



# BABIES VS. PLASTICS



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*“Our reliance on plastics could be the biggest gamble in the story of human health, in history. We are all ingesting and inhaling microplastics. They are everywhere. Are we just hoping they are safe, or is even the remotest possibility they might be toxic so terrifying, that we can’t contemplate it?”*

-Kathleen Rogers  
*President, EARTHDAY.ORG*



## INTRODUCTION

We are living in the Plasticene. An era in which plastics have permeated every aspect of our lives like an epidemic. Microplastics are impossible to avoid.

Since the 1950's when plastics first started appearing in our lives we have been force fed the idea that they make our lives better—plastics were almost good enough to eat. In a 1997 advert from the American Plastic Council that is exactly how they touted plastic wrappings and containers. They joked plastics were the sixth food group, there to keep contamination out of our foods as well as extending their shelf life.

We are only now discovering how pertinent that sentiment is as we find microplastics in our water and in the food chain itself. We are indeed almost certainly all eating plastics.

While we can be pretty sure the copywriter was not laughing at our expense—the real question is—what did the plastic industry actually

know back then? As plastic production sets to double by 2040 what do we really know about this non-inert material and its array of additive chemicals?

This is an EARTHDAY.ORG primer on plastics, microplastics and their additive chemicals, with over 120 sources, capturing what studies from around the world have been discovering about how we ingest microplastics, how they can bioaccumulate inside of us and what the health consequences might be. We have included recent studies, pilot studies, studies with large sample groups and some with far smaller ones.

The results, taken collectively, are alarming and demand answers. We can no longer just 'trust' that plastics are safe, we need them proven to be safe by independent research. Until such time—the precautionary principle should be applied.

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## EXECUTIVE SUMMARY

**The full extent of the health risks associated with microplastic exposure is not yet fully understood. But evidence is mounting that plastics, microplastics and their additive chemicals pose potentially serious health risks to humans, with babies and infants being especially vulnerable, for reasons we lay out in this report.**

- There is evidence that microplastics bioaccumulate in our major organs (including the brain), and evidence that nanoplastics can breach the blood-brain barrier.
- Microplastics have been found in the human placenta.
- Microplastics (and their additive chemicals) have been linked to higher rates of both miscarriage and male infertility.
- Microplastics have been detected in dairy milk and breast milk.
- There is evidence that babies ingest more microplastics and microfibres than adults because of key developmental stages—specifically crawling, teething and their habit of tasting inanimate objects. One study suggests babies ingest/inhale 10 times the level of microplastics to that of adults.
- Microplastics (and their additive chemicals) are both shed and leached from plastic toys, clothes, furniture and even the soft ‘crumb tire’ of playgrounds.
- Studies have shown there is a higher percentage of microplastics in the air we breathe inside than there are in the air we breathe outside. Some studies claim babies spend up to 90% of their time indoors.
- Microplastic ingestion, inhalation and bioaccumulation have been linked to a wide range of health issues in children; one study found that phthalate exposure (a chemical used in the making of certain types of plastics) was associated with a 20% higher rate of childhood cancer overall.
- Weathered microplastics are more damaging than virgin microplastics as they can absorb toxic chemicals and heavy metals, as well as potentially carrying viruses and hosting bacteria.

It feels as if we are drowning in information—research papers, articles and headlines—on the health implications posed by the ingestion and inhalation of microplastics (a derivative of petroleum) and the additive chemicals used in the manufacture of plastics. But let's be clear—we need MUCH more research on microplastics and human health. Secondly, we are of course not choosing to consume plastics. But tiny plastic particles, filaments and microplastics are in the air we breathe, inside our homes, and in the water and food we consume. *Why?* Because plastics truly have become ubiquitous in our world.

We wrap our food in plastics, we use a myriad of different types of plastic in every facet of industry and manufacturing: from making utensils to building cars to creating computers. [Even our clothes contain plastics](#)<sup>1</sup>. Practically everything we use in the modern world has some component [made of plastic](#)<sup>2</sup>. This ranges from fishing nets and furniture to microbeads found in soaps and toiletries, as well as items like tires, single-use water bottles, medical equipment, vitamin capsules, medicines, and beyond.

Well [over 20<sup>3</sup>](#) different basic types of plastic are used around the world, made with petrochemicals and various combinations of over [10,000 different chemicals](#)<sup>4</sup>. It is virtually impossible to opt out of coming into contact with plastics or microplastics.

This report seeks to review a spectrum of the most recent scientific papers and studies on this subject, as they relate to the risks associated with plastics, their associated chemical additives, and microplastics—with particular attention to their impact on the well-being of babies and infants.

Research suggests the health implications presented by microplastics extend to children both before and after birth. There's evidence microplastics can [interrupt maternal-fetal communication](#)<sup>5</sup> and potentially [damage DNA](#)<sup>6</sup>. Some studies even report finding [links between microplastic ingestion and attention deficit disorder](#)<sup>7</sup> (ADHD). Reports have linked them to [autism](#)<sup>8</sup>, behavioral & developmental issues, endocrine disruption (which can manifest as [early onset puberty](#)<sup>9</sup>), and some [cancers](#)<sup>10</sup>, including in the prostate gland of [fetuses](#)<sup>11</sup>, and much more.

New evidence from a pilot study suggests babies, perhaps more than any other demographic group, might be more susceptible to ingesting [microplastics](#)<sup>12</sup>. Researchers discovered that median levels of some microplastics were over [10 times higher](#)<sup>13</sup> in baby feces than in that of adults. Is it surprising given their toys, their clothes, their cribs, their playgrounds, breast milk, can all contain, leach or shed microplastics? Babies and infants are inhaling and ingesting microplastic particles at nearly every stage of modern life. So how did we get here, the age of plastics?



## WELCOME TO THE PLASTICENE

Consumers did not create the plastic problem. The plastic industry and manufacturers have been force feeding us plastic for decades. They have encouraged the idea that any issues with plastics center around the ‘trash’ problem - an issue which they claim could be overcome if we would embrace [recycling](#)<sup>14</sup> more. While plastics do present an ever-increasing trash problem, which recycling cannot solve, the real issue with plastics is the rapidly emerging health risks associated with them.

The word microplastic is becoming increasingly common in our vocabulary for a reason—we are slowly waking up to the potential harm these tiny plastic particles and their additive chemicals can have on human health and on the well-being of all living creatures.

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harm these tiny plastic particles, and their additive chemicals, can have on human health and on the well-being of all living creatures.

Scientists have speculated that plastic is so pervasive it will soon show up in our [geological record](#)<sup>15</sup>, like dinosaur bones and sandstone deposits. This truly is the age of plastics, and what some are now calling [the Plasticene](#)<sup>16</sup>. They cover the bottoms of our oceans, even the deepest part known as the Mariana Trench, in the west Pacific, some [36,000 feet down](#)<sup>17</sup>.

They are in our deserts, soils, and atop the peaks of our [tallest mountains, including Everest](#)<sup>18</sup> with an elevation of over 29,000 feet. Plastic filaments have even been discovered entangling the legs of tiny ants in [pine forests](#)<sup>19</sup> on the remote volcanic island of La Palma. Plastics have invaded our cities, towns, villages, and farmland. Perhaps most alarmingly of all, plastics and microplastics have been found bioaccumulating inside many living species, including inside us.

## WHAT EXACTLY ARE MICROPLASTICS?

In 2004, Professor Richard Thompson, an oceanographer from the University of Plymouth in the UK, coined the term “microplastic.” This term describes the billions of minuscule bits of plastic that result from either the breakdown of larger pieces of plastic or which have been deliberately manufactured for use in commercial products.

This latter type is known as **primary microplastics**. Often nurdles, they consist of resin pellets approximately 2 to 5 mm in diameter and they are used by industry to manufacture all manner of plastic products.

Often a range of additive chemicals are added to imbue the plastic being produced with specific qualities, for example softness or durability.

Another form of primary microplastics are known as microbeads—which are used in beauty and healthcare products—such as skin exfoliants and toothpastes.

The second type of microplastic, often referred to as secondary microplastics, are made from the fragmentation and weathering of larger plastic objects.

These microparticles are 5 mm in size or less and they are created when larger plastic pieces are impacted by tides, hydrolysis, ultraviolet light degradation, wind weathering, and everyday wear and tear. Gradually over time the larger plastic pieces degrade into tiny pieces: commonly called microplastics. In their more formal description microplastics are described as “[synthetic solid particles or polymeric matrices](#)<sup>20</sup>, with regular or irregular shape and with size ranging from 1 µm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water.”

[Microplastics come in several forms: fragments, pellets, beads, fibers, and film](#)<sup>21</sup>. But the simplest explanation is that microplastics are essentially tiny specks of plastic. Typically smaller than a grain of rice. Meanwhile, nanoplastics are far smaller, just 100 nanometres or less (1/5000th of a grain of rice) and not visible to the naked eye.



Microplastics are roughly the size of a grain of rice

How these microplastics might potentially harm us is still in the early stages of research, but it's clear the adverse effects of these microplastics can impact us in one of two ways:

- There can be physical effects, determined by the size, concentration, and shape of the actual microplastics ingested, often as microfibrils or filaments.
- There can be chemical effects, which concern the additive chemicals used in the making of plastics. [These additive chemicals](#)<sup>22</sup> can include inert or reinforcing fillers, plasticizers and phthalates, antioxidants, UV stabilizers, lubricants, dyes, and flame-retardants.
- In addition to microplastics being a contaminant in their own right, they also [act as vectors for other contaminants and pollutants](#)<sup>23</sup> which they attract and adsorb—such as [toxic chemicals like heavy metals](#)<sup>24</sup>.
- Microplastics have also been [linked to hosting antibiotic resistant bacteria](#)<sup>25</sup> and antibiotic resistance genes. Now there's new evidence that microplastics [can carry viruses too](#)<sup>26</sup>.

## MICROPLASTICS IN OUR HOMES

Microplastics are undoubtedly [everywhere](#)<sup>27</sup>. We know they have been found all [over the planet](#)<sup>28</sup>, even in remote locations, but not surprisingly babies and children are most likely to encounter microplastics in their own homes. Some research claims it is where they can spend [90%](#)<sup>29</sup> of their time.

A [2022 study published by Environmental Pollution](#)<sup>30</sup>, conducted across 29 countries and in 108 homes, collected data on the types of microplastics found inside dust samples. Of the total dust discovered in these households, scientists recorded the following percentages of synthetic polymer fibers:

