, has been feeding microbeads and microfibers to baby oysters for months now to see what happens.

Existing research had already found that tiny Pacific oyster larvae could not only consume



An oyster larva pictured under a microscope with a 6-micron diameter polystyrene microbead in its gut.

Provided by Christine Knauss.

polystyrene microbeads but also experience impacts to their growth and reproduction because of it. Knauss wanted to see if the same is true for a bay oyster species.

She presented her initial findings at the microplastics workshop in April 2019. She included the plastic beads in the feed mix for *Crassostrea virginica* larvae and found that they do have an impact during their first six days in the larvae's system, before the larvae excreted most of the plastics. During that period, the larvae had higher respiration rates and seemed to clear out their guts more quickly, though growth and mortality did not seem to be heavily impacted.

This summer, Knauss conducted experiments examining the effects of polyester and nylon microfibers on oyster larvae and is still analyzing the data.

"I can only say that oyster larvae can ingest both types of microfibers and can ingest a variety of plastic particle sizes and shapes," Knauss wrote in an email.

Knauss said more studies are needed not only in the lab but also in the field, where a combination of factors—from pollution and plastics to climate change and predation—impacts the larvae's ability to grow.

Yonkos, who did the first survey of microplastics in bay waters, is now looking at the impacts of microplastics on earthworms and mussels in the Anacostia River, among other projects, to see whether they could be pulling plastics out of the water column, too.

## FISH

Susanne Brander, a researcher at Oregon State University, has been studying the consumption of microplastics by black sea bass, a fish commonly found in the southern portion of the Chesapeake Bay and along the Mid-Atlantic coast. The sea bass is an opportunistic feeder and, given its value to commercial and recreational fishermen, scientists are interested in how microplastics consumption could impact fish health—and that of humans who eat them.

"If you think about it, plastics are one more pressure added on top of many other pressures," Brander said during her presentation at the April 2019 workshop. "We always say that more research is needed."

Brander began a two-year project on the important East Coast fishery while at the University of North Carolina. Researchers were often finding microplastics in the guts of black sea bass in the wild. In the lab, Brander found that *Centropristis striata* larvae often discriminated between floating foodstuffs and microplastics—but the single-celled organisms they ate did not. She showed images of microscopic organisms vacuuming tiny plastics into their guts, where they remained when they were eaten by the sea bass.

Her research so far has found that juvenile black sea bass that have eaten microplastics seem to have decreased immune responses. Their respiration also appeared to be affected when they were exposed to plastic fibers in the water column.

"Quantifying mortality can be challenging in the lab," she added. That's because, in the wild, there are many other factors in play.

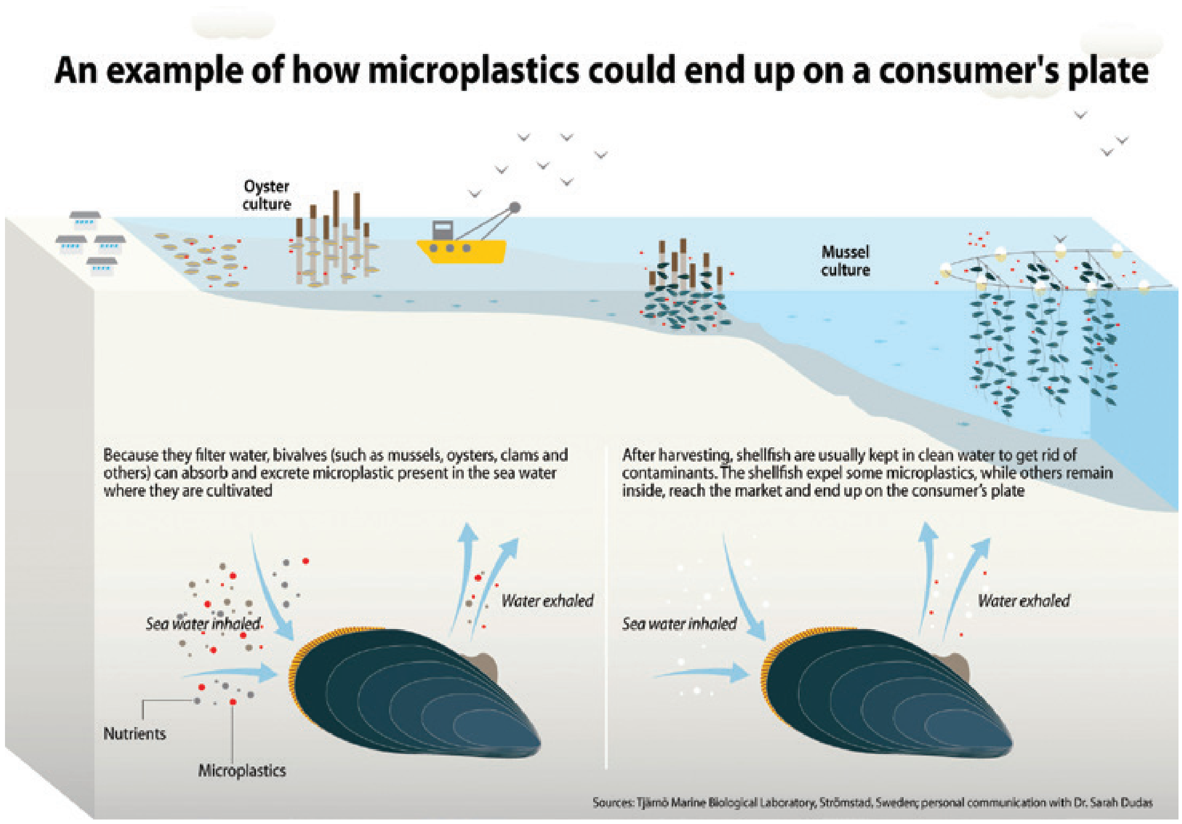
New research out of Hawaii also found that microplastics were more prevalent in ocean surface waters, called surface slicks, where ocean waves converge and larval fish tend to congregate to feed on plankton. Plastic densities in these surface slicks were, on average, eight times higher than plastic densities in the Great Pacific Garbage Patch, a massive collection of marine debris in the Pacific Ocean.