**Polyester 9.1%**  
typically used in clothing

**Polyamide 7.7%**  
typically used in textiles

**Polyvinyls 5.8%**  
typically used in floor varnishes

**Polyurethane 4.4%**  
typically used in coatings on furniture

**Polyethylene 3.6%**  
typically used in food containers/reusable bags



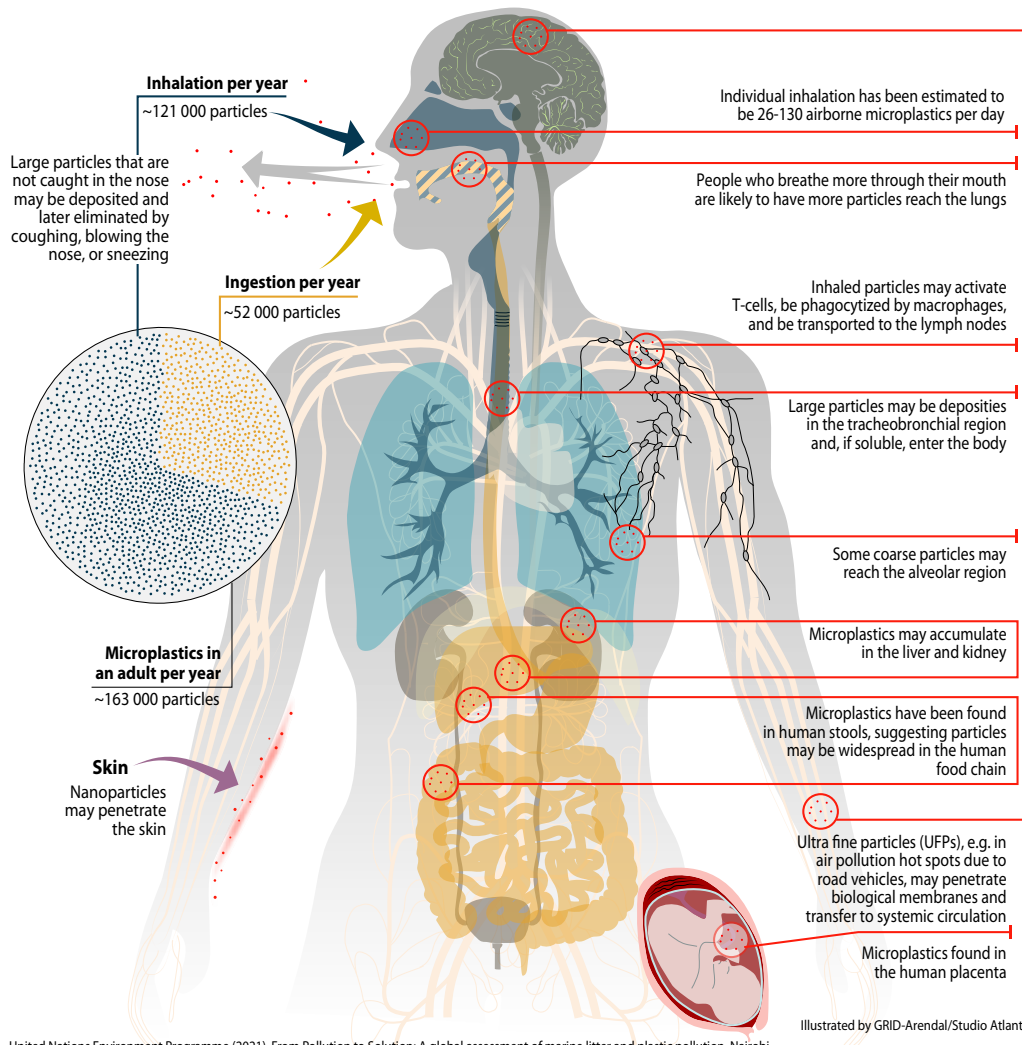
The researchers discovered that the best way to counter this was through good old-fashioned vacuuming. And while they characterized this exposure as ‘low risk,’ the total exposure to microplastics, across the board, was not studied.

This study of dust and its component parts is not new. In the 1970s researchers studied household dust to determine the levels of lead<sup>31</sup>, largely originating from lead-based paints, that children were being exposed to inside their homes. The US federal government banned consumer uses of lead based paints in 1978<sup>32</sup>.

Exposure to lead is extremely harmful especially in children<sup>33</sup>. It can damage the brain, slow development, and decrease the ability to pay attention.

While lead is being phased out globally<sup>34</sup>, there are signs that plastics, their additive chemicals and microplastics might pose risks that have not yet been fully taken into consideration and are only now beginning to emerge. One of the key factors that makes the potential health risks surrounding plastics (and their various constituent parts) so concerning is just how pervasive plastics are.

### Human exposure to microplastic and nanoplastic particles



United Nations Environment Programme (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.

## MICROPLASTICS IN OUR ATMOSPHERE

Microplastics aren't just in household dust accumulating under our furniture and on our floors—they are present in the air we breathe.

Research has discovered the average human being could be inhaling up to [11.3 MP microplastics per hour](#)<sup>35</sup>. Of the air sampled in three apartments in Denmark, the concentration of microplastics, as a percentage of particulates in the air, was on average 4%. So across all of the apartments and all of their rooms on average 4% of all the particles in the air collected was made up of microplastics. Primarily these microplastics were made from polyester. But different percentages of particulates ranged between apartments by values of 58% and between different spaces inside the same apartments by [16 percent to 77 percent](#)<sup>36</sup>, which suggests that the levels of contamination in the air we breathe can vary significantly even within the same home.

Furthermore, the quantity of microplastics detectable in ambient air also depends on where you are in the world. [Airborne microplastic concentrations range from 0.01 particles](#)<sup>37</sup> per cubic meter in parts of the Pacific Ocean to [several thousand particles](#)<sup>38</sup> per cubic meter in cities like London and Beijing.

A 2023 [preliminary study](#)<sup>39</sup> looking at the potential risks of microplastics weathered by ultraviolet radiation discovered worn microplastics were more toxic than so called virgin microplastics, which are not weathered in the same way. The worn or weathered microplastics appeared to cause an inflammatory reaction in human brain tissue.



## MICROPLASTICS IN OUR FOOD CHAIN

Microplastics are in the food chain<sup>40</sup> too. Fish, and all manner of smaller creatures, consume tiny microplastics in our waterways and oceans. When these fish, crustaceans, and sea birds are in turn consumed, the microplastics inside them keep traveling up the food chain, through a process called “trophic transfer”<sup>41</sup>, until they reach us.

A Nature, Scientific Reports, 2017 study<sup>42</sup>, which claimed to be the first of its kind, discovered plastic

nano-particles<sup>43</sup>, essentially pieces of plastic that are smaller than microplastics in a range between 1 to 100 nanometres in diameter, can penetrate the blood-to-brain barrier in fish. They observed this changed fish behavior. Fish that consumed nano-particles, even third-hand, engaged in more dangerous swimming behaviors vis-à-vis predation.

The study concluded plastic nano-particles travel upwards through the food chain to enter the brain of the apex predator. The apex predator at the top of the food chain is often human beings.

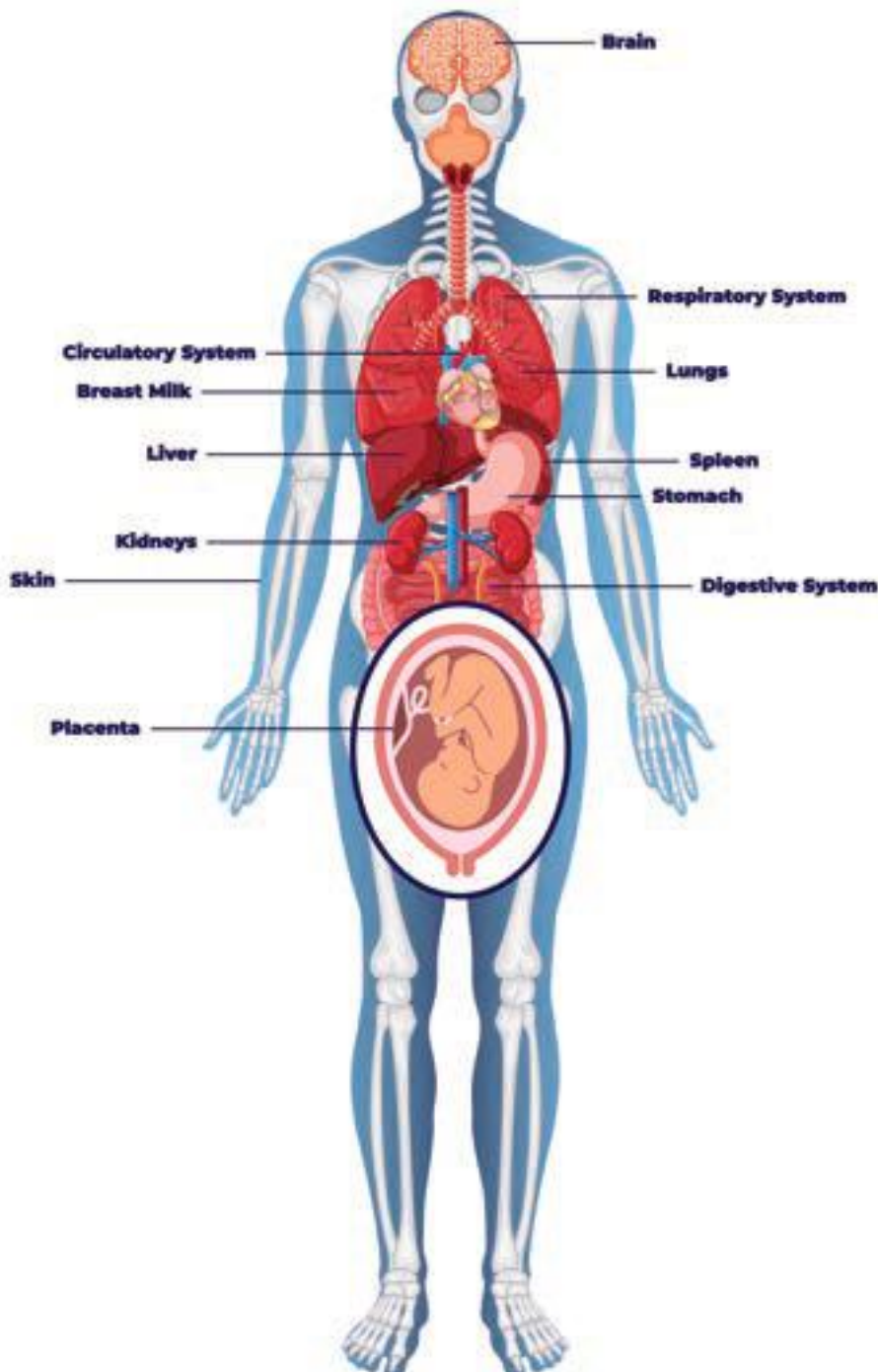


Microplastics and nanoplastics travel up through the food chain

A [study in the journal \*Environmental Science and Technology\*](#)<sup>44</sup> claims humans could be consuming 39,000 to 52,000 microplastic particles a year. This figure rises to 74,000 to 121,000 microplastic particles when particles we inhale are factored in too (**which is annually roughly about the weight of a bar of soap**).

New animal research has discovered microplastics can accumulate inside major organs, [like the brain and liver](#)<sup>45</sup> of mice as well as human [lung tissue](#)<sup>46</sup>, as well as [the tissue of human hearts](#)<sup>47</sup> after surgery and [the urinary and gastrointestinal systems](#)<sup>48</sup> of a sample of young people, aged 16–35 years.

### Organs Most Affected by Microplastics



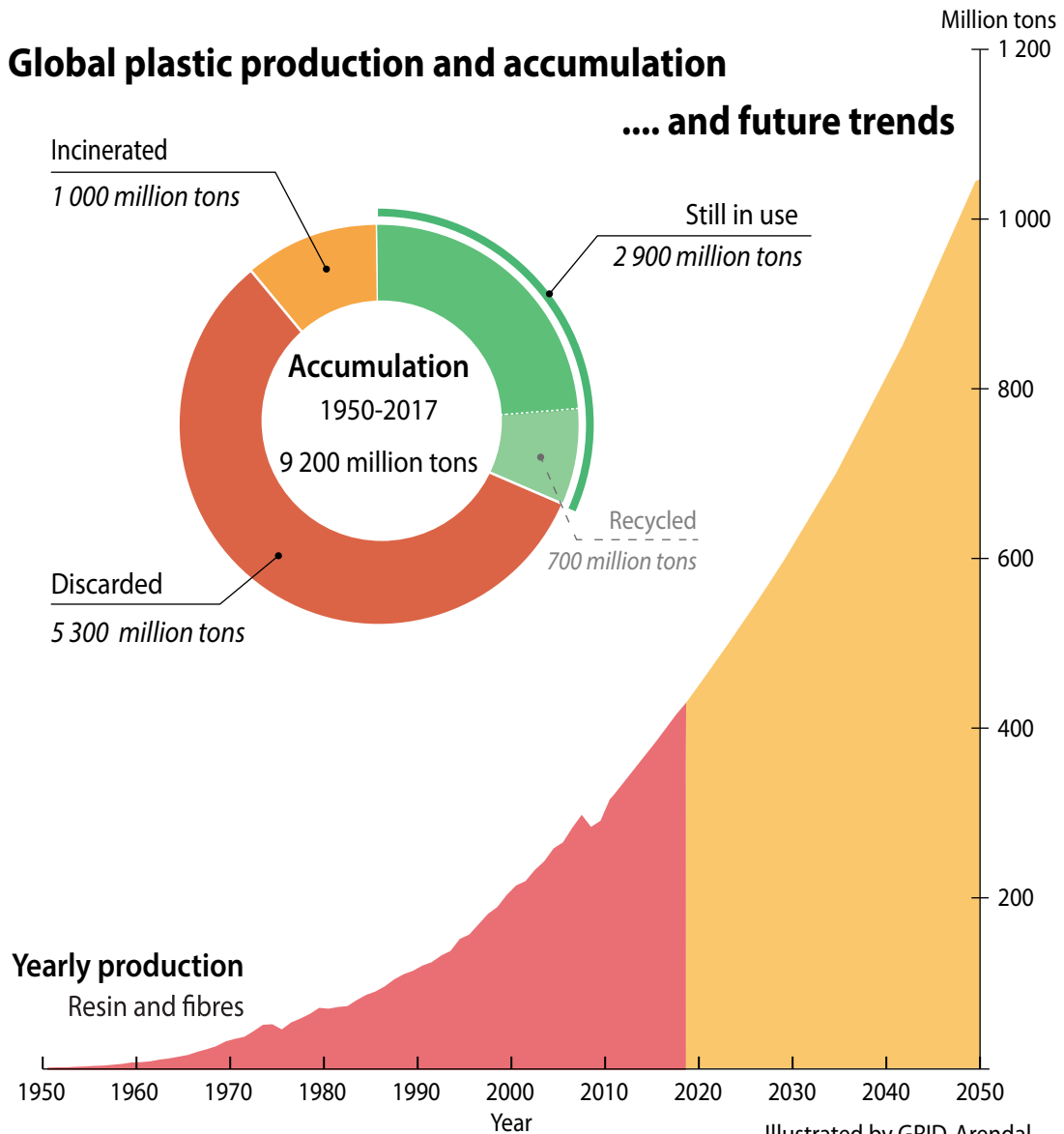
# PLASTIC PRODUCTION IS INCREASING

There are more plastics now than there have ever been and production is increasing. In 2021, over 390 million tons of plastic<sup>49</sup> were produced with a market value of 593 billion US dollars<sup>50</sup>.

Plastic production already accounts for 3.4% of global greenhouse gas (GHG) emissions<sup>51</sup>, a percentage

that will increase as the petrochemical industry pivots to plastic production, partially to counter a consumer market shifting away from petroleum-based fuel sources. And those figures don't include the additional GHG contributions from incineration, landfilling, and other waste management practices.

Unless something is done to curb this trend, current rates of plastic production could double by 2040.



UNEP (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.



## THE PRECAUTIONARY PRINCIPLE

So, given plastics are ubiquitous and the production of it is on a trajectory to rapidly increase in the next decade, should we be applying a more precautionary approach to plastics?

The precautionary principle states that the introduction of a new product or process whose ultimate effects are disputed **or unknown** should be resisted. Or as [the European parliament defines it](#)<sup>52</sup>—  
*“...the precautionary principle enables decision-makers to adopt precautionary measures when scientific evidence about an environmental or human health hazard is uncertain and the stakes are high.”*

What stakes could be higher than the possibility that one of the most prevalent man-made materials on the planet might be toxic or have additive chemicals that are damaging to human health, if ingested or inhaled? This is especially important given that this ‘consumption’ of plastics, via microplastics and micro fibers, is involuntary and virtually impossible to avoid.

The European Union has adopted the precautionary principle as a key tenet of EU environmental law—albeit with checks and balances that consider costs and benefits as factors too. While in the US the precautionary principle is not expressly mentioned in any laws or policies, it is not entirely absent either.

In 1975, it was ironically [a case involving plastics](#)<sup>53</sup>, [The Society of Plastics Industry, Inc v Occupational Safety and Health Administration](#)<sup>54</sup>, that best exemplifies how the precautionary principle can be applied. The plastics industry challenged the US Occupational Safety and Health Administration’s (OSHA) worker exposure standard for vinyl chloride (VC is an additive chemical used in the making of some plastics like PVC).

The court stated that it was the OSHA’s duty to protect workers from higher levels of VC exposure, **even when existing methodology or research is deficient**, which sounds like another way of describing the precautionary principle.

The EPA too has won cases using this principle: The Clean Air Act's **“precautionary and preventive orientation”** approach was upheld by the DC Circuit Court of Appeals in 1980, in a case involving lead, when the Court agreed with the EPA that Congress had directed them to **“err on the side of caution”** in making necessary decisions.

While the rising Greenhouse Gasses alone caused by plastic production are of concern in their own right and understood, the potential harmful impact of microplastic particles on human health, as well as the 10,000 chemical additives used to make them, is only just beginning to be investigated in earnest.

It has been calculated that the health consequence of [PFAS](#)<sup>55</sup> alone, an additive chemical used in everyday plastics items like food containers, is an [economic burden on Americans, to the tune of somewhere between \\$5.5 billion and \\$63 billion annually](#)<sup>56</sup>. Medical bills and loss of productivity (due to illness) were both factored in.

Then there's the cost to the environment—[the United Nation Environment Programme](#)<sup>57</sup> calculated as far back as 2014 that plastic waste causes \$13 billion US dollars worth of damage to marine ecosystems alone—every single year.



*Isn't it time for the  
precautionary principle  
to be applied to plastics?*



Disclaimer: this image is generated by AI





*“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  
A Toxic Love Story'*

# 01

## OUR PLASTIC PLANET

### A BRIEF HISTORY OF PLASTICS

**So, how did this plastic planet come to be in the first place?**

**In 1907<sup>2</sup>, Leo Baekeland was looking for a new substance to insulate electricity cables in a rapidly modernizing US and invented Bakelite. It was the first synthetic plastic, produced using petrochemicals. Bakelite was a good insulator as well as being heat resistant and durable. Perhaps most importantly, it could be mass produced. Marketeers described Bakelite somewhat prophetically as “the material of a thousand uses,” because it could essentially be molded into any shape needed.**

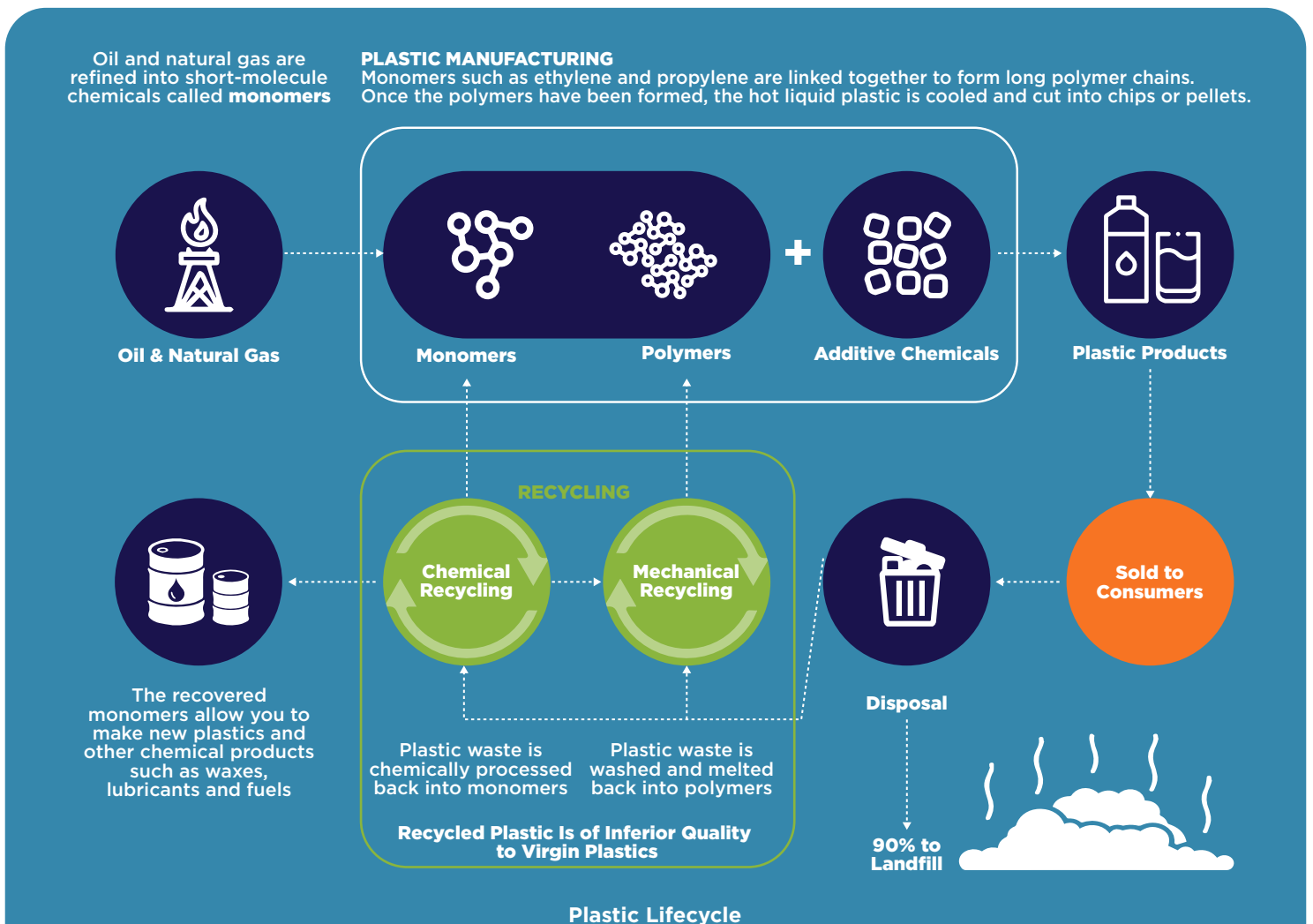
Different types of plastic would follow Bakelite, each imbued with specific qualities, such as softness, durability, rigidity etc., made possible by additive chemicals. As a result, the production of plastics in the United States alone increased by 300%<sup>3</sup> during WWII.

After World War II, there was no going back to a pre-plastic world; industry and consumers alike embraced how plastic<sup>4</sup> could be shaped and molded for practically any usage or need.

## HOW PLASTICS ARE MADE

So how is plastic actually made? The primary ingredient<sup>5</sup> in most plastics is derived from petroleum: oil, natural gas, or coal. **Which means the fossil fuel companies who helped create the climate crisis are now helping to create the plastics crisis too.**

Heating petroleum at very high temperatures causes it to break down into molecules, which in their simplest definition are groups of two or more atoms. The primary target of this heating process is to extract ethylene and propylene molecules known as monomers.



These extracted chemicals are put through various chemical processes, called [cracking or polymerization](#)<sup>6</sup>. During this process, extracted monomers are linked together through a series of complicated chemical processes, to become chains of self-repeating monomers, known as polymers.

Following polymerization, additional chemicals are added to give the polymers the specific qualities needed. For example, additives can make them more or less flexible or durable—they can even alter their color. Many of these additives include chemicals called phthalates or [plasticizers](#)<sup>7</sup>, such as [PFAS](#)<sup>8</sup> (Perfluoroalkyl and Polyfluoroalkyl Substances), which make plastics more flexible. Chemical compounds like [BPA](#)<sup>9</sup> (Bisphenol A), which make plastics more durable, are another common additive. BPA is classified as an Endocrine Disrupting Chemical (EDC). All of these substances have been linked to various sorts of [cancer](#)<sup>10</sup>.

Once these additives have been introduced, the resulting plastic is laid into specific [molds](#)<sup>11</sup> to make whatever the manufacturing industry wants to make—be it toys, packaging, furniture, clothing, utensils, or bibs.



## THE PLASTIC BOOM = A MICROPLASTIC MEGA BOOM

According to the **Plastic Health Map** created by the Minderoo Foundation, from 1961 to 1980 only 47 studies were conducted to assess the human health effects of plastics. Most of these studies examined **synthetic polymers** which had become inescapable in the average household. Brand name polymers such as Nylon, Teflon, and Mylar were virtually everywhere. The limited research focused on the impact polymers have on the skin as well as the digestive and immune systems. It has taken decades for scientific investigation to finally start trying to catch up with plastics production.