## *The impact on humans*

We know that plastics are everywhere, and that, in large volumes in labs, they can clog the guts and slow the bodily systems of sea creatures. But how present are microplastics in the ecosystems of our own bodies—and what's the harm? It is now accepted that humans are likely ingesting plastics from a variety of sources: from the air we breathe to the water we drink and the food we eat. A recent report estimated the average person could be ingesting about 5 grams of plastic per week—the equivalent of one credit card.[50]

But nearly every article or scientific study revealing a new hiding place of these tiny pollutants ends something like the one that found tea bags releasing microplastics into our cups: "More research is needed to determine if the (micro)plastics could have more subtle or chronic effects on humans."[51]

Anthropogenic debris such as microplastics has been found in more than 80% of tap water samples from major cities around the world—including tap water at the U.S. Capitol's visitor's center in Washington, D.C. Bottled water fared worse, with 93% of bottled water samples from the world's top 11 brands containing microparticles that are most likely plastic (the infrared technology the scientists used to identify types of plastic in the bottled water is ineffective on the smallest of particles).

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http://www.grida.no/resources/6915

## A recent study estimated that Americans are consuming an average of up to 52,000 microplastic particles annually, not counting the microplastics that are likely inhaled each year (between 74,000 and 121,000) or taken in with drinking water.

Another study found beer (often made from tap water) and salt to be potential sources of microplastics to humans. And one of the most largely suspected diet-based sources—considering the presence of plastics in the world's oceans—is seafood.[52]

In 2018, researchers at Johns Hopkins Center for a Livable Future surveyed the existing science on microplastics in seafood and its implications for human health. So far, they found that seafood such as mussels, oysters, and whole fish that is consumed with its gastrointestinal tract—where microplastics often end up in species—is likely to contain more of the tiny plastic particles than the average fish fillet.[53]

A study published this summer tried to synthesize the data about diet-based sources of plastics to estimate how many particles the average American is consuming.[54] The authors estimated that Americans are consuming an average of up to 52,000 microplastic particles annually, not counting the microplastics that are likely inhaled each year (between 74,000 and 121,000) or taken in with drinking water, depending on the source.

And, if any doubt remains that these tiny plastics are getting inside us, a recent report published in the Annals of Internal Medicine found them in the excrement of people from eight different countries.[55]

Noting the preponderance of microplastics in drinking water, the World Health Organization released a report this summer surveying the existing data to better understand "the potential human health risks."

If you only read the headlines about that report, you might conclude that microplastics in drinking water are not a concern. But the international organization's report actually stated what so many others have: that there's not yet enough information.

"There are no studies on the impacts of ingested microplastics on human health, and there are only a limited number of animal studies of questionable reliability and relevance," the report states.[56]

The report acknowledges three categories of "potential hazards" posed by the presence of plastics, with a focus on drinking water: (1) the particles themselves could be physically hazardous; (2) the chemicals and microorganisms colonizing on the plastics could be harmful; and (3) the particles or the chemicals they carry could present toxicity risks in certain quantities. One study in the Chesapeake Bay watershed found that plastic debris can carry all three species of the bacteria Vibrio, which can cause disease in humans, from one coastal environment to another.