Global plastic production has [practically doubled in the last 20 years alone](#)<sup>12</sup>, and with this there has been an exponential increase in the amount of microplastics leached into the environment. Microplastics can now be found [everywhere on our planet](#)<sup>13</sup> and in turn, inside [the human body](#)<sup>14</sup> too.

We are almost certainly only just beginning to understand how potentially harmful plastics, microplastics, and the additives used to make them could be for human health, but it is likely [the demographic most impacted by plastics, microplastics, and their chemical additives could be babies and infants](#)<sup>15</sup>.



## BPA: A PLASTIC SNAPSHOT

So what do we really know about this ubiquitous substance commonly called plastic, [99% of which is derived from petroleum](#)<sup>16</sup> (be it oil, coal, or natural gas)? And what do we know about the health implications surrounding it? Increasingly, researchers are gathering more and more information about microplastics as well as the additive chemicals used to make plastics, but here is a snapshot of just one of the chemicals found in plastic that has raised serious alarm bells: [Bisphenol A \(BPA\)](#)<sup>17</sup>. [Bisphenol A \(BPA\) was invented over 120 years ago](#)<sup>18</sup> and is currently used in the manufacture of things like hard plastic water bottles and the lining of metal food cans.

Long-term studies, carried out over 20 years, have determined there is evidence of [BPA in nearly 93% of the US population](#)<sup>19</sup>. 2,517 urine samples from people six years and older were used to determine this. [The plastic industry](#)<sup>20</sup> claims the low levels of BPA used as industry norms right now are safe for use in food packaging. [The FDA has backed those claims](#)<sup>21</sup>, but they come with some carve outs.

In July 2012, BPA was [banned](#)<sup>22</sup> by the [FDA](#)<sup>23</sup> from use in baby bottles and sippy cups—ironically at the behest of the [American Chemical Council \(ACC\)](#)<sup>24</sup> who filed a food additive petition requesting the ban.

The American Chemical Council is just one organization that represents the plastic industry in the US:

*“The Plastics Division of the American Chemistry Council (ACC) represents leading manufacturers of plastics, as well as other companies throughout the entire plastics value chain and focuses on advocacy initiatives that promote sustainability and contribute to a more circular economy for plastics.”*

Ironically the ACC asked for the ban to reassure worried consumers that baby bottles and sippy cups were now ALL BPA free, after sections of the industry had begun to voluntarily limit the use of BPA in these key items. The ban was a way to reassure consumers that plastic baby bottles and sippy cups were safe.

In 2013, a citizen petition filed by then [Rep. Edward Markey \(D-MA\)](#)<sup>25</sup> also prompted the FDA to ban the use of BPA in infant formula packaging too.

In March 2023, the European Court of Justice decided the [European Chemicals Agency](#)<sup>26</sup> (ECHA) was right to identify BPA (Bisphenol A) as a substance of very high concern with regard to the environment<sup>27</sup>, due to its endocrine disrupting properties - but only after several failed appeals by the plastic industry in Europe. It is worth noting the use of BPA is more heavily [restricted in Austria, Belgium, Denmark, France and Sweden](#)<sup>28</sup>.

The regulation of plastics is complex, but the industry in the US employs [preemptive tactics](#)<sup>29</sup> to counter impending plastic restrictions or legislation at state and federal level, describing this as going on “the offensive.”

In 2021, the Canadian government formally [classified plastics](#)<sup>32</sup> as **toxic to wildlife** under the Canadian Environmental Protection Act with a detailed [assessment of plastic pollution to back their decision up](#)<sup>33</sup>, which means the Canadian government has increased powers over the manufacture and usage of plastics.

But the plastic producers are fighting back and this case is now in court. As of March 2023, there is still no final ruling and one is not expected for several more months.

*“Legislation and regulation threaten to fundamentally change our business model. We can’t continue to fight back just at the reactive stage when things are emotionally charged. We have to take the offensive.”*

~[William Carteaux](#)<sup>30</sup>

Society of the Plastics Industry’s then-president, talking to his industry peers in 2009 as reported by the [Milwaukee Journal Sentinel](#)<sup>31</sup>.





## 02

### WHY BABIES?

#### **MOUthing, CRAWLING & TEETHING**

**Why are babies and infants adversely impacted by exposure and ingestion of microplastics and additive chemicals? Well first off, they are obviously smaller than adults, so what may be a small dose for an adult is a much larger dose for them, consequently meaning bigger potential effects for a baby or a child.**

**Plus, babies and infants love to do many things adults don't. Two of them are chewing on inanimate objects and crawling on the ground! It is therefore harder for children and infants to avoid microplastics as both activities increase their chances of encountering them.**

Babies and infants rely heavily on taste to decode their world and that involves putting practically everything into their mouths. The mouth is full of sensory nerve endings that communicate directly with our brain. Chewing tells babies if the item they are mouthing is food or not, if it is hot or cold, sweet or sour, hard or soft, as well as lots of other information that babies seem to want. Typically this ‘tasting’ stage stops at around 3 years old<sup>1</sup>, but it means babies are essentially hardwired to chew on plastics.

***“High concentrations of microplastics in the feces of one-year-old infants can be attributed to extensive use of plastic products/articles such as baby feeding bottles, sippy cups, utensils such as spoons and bowls, plastic teethingers, and toys, among others, during that growth stage.”***

***~Kurunthachalam Kannan<sup>2</sup>  
PhD, Department of Pediatrics  
NYU Grossman School of Medicine***



***“If you really look at a 1-year-old baby’s lifestyle, they use lots of plastic materials, such as toys. They put everything in their mouths. Toys are one of the most important sources of microplastic exposure,”***

***~Kurunthachalam Kannan<sup>3</sup>  
PhD, Department of Pediatrics  
NYU Grossman School of Medicine***



Babies and small children, from the age of 6 months typically until a year old, also spend a great deal of time crawling on the ground as they explore their world and embrace mobility. Which means coming into contact with household dust, some of which consists of microplastics. This is probably why the level of microplastics found in the feces of babies, as reported by a small study from 2021 by the NYU Grossman School of Medicine, appeared to be over 10 times higher<sup>4</sup> than that found in adults.

Therefore, in a world where so much of everything around us is made of plastic, or coated in plastics, children by their very nature, partially dictated by the stages of their development, appear to be ingesting microplastics and their additive chemicals at rates higher than the average adult.

Plastic baby bottles [account for 80%](#)<sup>5</sup> of all baby bottles around the world, the vast majority of which are made of a plastic called polypropylene. A widely reported research paper published by [Nature Food](#)<sup>6</sup> found using this type of plastic bottle releases microplastics directly into the liquid in the baby’s bottle. Scientists from Trinity College, Dublin in Ireland published the [study](#)<sup>7</sup> in October 2020, and their findings were shocking to many in the science community.

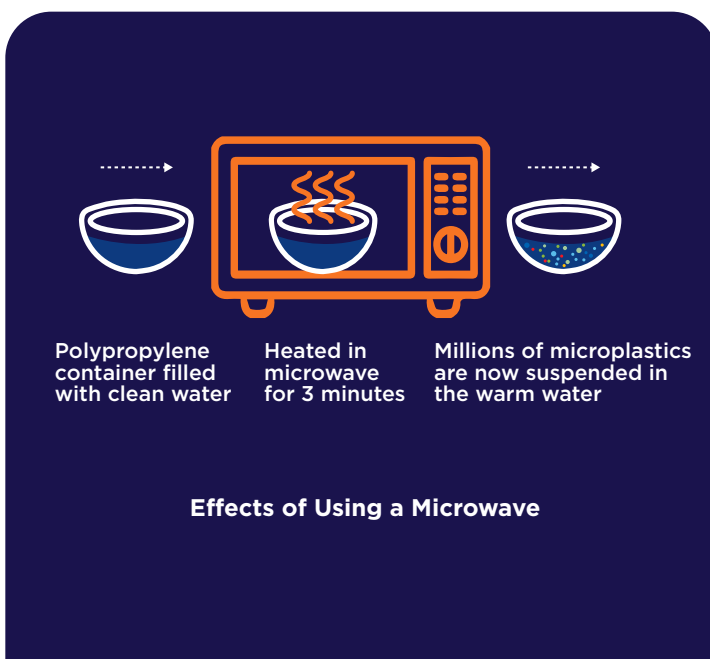
They estimated infants could ingest up to 4.5 million plastic particles per day when fed from polypropylene baby bottles. For 21 days the authors recorded as microplastic release rates from the plastic bottles fluctuated from just a few thousand to as many as 16.2 million particles per liter into the water inside the bottles. Extrapolating from bottle-feeding rates from 48 different regions, they determined infants up to a year old, fed using polypropylene bottles, may be exposed to a range of microplastics from [14,600 to 4.55 million particles](#)<sup>8</sup> per infant per day.

Similar research needs to be carried out on plastic sippy cups, bibs, utensils, and feeding bowls—all items which babies and infants use to consume food and drink from. What levels of microplastics are leaching into their food from these items? And what levels of microplastics are they ingesting from them via sucking and chewing on them too? It’s important to note teething can intensify periods of this biting and chewing on inanimate objects as well.

Even using a microwave to heat up children’s food in plastic containers, specifically made of polypropylene, and reusable food pouches made with polyethylene, can increase their exposure to microplastics.

A [study from a team of researchers at the University of Nebraska-Lincoln](#)<sup>9</sup> published in June, 2023, in the journal *Environmental Science & Technology*, indicated microwave heating caused the highest release of microplastics and nanoplastics to leach into food compared to other usage scenarios, like refrigeration or storing food at room temperature. It was found that some containers could release [more than 4 million microplastics](#)<sup>10</sup> and 2.11 billion nanoplastic particles from only one square centimeter of plastic area within 3 minutes of microwave heating. The Nebraska team reported three-quarters of cultured, human embryonic kidney cells died at 1000 µg/mL concentration after exposure for 48 hours.

While the specific health impacts of this exposure to high levels of microplastics are still largely unknown, these results demand attention and further research.





## BREAST MILK

In 2022, a pilot study [detected microplastics in dairy milk](#)<sup>11</sup>.

They tested 25 milk samples, from supermarket cartons, from milk tanks on farms, and from hand-milking. They found microplastics in eighteen of the samples, including at least one of each type.

In October 2022, [researchers in Italy](#)<sup>12</sup> reported in the journal *Polymers* they had detected microplastic in human breast milk for the first time. Samples were taken from 34 healthy mothers, a week after giving birth in Rome. The scientists detected microplastics in 75 percent of them. The authors of the report concluded:

*“In fact, the chemicals possibly contained in foods, beverages, and personal care products consumed by breastfeeding mothers may be transferred to the offspring, potentially exerting a toxic effect.”*

In a subsequent study from [2023](#), [published in Environmental Pollution](#)<sup>13</sup>, a team of researchers from China analyzed the quantity, size, and composition of microplastics released into the disposable storage bags used for expressed breast milk. They reported finding microplastics, most commonly polyethylene (PE), [polyethylene terephthalate](#)<sup>14</sup> (PET), and nylon-6. This equates to between 0.61–0.89 mg/day of microplastics in the average daily breastmilk intake by infants drinking breast milk stored this way.





## TOYS

Plus, most baby and children’s toys (unless sustainability sourced) will nearly always contain a component of plastic. Some reports claim [90%](#)<sup>15</sup> of the toy market is made of plastic. [Two components commonly used](#)<sup>16</sup> are Polyvinyl chloride (PVC) and Bisphenol A (BPA). [Vinyl chloride \(VC\)](#), which is used to make PVC, is a [known animal and human carcinogen](#)<sup>17</sup>, and could potentially leach out of plastic toys made with PVC when they are chewed. BPA is used to make plastics more durable. But as stated earlier in this primer, [BPA is a known endocrine disruptor](#)<sup>18</sup> that can interfere with the body’s hormone system, creating high levels of estrogen.