So far, the organization found there's not enough evidence to declare any one of those a pressing human health concern, especially when compared to the known dangers posed by pathogens and other chemicals in inadequately treated water in some countries.

"Just because we're ingesting them doesn't mean we have a risk to human health," said Bruce Gordon, WHO's coordinator of water, sanitation, and hygiene.[57] "The main conclusion is, I think, if you are a consumer drinking bottled water or tap water, you shouldn't necessarily be concerned."

Noting the risks that plastics have posed to the environment and wildlife, however, the report highlighted the continued need to curb plastics pollution. The potential for risk could grow as plastics continue to proliferate in the environment, and as more research is conducted.

In its series of stories on plastics pollution, National Geographic summed up the current moment of understanding about plastics' cumulative impact on us: "It's difficult to parse whether microplastics affect us as individual consumers... because we're steeped in this material."[58]

## The Search for Solutions

The research community agrees that there is still much to be learned about microplastics, particularly about any harm they pose to living organisms and humans. But work to reduce their impact isn't waiting for the research process to be complete, either. Denice Wardrop, a research professor at Penn State and director of the university's Sustainability Institute, said at the April 2019 workshop that her work has taught her that policy changes don't always have to wait on scientists having all the answers.

"As a scientist, I thought that to give people useful information for a piece of legislation, I had to have 95% certainty on the data," she said. But it turns out, "people are willing to use a legislative tool or management action at a lower level of certainty than we assume."

She pointed to the rapid spread of bans on plastic straws among localities along the East Coast as evidence; in some areas, a photo of a pile of straws on a beach or in a bird's nest was enough to get people concerned—even if the impact wasn't yet fully understood.

Wardrop urged the group that would be submitting a report to the Chesapeake Bay Commission to consider the potential risks of microplastics in its recommendations—even if these risks couldn't be written in stone just yet.

"We may still be uncertain, but the potential risk is high," she said.

Many big-picture solutions are already in the works. Here are a few examples:

- **The National Science Foundation** this year is looking to fund research into plastic materials that will "no longer languish in landfills and the environment" but will help "achieve the promise of a world without plastic waste." These solutions could include turning plastics into materials that can be more easily reused or creating them from more biodegradable materials. The foundation intends to offer a total of $30 million to 15 teams to investigate these problems during four-year projects.

- **Economists are recommending** the plastics industry, local waste managers, and individuals move toward more "closed-loop" or "circular economy" systems. These aim to reduce the amount of raw materials going into production, to extend the useful life of products, and to capture plastic products and reuse them to make new ones. Basically, it's the "reduce, reuse, and recycle" mantra, with the addition of the option to also "refuse" certain products.[59]

- **Researchers are working on standardizing** several measures that will make quantifying and reducing the presence of microplastics easier. These efforts include developing size protocols for categories of microplastics and creating biodegradability standards. These would detail how quickly alternative "compostable" products need to decompose to be considered beneficial alternatives to plastics.

- **Some clothing manufacturers**—in the wake of information about how much microplastics pollution comes from washing our clothes—are retooling their materials and designs to reduce the number of plastic fibers they release. Brands such as Patagonia, Arc'teryx, and REI are partnering in a Microfiber Partnership with the Ocean Wise Plastics Lab to tailor their products to the latest research.

- **At 2019's Google Science Fair** in October, judges awarded their top prize to an 18-year-old student from Ireland who found that a magnetic liquid can remove microplastics from water—a technology that could inspire wastewater treatment plants in the future.[60] The liquid, called ferrofluid, was invented by NASA so its rocket fuel could be transported in zero-gravity conditions. It also attracts plastics. In his experiments, the student found ferrofluid was able to remove about 88% of microplastics from water samples.

The seeming omnipresence of microplastics can make the problem feel insurmountable, particularly to individuals. What can one person do to reduce his or her contributions, even as broader solutions are in the works? It turns out the marketplace is eager to answer that question with a suite of new products aimed at curbing microplastics pollution.

Let's start with the morning routine. You can take heart that 2015 regulations in the United States began to ban the use of microbeads in many rinse-off products, such as face wash, by mid-2017. But microplastics could still be lurking in cosmetics such as makeup foundations and blushes that are eventually washed down the drain. Consumers can scan product labels looking for words like "polypropylene" and "polyethylene" and consider alternatives to those products.