In [2017](#), the [U.S. Consumer Product Safety Commission \(CPSC\)](#)<sup>19</sup> voted to prohibit children’s toys and child care articles containing more than 0.1 percent of certain phthalate chemicals used in the production of plastics. In total, they have now restricted 8 phthalates to these levels. PVC and BPA are not banned.

[The Toy Association](#)<sup>20</sup> represents much of the toy industry in the US. Their manufacturing members account for 93% of the US toy and game market, which as of 2022 in its entirety, is worth \$40 billion. In September 2023, they made their position clear:

*“No federal or state jurisdiction has restricted the use of BPA in toys.”*

## BABY CLOTHES

Today, [69%](#)<sup>21</sup> of the fabrics we wear are made of oil-based plastics: polyester's chemical name is polyethylene terephthalate, acrylics are polyurethane, nylon is polyhexamethylene adipamide, and spandex is a polyether-polyurea copolymer.

These synthetic materials create textiles that don't need to be ironed, dry quickly, and are water resistant—qualities parents often like in baby clothes. As well as some qualities they don't like—some synthetics don't “breathe” as well as natural materials and they can trap moisture. But all of these synthetic fabrics break down into potentially harmful microplastics and microfibres. It is not just clothes either—bedding, furniture, cots and mattresses can also contain the same synthetic material. All of them generating more microplastics and microfibres.

Every time we wash our clothes and bedding, thousands of these tiny particles (5 mm or less in length) are discharged into the water. Globally, 500,000 tons of these microfibers are deposited in oceans every year from our washing machines. Of the [171 trillion microplastics](#)<sup>22</sup> floating in oceans, the microfibers from clothing are responsible for [35%](#)<sup>23</sup>.

Research is needed to determine the health implications of babies and children inhaling or ingesting these microfibres but already animal

studies are showing that they can accumulate in living organisms. These fibers have been found to impact marine life affecting [feeding and growth](#)<sup>24</sup>, [causing genetic damage](#)<sup>25</sup>, [oxidative stress](#)<sup>26</sup>, [impacts on behavior](#)<sup>27</sup>, [fertility and reproduction and mortality](#)<sup>28</sup>.

Added to the dilemma are the toxic chemicals microfibers are coated with—the azo dyes and the formulations to make clothes wrinkle-free, stain-resistant, and water repellent such as toxic fluorinated compounds (PFCs), [PFAS](#)<sup>29</sup>, PBPA, and phthalates.

[Research commissioned](#)<sup>30</sup> at an independent laboratory, to test for PFAS in baby and children's textile products, found fluorine, a reliable indicator of the likely presence of PFAS, in all 34 samples. PFAS have been [linked to a range of health issues from cancer to immune suppression](#)<sup>31</sup>.

The Department of Epidemiology at Brown University worked with colleagues to analyze 16 studies looking at the side effects of phthalates and found evidence that [exposure to them during pregnancy can increase the risk of preterm birth by 12-16%](#)<sup>32</sup>. Preterm refers to delivery before 37 weeks.



*“Ideally, governments would develop and enforce regulations to reduce exposure to these harmful substances. It is unreasonable to assume that individual consumers can avoid these substances and manufacturers often take the path of least resistance when it comes to self-policing.”*

~ [Dr. Joseph M. Braun, Ph. D.<sup>33</sup>](#),  
Associate Professor, Department of  
Epidemiology at Brown University,  
as quoted in [Parents<sup>34</sup>](#), August 2023

## PLAYGROUNDS

It’s not just items inside the home that are cause for concern. Playgrounds need to be further investigated as well. [One recent study<sup>35</sup>](#) found playgrounds could contain more microplastics than other areas inside an urban park. Microplastic concentrations inside the playgrounds were [on average 5 times greater<sup>36</sup>](#) than concentrations outside the playgrounds, indicating children playing within the playground may be exposed to more microplastics than children playing outside the playground in the same park.

Styrene butadiene rubber (SBR), often referred to as [crumb rubber<sup>37</sup>](#), is often obtained from [scrap tires<sup>38</sup>](#) and employed in the construction of all kinds of facilities for sports, playing fields, indoor and outdoor play areas, parks, and other recreational facilities. It is frequently used to create the bouncy surface of children’s playgrounds.



But crumb rubber is believed to have the potential to release a range of chemicals and microplastic particles into the environment, according to [three reports<sup>39</sup>](#) from 2007, 2010, and 2016, by the California Office of Environmental Health Hazard Assessment (OEHHA). A [2017 study by The Open University of the Netherlands<sup>40</sup>](#) published in the International Journal of Environmental Research and Public Health, estimated tires accounted for as much as 10 percent of overall microplastic waste in the world’s oceans. A [2017 report by the International Union for Conservation of Nature<sup>41</sup>](#) begged to differ and reported tires accounted for 28 percent of overall microplastic waste in the ocean.

In 2019, [the Environmental Protection Agency \(EPA\)<sup>42</sup>](#) in the US determined there was no increased risk from playing on fields made with crumb rubber, but they acknowledged important data gaps exist and called for more research.

In September 2023, [the European Commission took measures<sup>43</sup>](#) to restrict microplastics intentionally added to products. This will include the use of scrap tires (or crumb rubber) in sport fields and playgrounds.

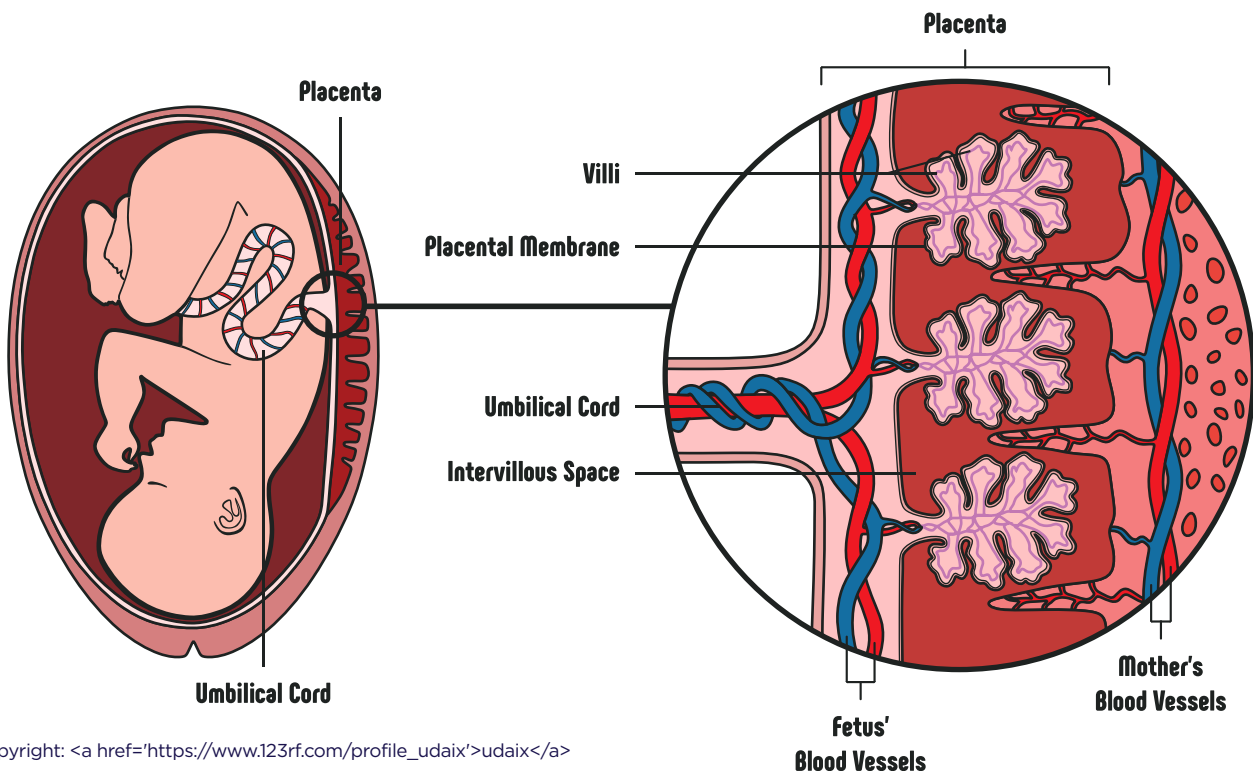


## MISCARRIAGE

Perhaps even more concerning, exposure to microplastics and their related chemical additives begins even *before* birth.

A [study](#)<sup>44</sup> published by *Fertility and Sterility* measured the levels of BPA in 114 pregnant women in an effort to determine the relationship between

BPA and miscarriage. They concluded that the median level of BPA among women who miscarried was higher than that among women with live births. In particular, women with the highest measured levels of BPA were **83% more likely** than women with the lowest levels to miscarry in the first trimester, even when controlling for such identity markers as BMI and age.



## MICROPLASTICS IN THE PLACENTA

Newer research has found **microplastics inside the placenta itself**. In 2022, a research team from China using [laser direct infrared spectroscopy](#)<sup>45</sup> identified microplastics [inside of the placenta](#)<sup>46</sup>. The study identified two types of microplastics as the polymers polyvinyl chloride and polypropylene. These two polymers are known to induce potential health hazards, such as oxidative stress, reproductive system dysfunction, carcinogenesis, and immune system dysfunction.

This study from China came after a team in Italy, in 2020, investigated six human placentas collected (from six participating women) and in this case the team used [Raman Microspectroscopy](#)<sup>47</sup> to evaluate the presence of microplastics.

[Italian researchers](#)<sup>48</sup> found 12 microplastic fragments (ranging from 5 to 10  $\mu\text{m}$  in size) with spherical or irregular shapes in 4 placentas (5 in the fetal side, 4 in the maternal side, and 3 in the chorioamniotic membranes). All of them were described as pigmented; three were identified as stained polypropylene, a thermoplastic polymer, while for the other nine it was possible to identify only the pigments, which were all used for man-made coatings, paints, adhesives, plasters, finger paints, polymers, cosmetics, and personal care products.

The placenta allows a fetus to receive oxygen and nutrients from its mother, and also eliminates waste products from the baby's blood. All these actions are normal and necessary to allow a fetus to reach full term. But microplastics accumulating within the placenta [can interrupt communication between maternal and fetal environment](#)<sup>49</sup>, leading to birth defects. These birth defects can come from the development of [preeclampsia](#)<sup>50</sup>, which is the elevation of blood pressure for a pregnant person, which in turn can stress the heart and affect blood flow into the placenta. This means fetal development may be restricted due to a lack of necessary nutrients flowing into the placenta.

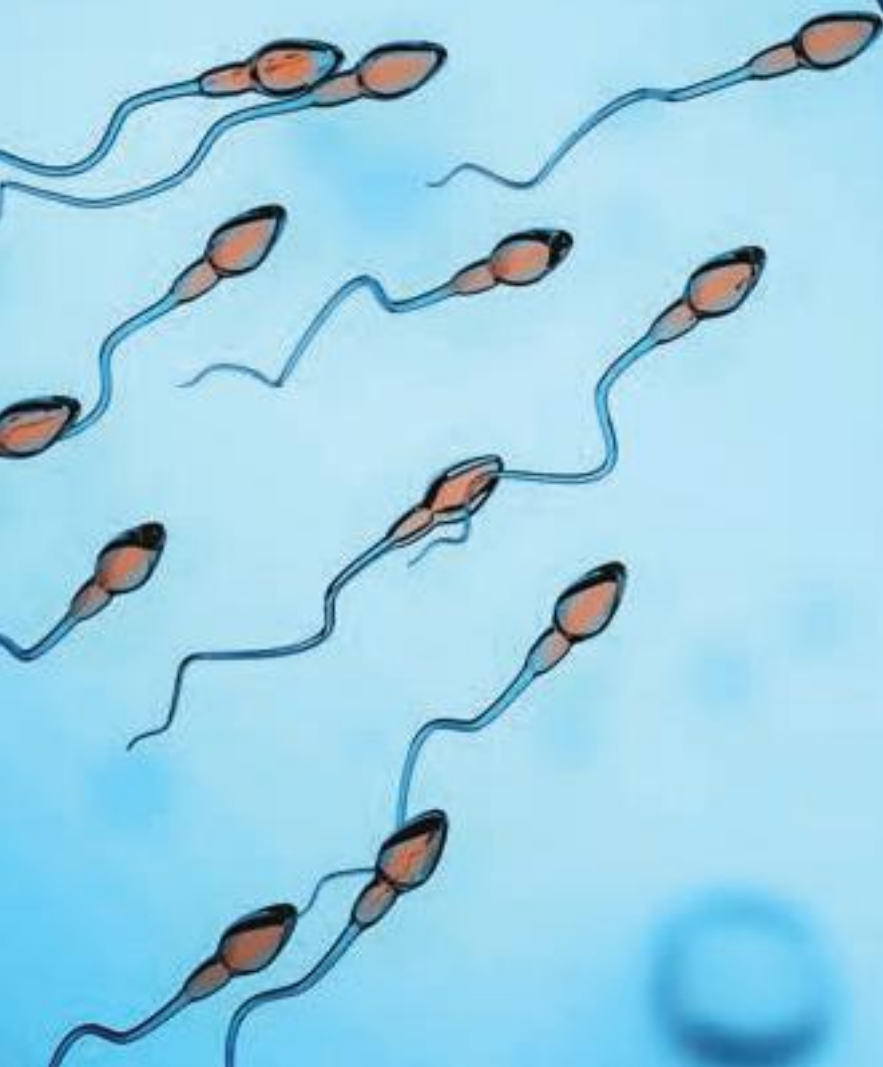
The introduction of microplastics into the placenta could [introduce Endocrine-Disrupting Chemicals to the fetus](#)<sup>51</sup> before they have even been born and experienced a breath of atmospheric air, a sip of water, or a taste of solid food on their own. The endocrine system governs our hormones, which is critical to human development and health, especially at the fetal stage.



## PLASTICS & MALE FERTILITY

It is worth noting there is evidence plastics appear to be contributing to a decrease in male fertility<sup>52</sup>. Researchers have begun to connect plastics, specifically polystyrene microplastics, with decreased sperm motility and concentration. Without ample ability to move, sperm effectiveness and fertility of the male will drop<sup>53</sup>.

Another study looked into sea urchin fertility and discovered how detrimental plastics were to the larvae of these creatures<sup>54</sup>. Other studies point out the same findings with fish larvae<sup>55</sup> and crustaceans<sup>56</sup>.





## 03

### BIOACCUMULATION

**Increasingly animal and human testing is discovering microplastics can accumulate in specific organs of the mammalian body. Microplastics can work their way into the hearts, lungs, and brains of mice and “men”—are they doing the same to babies too?**

**Here’s what we know: a mixture of animal and human testing has found microplastics in the urinary system<sup>1</sup>, digestive system<sup>2</sup>, blood<sup>3</sup>, heart<sup>4</sup>, lungs<sup>5</sup>, brain<sup>6</sup>, other major organs and in our feces<sup>7</sup>. Microplastic exposure could be affecting many of the major organ systems<sup>8</sup> in a developing child.**



## GASTROINTESTINAL & DIGESTIVE SYSTEMS

Scientists used to believe microplastics, if ingested, would benignly pass through the gastrointestinal tract. However, [recent research](#)<sup>9</sup> suggests that the smallest pieces of plastic are able to bioaccumulate in various parts of the body, including the gut. Bioaccumulation takes place when a body takes in microplastics faster than it can dispose of them. Once bioaccumulation occurs, microplastics have been shown to cross cell membranes, [such as the blood-brain barrier \(BBB\)](#)<sup>10</sup>. To make matters worse, concentrations appear to be higher for infants than in adults.

The previously referenced NYU Grossman School of Medicine discovered that infants may have over [10 times more](#)<sup>11</sup> microplastics in their feces than adults - in particular, PET (polyethylene terephthalate) microplastic, which is commonly used in the production of textile fibers and water bottles. The research was published in the [Environmental Science and Technology Letters](#)<sup>12</sup> of the [American Chemical Society \(ACS\)](#)<sup>13</sup> (not to be confused with the plastic industry's lobbying group—the American Chemical Council (ACC)).

Microplastics have been found in children's urine as well. A 2020 study in Germany detected some of the plasticizers associated with plastics in [97-100%](#)<sup>14</sup> of morning urine samples tested. These tests were performed

on children aged 3 to 17 and a total of 8 different plasticizers or phthalates were detected.

A [study from 2023](#)<sup>15</sup>, published in *Environmental International*, discovered that polystyrene nanoplastics, particles of plastic even smaller than microplastics, can cross the embryonic gut wall of chicks. Their research reported that nanoplastics cause severe defects in the heart and great vessels, and they discovered that the nanoplastics were able to bind to specific cells. According to these scientists, this was the first evidence of nanoplastics disrupting the migration and survival of an embryonic population of [stem cells](#)<sup>16</sup>. Nanoplastics, therefore, may pose a health risk to the developing embryo.

Stem cells are the body's raw materials—they are the cells from which all other cells with specialized functions are generated. Stem cells become blood cells, brain cells, bone and heart muscle cells, and so on. No other cell in the body has this natural ability to generate new cell types, only the stem cell. So anything interfering with their survival is potentially very serious, especially in these early stages of embryonic development.



## BLOOD

In 2022, researchers from [Vrije Universiteit Amsterdam](#) and the [Amsterdam University Medical Center](#)<sup>17</sup> analyzed 22 blood samples from healthy, anonymous living blood donors for traces of common synthetic polymers and microplastics larger than 700 nanometers. [They discovered evidence of several plastics in the blood across 17 of the 22 samples](#)<sup>18</sup>.

The microplastics detected included [polyethylene terephthalate \(PET\)](#)<sup>19</sup>—often used in clothing and drinking bottles—and polymers of [styrene](#)<sup>20</sup>, which is frequently used in vehicle parts, carpets, and food containers. This research was the first to find microplastics can get into the human bloodstream itself. This is key because if microplastics can enter our bloodstream, they can potentially reach, and even accumulate, in any organ in the body.

Perhaps not surprisingly given that microplastics have been detected in the blood, researchers in a [small pilot study](#)<sup>22</sup> reported in Environmental Science & Technology found microplastics in heart tissue samples of patients undergoing heart surgery.



***“It is certainly reasonable to be concerned. The particles are there and are transported throughout the body.”***

***~Study author Dick Vethaak<sup>21</sup>,  
Ecotoxicologist at Vrije Universiteit  
Amsterdam***

*“We did not expect to find the highest number of particles in the lower regions of the lungs, or particles of the sizes we found. This is surprising as the airways are smaller in the lower parts of the lungs, and we would have expected particles of these sizes to be filtered out or trapped before getting this deep into the lungs.”*

~Dr Laura Sadofsky  
Author of the study, senior lecturer in respiratory medicine at Hull York Medical School



## LUNGS

Our lungs not only move oxygen into the body and carbon dioxide out of it, but they also act as gatekeepers: essentially, they are our filters. Mucus in our lungs catches and holds dust, germs, and other foreign bodies that have entered the lungs. There is growing evidence that our lungs are breathing in plastic particles floating in the air.

A study<sup>23</sup> conducted by researchers at the University of Hull and Hull York Medical School looked for the presence of microplastics in human lung tissue obtained following lung reduction surgery<sup>24</sup> or lung cancer<sup>25</sup> surgery. They discovered microplastics in every region of the lung<sup>26</sup>, finding 39 microplastics in 11 out of the 13 lung tissue samples.

As plastic production and usage rises, it is likely the levels of atmospheric microplastics will rise too. A research study in 2020<sup>27</sup> found that **breathing the air inside buildings exposes us to much higher levels of microplastics than breathing air outside.**

The effects of these bioaccumulations of microparticles in the lungs are new and they are currently understudied, but given that we know plastic particles can include chemicals like BPA and PFAS, which are linked directly to various cancers, these results are concerning.

## BRAIN


Our brain is our chief operating system and the most complex organ in our body. Yet the study of how microplastics might affect the brain is relatively new. So, what DO we know about how microplastics and the additive chemicals used to make plastics impact our most precious organ: the [brain](#)<sup>28</sup>?

A 2023 University of Rhode Island [study](#)<sup>29</sup> published in the *International Journal of Molecular Science* found that acute exposure to microplastics in mice resulted in accumulation of small plastic particles in every tissue

they examined, including deep in the brain tissue. The study reported that small doses of pristine polystyrene microplastics fed via water orally to mice over a period of three weeks, caused behaviors similar to dementia.

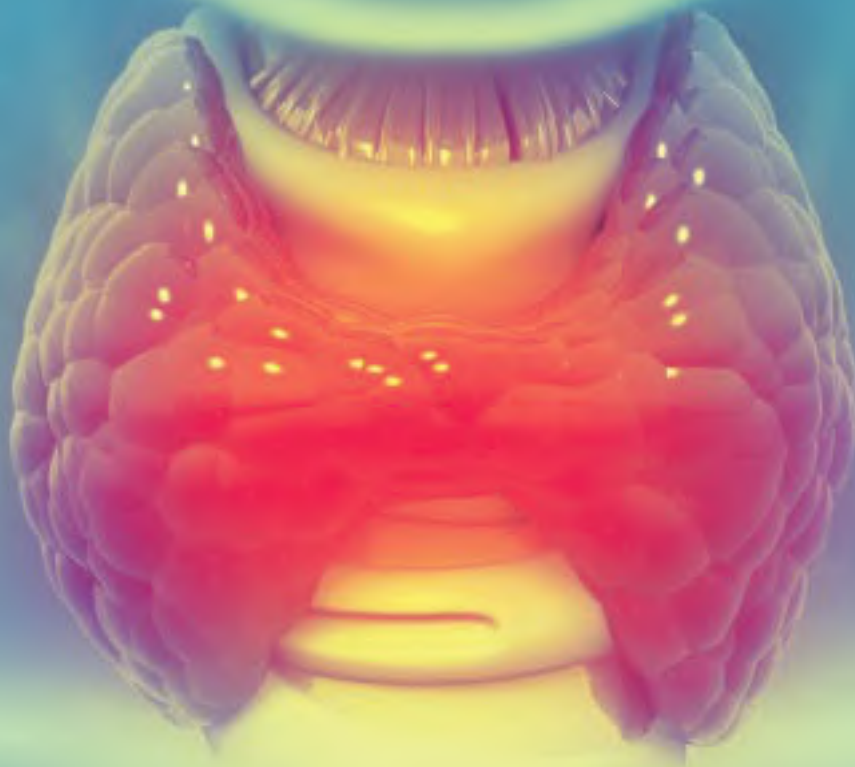
Separate research has also determined that [the blood-brain barrier \(BBB\)](#)<sup>30</sup> can be breached by nanoplastics in mice, which can then in turn **“trigger the activation of microglia, and lead to damage of neurons.”** Other studies have linked damage to neurons (not specifically microplastics) caused by the activation of microglia, to [Parkinson’s](#)<sup>31</sup>.