In addition, several companies are responding to consumer demand and taking aim at an even higher target: reducing the plastic packaging associated with many cosmetics and hygienic products. After use, these containers are not easily recycled and end up in landfills or as litter. To reduce your contributions, do a Google search for "zero-waste" or "plastic-free" makeup, soaps, or even toothpaste. Some makeup companies have replaced their plastic cases with bamboo or stainless-steel casings that can be refilled or recycled. (You can even send your used mascara wands to the Appalachian Wildlife Refuge, where they clean and use them to care for orphaned animals.)

Websites such as WellEarthGoods.com aggregate these products with a focus on reducing consumers' plastic waste. Other companies such as Grove Collaborative focus on products with fewer chemicals but also tend to offer soaps and cleaning products with less packaging and refillable options. The market even has solutions to replace your plastic tube of toothpaste, with more than one brand offering toothpaste tablets in glass or paper packaging that foam when you bite and add water. Many of these products do come at a premium compared to off-the-shelf varieties, which is why some zero-waste bloggers recommend replacing products over time. But some solutions, like replacing liquid soap with bars, can be both cost-effective and simple. (Also, no matter what products you use in the bathroom, do not toss used ones in the toilet, especially plastic floss or cotton swabs.)

But, if you want to make a bigger dent in the microplastics problem with a small investment, consider starting with your washing machine. As you've read in this report, your clothes are likely shedding thousands—if not millions—of microplastic particles each time you wash a load, depending on variables such as the fabric's construction and the type of washing machine used. Though this source of contaminants is one that researchers are just now learning about, the advocacy organization Surfrider Foundation already has recommendations to reduce how many microplastics leave our washing machines.

If the world's demand for and disposal of the materials go unchanged, experts estimate that there will be more plastic in the ocean than fish by 2050.

Here are a few:

- What you wash: Buy less; buy natural fibers; and wash less.
- How you wash: Use a front-loading washing machine instead of a top-loading one. Front-loaders shed up to seven times fewer microfibers per wash. Use cool water; do not wash clothes with heavy items like shoes that cause friction; skip the spin cycle; and use less detergent.
- Add to the wash: Consider adding a filtration system to your wash or dry cycles to capture some of the microfibers that are released. The Cora Ball and the Guppyfriend wash bag both aim to catch microfibers in the washing machine. Filters like the Lint LUV-R or the Filtrol 160 can be added to the back end of machines to catch up to 87% of fibers before they enter the drain.

## Conclusion

Plastics were first floated to consumers as a boon for the environment that would reduce humans' reliance on natural resources and, in many ways, they have. They have made life more convenient, more functional, and, when their myriad medical uses are considered, safer and longer.

But these miracle materials—especially when they make their way into the natural environment and break down into microplastics over time—are also having deleterious effects on the ecosystems we all inhabit. Researchers are working at breakneck speed to further quantify and describe those impacts. But the verdict so far is that plastics—and the tiniest versions of them, in particular—are everywhere. They are likely causing harm to animals and, potentially, humans who are ingesting them from a variety of sources.

Meanwhile, plastic production is expected to almost quadruple over the next 30 years from the 343 million U.S. tons produced in 2014. If the world's demand for and disposal of the materials go unchanged, experts estimate that there will be more plastic in the ocean than fish by 2050.[61]

On the individual level, there is plenty to take away from a better understanding of plastics, microplastics, and their impact on the ecosystem and us. Understanding the endgame of our plastics habits equips us to better evaluate how we use plastics in the first place. It raises the stakes on daily decisions about how we purchase, deploy, and dispose of plastics. There is plenty of action to be taken—from participating in a local beach cleanup to reconsidering clothes-washing habits. But, as Trash Free Maryland's Van Stone points out, the solutions are often a lot simpler than we imagine.

"There isn't one great alternative beyond reducing single-use plastic materials all together," she said. "We've got to be making less waste, and then what we make should be as recoverable and recyclable as possible—and not carry contaminants that we could later ingest."

## About the Author

Whitney Pipkin is a reporter for the Chesapeake Bay Journal and a freelance writer whose work has appeared in National Geographic, The Washington Post, NPR, and many other outlets. She began covering environmental issues as a reporter working near the Puget Sound in Washington state, where she also did a fellowship with the Institute for Journalists of Natural Resources. Her latest work can be seen at BayJournal.com and WhitneyPipkin.com.

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**Microplastics: The grand reach of our tiny plastics problem**

**by Whitney Pipkin**

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