*“In the brain, plastic particles could increase the risk of inflammation, neurological disorders or even neurodegenerative diseases such as Alzheimer’s or Parkinson’s”*

*~Lukas Kenner,  
A researcher at the Medical University  
of Vienna in Austria, as reported to  
Sustainability Times, April 2023*



# 04

## HEALTH RISKS

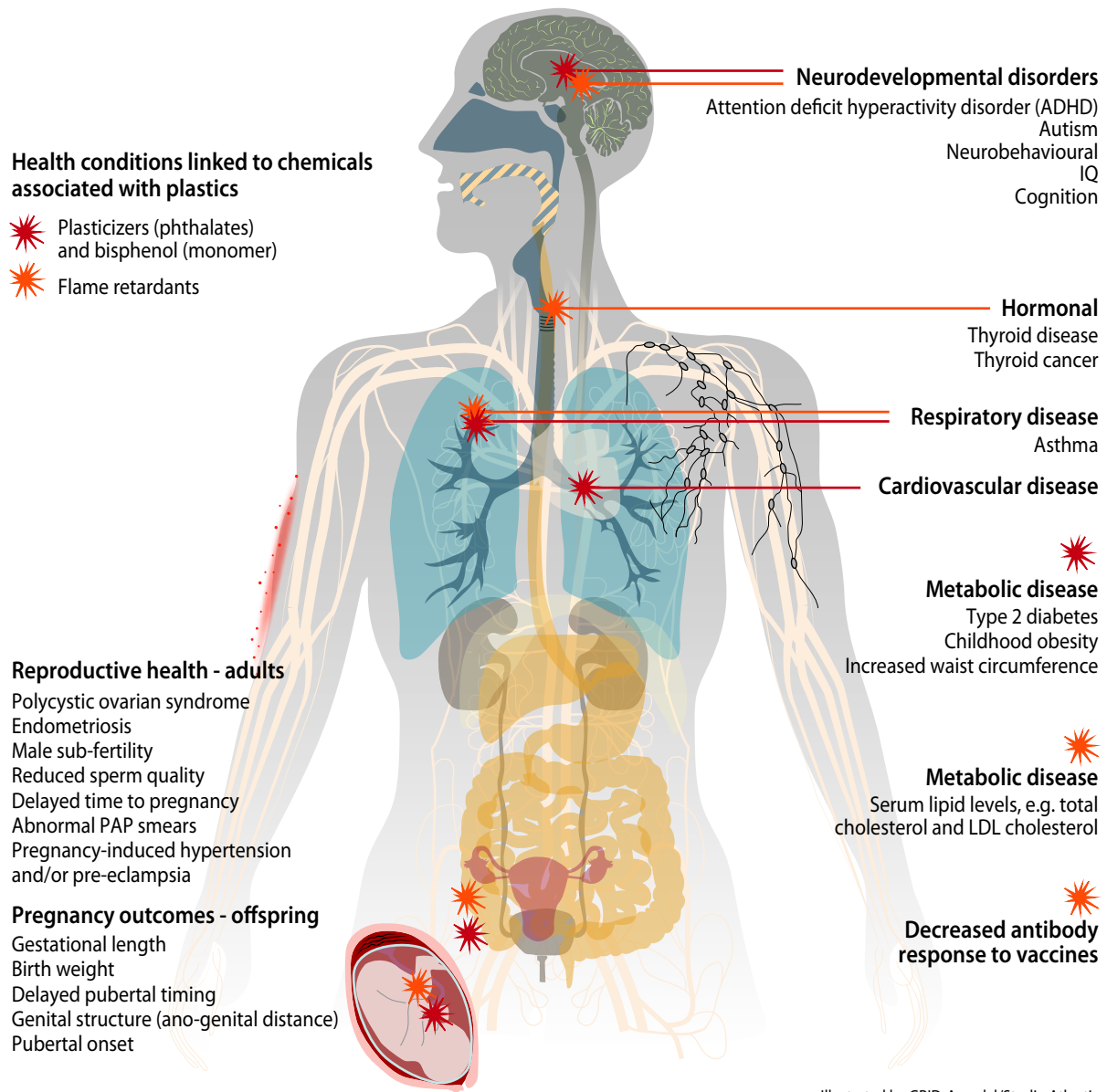
### THE ENDOCRINE SYSTEM

The **endocrine system**<sup>1</sup> describes a series of interconnected glands and organs working together within your body to manage metabolism, reproduction, development, and mood—essentially they ensure your body is working properly. Microplastics often contain what are called **Endocrine-Disrupting Chemicals**<sup>2</sup> (EDCs), which disrupt or imitate hormones within our bodies and can be linked to a large array of health issues.

Diseases related to endocrine disruptors<sup>3</sup> and our hormone system include Autism Spectrum Disorder (ASD)<sup>4</sup>, attention deficit hyperactivity disorder<sup>5</sup>, obesity, Type 2 diabetes<sup>6</sup>, infertility<sup>7</sup>, and cancers sensitive to hormone changes<sup>8</sup>. Many of the additive chemicals used in the production of plastic are considered endocrine disruptors, such as BPA<sup>9</sup>. Nearly all of us are being exposed to varying amounts of microplastic, but children, due to their natural

exploratory behaviors, encounter them the most. As cited earlier in this report, their tendency to put inanimate objects, often plastics, into their mouth and their desire to crawl on the ground for long periods of time (as they learn to become mobile and eventually walk) are important factors in their elevated exposure and ingestion of micro particles. Below are just some of the specific health and behavioral implications of this exposure.

### Human health impacts of exposure to plastic-associated chemicals



Illustrated by GRID-Arendal/Studio Atlantis

United Nations Environment Programme (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.

## AUTISM

Researchers are seeing an [uptick](#)<sup>10</sup> in Autism Spectrum Disorder (ASD) around the world over the last decade. The Center for Disease Control and Prevention (CDCP), America's leading public health, science-based, data-driven, organization, found an increase in the prevalence of autism among children.

In one CDCP report from 2023, focused on [8-year-olds](#)<sup>11</sup>, they found 1 out of every 36 children of this age group had autism. A significant increase from the 2021 figures which estimated [1 in 44](#)<sup>12</sup> children had autism, which was a large leap from the numbers estimated in 2006, reporting that [1 in 110](#)<sup>13</sup> in children had autism. Of course, better testing and diagnosis for autism allows for a large part of this significant leap in numbers, but there also appears to be a [potential link between certain plastics such as polyethylene and ASD-like traits in mice](#)<sup>14</sup>.

Plastics were found to be accumulating in the brains of the mice, leading to metabolism and gene expression issues. These same plastics were also found to be accumulating in the [microbiomes](#)<sup>15</sup> of tested mice. Microbiomes refers to the microbes, like bacteria, fungi, viruses, and their genes, that naturally live on or inside our bodies. The linkage between microbiome health and symptoms of ASD [has been studied](#)<sup>16</sup> and there does appear to be a connection. But ASD is not the only way in which plastics might be affecting development in children and babies.

## LEARNING DIFFICULTIES & ADHD

The endocrine disruption can lead to other neurological complications especially in developing children and fetuses, this includes hyperactivity and attention issues. Plasticizers such as BPA and PFAS have been linked to [decrease in memory and learning issues](#)<sup>17</sup> because of their effect on the [central nervous system](#)<sup>18</sup>.

While the research is new and understudied it is leading some researchers to believe this may be a cause in the [uptick of attention deficit hyperactivity disorder](#)<sup>19</sup> (ADHD). Constant exposure to these plastics and the chemicals within seem to have harsh effects on [children's ability and ease of learning](#)<sup>20</sup>, and in some European countries there is an outcry for more research and studies to be conducted.

Other researchers are showing a [larger amount of BPA and phthalate](#)<sup>21</sup> in children with ADHD compared to those who do not. Further evidence there is at least a correlation between plastics and the attention issues affecting children today.





## CANCERS

Pediatric cancer rates have increased<sup>22</sup> at the same time as those of plastic production. While correlation in these two trends does not prove causation there are studies that have linked phthalates to childhood cancers. Phthalates are the synthetic chemicals which make plastics flexible.

A University of Vermont Cancer Centre study<sup>23</sup> found childhood phthalate exposure was associated with osteosarcoma and lymphoma before the age of 19 years. Phthalates are the chemical additives used to make some plastics more durable, but they are also used as inactive ingredients in some medications, such as anti-inflammatory drugs and antibiotics - often to create the capsules for medication.



The team from Vermont worked with a team in Denmark<sup>24</sup> which allowed them to utilize data from the Danish Medical Birth Registry, the Danish Medicines Agency, and the Danish Cancer Registry. Altogether, this data accounted for all live births in Denmark between 1997 and 2017. This totaled nearly 1.3 million children. In a 2022 article from the University of Vermont's Larner College of Medicine, Katherine Strotmeyer summarizes the study's findings<sup>25</sup> as follows:

*“Among the 2,027 cases of childhood cancer, researchers measured associations between gestational and childhood phthalate exposure and the incidence of specific cancers. Childhood, but not gestational (in utero) phthalate exposure was associated with 20% higher rate of childhood cancer overall, with a nearly three-fold higher rate of osteosarcoma diagnosis, a bone cancer, and a two-fold higher rate of lymphoma diagnosis, cancer of the blood.”*

Researchers have also linked microplastics to the degradation of DNA within lymphocytes<sup>26</sup>, which could be related to cancer risk. Lymphocytes are a key member of your body's immune system<sup>27</sup>. They take out cells that have been damaged or attacked by outside invaders such as bacteria or viruses. While microplastics are not actively destroying the cells or their ability to reproduce, they are affecting the genes and genomic expression of them. This type of research specifically on lymphocytes is novel and suggests a possible correlation between microplastics bioaccumulation and cancer risk.

Risks of prostate cancer in men also have a link to plastic and the chemicals used throughout. Researchers have found that those exposed to BPA early in life have an [increased risk of prostate cancer as they age](#)<sup>28</sup>. The study also suggested that BPA was found in all of their [study population](#)<sup>29</sup>. Prostate cancer is the [most common cancer type](#)<sup>30</sup> in men and the connection to plastic and additives is frightening.

Other studies have linked different cell types and [genome degradation in skin cells](#)<sup>31</sup> similar to what has been seen in lymphocytes, which amounts to further evidence that microplastics may be contributing to cancer rates around the world. Moreover, the *Minderoo-Monaco Commission on Plastics and Human Health* has [linked the production of plastic to increased cancer rates](#)<sup>32</sup>, especially in the marginalized communities where plastic production plants are often located.



*“While there remain gaps in knowledge about plastics’ harms and uncertainties about their full magnitude, the evidence available today demonstrates unequivocally that these impacts are great and that they will increase in severity in the absence of urgent and effective intervention at global scale. Manufacture and use of essential plastics may continue. However, reckless increases in plastic production, and especially increases in the manufacture of an ever-increasing array of unnecessary single-use plastic products, need to be curbed. Global intervention against the plastic crisis is needed now because the costs of failure to act will be immense.”*

*-Last paragraph of the Summary of the Minderoo-Monaco Commission on Plastics and Human Health*

Given these findings alone—where there is evidence that plastics and the additive chemicals used to make them are associated with a range of recognized health risks—should we be practicing the [precautionary principle](#)<sup>33</sup>?

*“There is no other industry on the planet allowed to cause as much harm, on the scale, of the fossil fuel companies. First climate change and now the plastic health epidemic. It’s time to wake up to a morally bankrupt industry that puts profits above people every single time.”*

*-Kathleen Rogers  
President, EARTHDAY.ORG*



# 05

## HOW DO WE SOLVE A PROBLEM LIKE MICROPLASTICS?

### UPSTREAM ISSUES

**We need to take drastic action to reduce the exposure of everyone, especially babies and infants, to microplastics and all of their associated additive chemicals. Aside from the personal consequences there's also the cost to society as a whole.**

A [2022, NYU Grossman School of Medicine](#)<sup>1</sup> study sampled nearly 5,000 Americans and identified 13 medical conditions that may be linked to [PFAS](#)<sup>2</sup> (per- and polyfluoroalkyl substances) such as infertility, diabetes, and endometriosis. They calculated the [economic burden to Americans was a minimum of \\$5.5 billion and as high as \\$63 billion annually](#)<sup>3</sup>. Medical bills and loss of productivity (due to illness) were both factored in. PFAS are chemicals frequently used in plastic products, like food containers.

As previously stated, there's a real cost to the environment too. [United Nations Environment Programme](#)<sup>4</sup> calculated as far back as 2014 that plastic waste causes \$13 billion US dollars worth of damage to marine ecosystems alone, every single year.

Andrew Morlet, CEO of the Ellen MacArthur Foundation claims that to clean up the plastic and environmental problems in the world's oceans would cost [\\$150 billion](#)<sup>5</sup>.

To diminish the volume of microplastics, it is best to address the problem at its source, upstream, and to take action to drastically limit the production of plastic worldwide. While effective waste management, recycling, and monitoring are all part of the downstream process and hugely important, without focused upstream action, plastics and microplastics will continue to flood our environment, our homes, and our bodies. Which is why EARTHDAY.ORG is calling for a [60% reduction in plastic production by 2040](#)<sup>6</sup>.

## Where Does Plastic Come From? Plastic Item Exports by Country in 2018



Note: Only displaying countries with >\$10M in plastic item exports.  
Article & Sources:  
<https://howmuch.net/articles/plastic-trade-around-the-world>  
International Trade Center (TradeMap) - <http://trademap.org>

howmuch.net

Worldwide Producers of Plastic by Country

## POTENTIAL UPSTREAM SOLUTIONS

Human beings have an innate ability to solve problems and, when we want to, achieve extraordinary things. We have landed on the Moon, created all manner of medical advances, mapped our own genome, and invented the World Wide Web.

We can find alternatives, sustainable and biodegradable, to plastics. In the end, science and industry will have to come together to do this, even if they are not motivated by altruism, but profit. Whoever can devise a “new” plastic that does not shed microplastics, needs no poisonous additive chemicals, and truly is recyclable or easily degradable, will dominate manufacturing and reap incalculable rewards.

There are already early signs of potential solutions. One such class of biopolymers are [polyhydroxyalkanoates](#)

(PHAs)<sup>7</sup>, which mimic the functionalities of many of the top-selling plastics of petrochemical origin. They are still in the early stages of development and we cannot be sure if they will eventually come to fruition, but it offers us hope solutions are out there.

[Some mycelium-composite materials](#)<sup>8</sup>, grown on a mixture of sawdust-wheat bran, are showing signs of developing hydrophobic qualities making them potential biodegradable candidates for a new type of plastic-free food packaging.

The jury is still out on whether [mycelium](#)<sup>9</sup> is the supermaterial of the future [that will one day replace plastics](#)<sup>10</sup>, but there are companies all over the world investing in and researching it, determined to prove its potential. Governments should be aligning with them and funding this research as part of their efforts to counteract plastic pollution and microplastic related health issues.



## DOWNSTREAM ISSUES

While the long term solution is to produce drastically less plastic, we still have to deal with the plastics downstream—i.e. once we have discarded them. The “dream” of recycling is not the answer. The undeniable fact is that in the past 40 years, we have recycled less than 10%.

Consumers are currently being fed false promises that recycling will solve our plastic problem. Globally, a mere 9% of plastic waste<sup>11</sup> is actually recycled, and in the United States, it is only 5%<sup>12</sup>—a stark contrast to the 68%<sup>13</sup> recycling rate for paper. Why? Because plastic is cheap to make and the industry has convinced the consumer that plastic is infinitely recyclable, and that mass-scale recycling is being done. The truth, however, is this: not all plastic is recyclable, and it’s largely going un-recycled globally.



Many of us are familiar with the triangle formation found on a plethora of plastic products. This formation surrounds what are called resin identification codes<sup>14</sup> (RICs), which range from 1 to 7<sup>15</sup> and serve to identify both what type of plastic is present and how/where it can be disposed of.



represents polyethylene terephthalate (PET), often used in plastic bottles.



signifies high-density polyethylene (HDPE), found in such products as milk jugs and yogurt containers.



stands for polyvinyl chloride (PVC) and makes up things like detergent bottles and clear food packaging.



low-density polyethylene (LDPE), constitutes many of the grocery bags at your local supermarket.



is polypropylene, the plastic behind most take out containers and cutlery.



polystyrene (PS), comprises disposable plates and cups.



denotes “Other,” which acts as a catch-all for acrylic, nylon, fiberglass, and the like.

Consumers may assume that a plastic marked with one of the resin identification codes above will ultimately be recycled. Unfortunately, this is far from the truth. Although RICs #1–6 are all technically recyclable, **trucks only routinely collect Plastics #1 and #2 in curbside recycling bins across the United States.** Meanwhile, those marked #3 and #6, deemed “hard to recycle materials,” often require special collection programs. RICs #4 and #5 typically end up in the landfill because they cost more to recycle than companies are willing to pay. Moreover, RIC #7 is virtually never recycled.

Even the relatively “easy” to recycle plastics (RICs #1 and #2) ought to be rinsed and dried before collection in order to avoid the contamination of other recyclables in the bin. Not to mention that recycling rules [vary from municipality to municipality](#)<sup>16</sup>.

One reason why such a large portion of recyclable plastics shares the same fate as common trash has to do with separation. As noted above, there are many different types of plastics; when they are all in the same stream of waste, it is expensive and [difficult](#)<sup>17</sup> to sort through them. Different types of plastic simply cannot be recycled together; in fact, recycling different types of plastic all in one process is [virtually impossible](#)<sup>18</sup>. Certain companies assert that

“advanced recycling” or “chemical recycling”—a process that entails melting down plastic for use alongside mixed plastics—represents the solution. However, this process is more [energy intensive](#)<sup>19</sup> than traditional mechanical recycling—up to 73 MJ/kg versus 8.6 MJ/kg.

Which brings us to the second reason most plastics go to landfill: it is more expensive to recycle waste than to simply landfill or incinerate it. Recycled plastic [costs more to produce](#)<sup>20</sup> than virgin plastic and cannot be utilized for some food packaging. Therefore, the market price of recycled plastic is higher and the customer base is smaller compared to their virgin plastic competitors, so the return on investment and production is small.

Recycling also emits fossil fuels, uses more water, and has the potential to [release hazardous chemicals](#)<sup>21</sup> into surrounding areas. Due to a lack of regulation, recycling plants are already [releasing microplastics directly into waterways](#)<sup>22</sup>.

One of the key ways we can effect change on the plastics downstream, aside from limiting production, is by taking legislative action against the use of plastics, especially single-use plastics.



## GLOBAL SOLUTIONS

**AFRICA** Some governments have begun to take positive steps to address the problem of plastics. Notably, the East African country of Rwanda<sup>23</sup> has had anti-plastic legislation in place since 2008, prohibiting the manufacturing, use, sale, and importation of all plastic bags. This led the way for 33 other African countries to implement policies restricting throwaway or single-use plastics. Regionally, the East African Community<sup>24</sup>, comprising Kenya, Tanzania, Uganda, Rwanda, Burundi, South Sudan, and the Democratic Republic of the Congo, introduced a ban in 2017 on the manufacture, sale, importation, and use of polyethylene bags in this region.

**INDIA** India introduced a ban<sup>25</sup> on many single-use plastics. These types of laws will do little without enforcement, but if handled correctly they can be extremely effective and could go a long way in curbing the plastic

problem. The state of Tamil Nadu, India<sup>26</sup>, for example, has had more success in curbing plastics due to heavier enforcement.

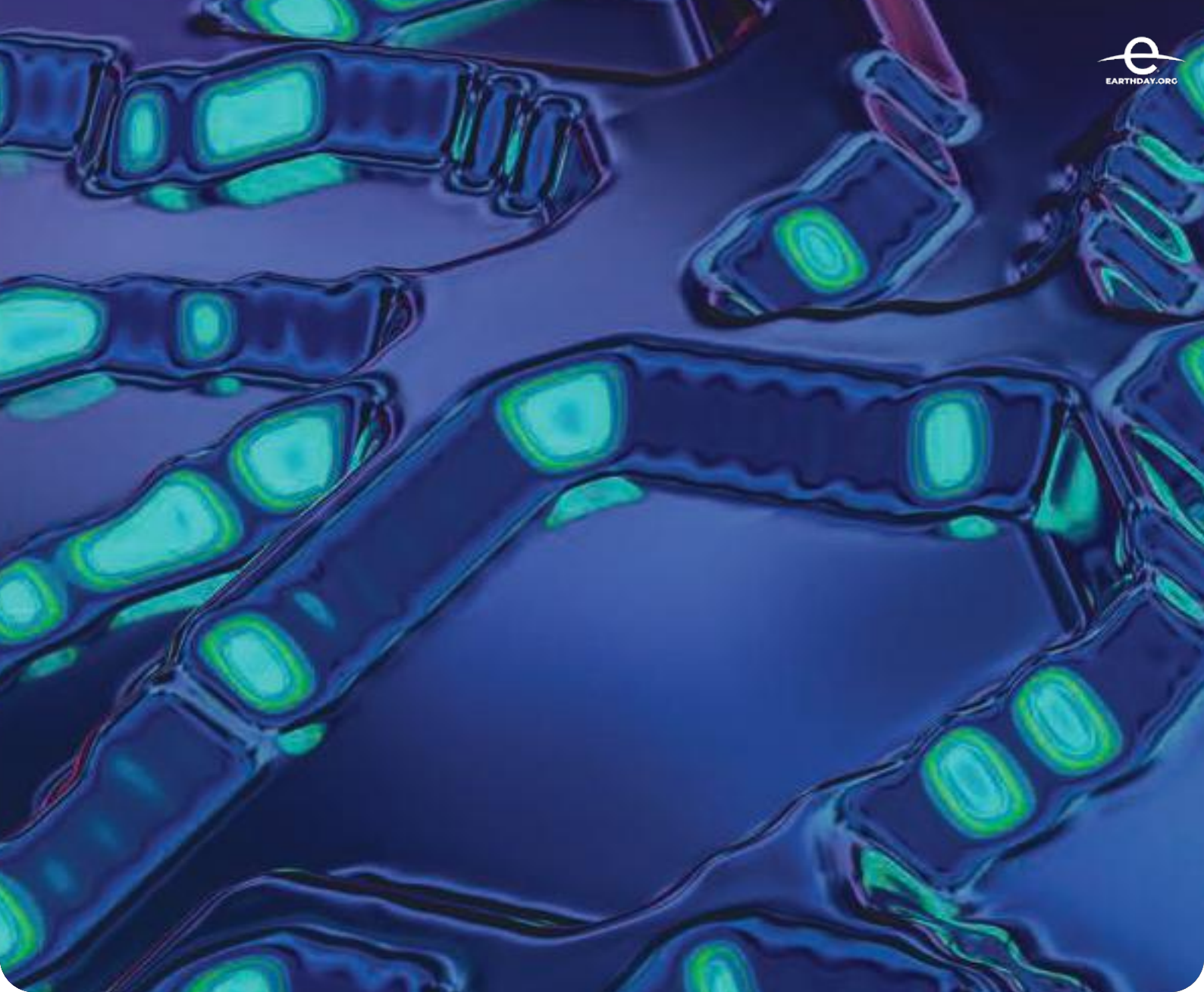
### EUROPEAN UNION (EU)

The European Union (EU) has imposed certain restrictions on single-use plastic<sup>27</sup> plates, cutlery, straws, and other items since July of 2021. There has also been the implementation of producer responsibility programs in the textile industry in the EU<sup>28</sup> to help separate, sort, reuse, and recycle textile materials within the EU. These types of EPR schemes can be useful in curbing plastic and push the industry to make changes.

Countries can take steps to curb plastic on their own, but a strong Global Plastics Treaty<sup>29</sup> incorporating both the health risks of plastics and a pathway to a reduction in production is vital if we are to collectively transition away from plastics. The treaty should be legally binding and universal so all countries are held accountable for their plastic throughout the lifecycle of the product.







## PLASTICS & THE POWER OF MICRO-ORGANISMS

There is also a new way to potentially manage microplastic pollution. This solely addresses waste escaping from recycling facilities, landfills, and treatment plants, but this waste is extremely important to address. There is some promising research on better ways to degrade microplastic in waste streams that avoid incineration or landfilling.

Microorganisms have been degrading biological materials<sup>30</sup> for as long as there have been microorganisms, but some studies are finding the potential of microplastic breakdown via these microscopic organisms. This is still very new research, but there are some suggestions that through genetic manipulation, certain microorganisms can help remove microplastic from our natural systems<sup>31</sup>. It needs to be noted this is also not a total solution to the plastic problem, but could be a useful tool<sup>32</sup> in the future with further research.



## CONCLUSION

In order to solve the microplastic crisis, we need to curb plastic production. It is vital for the [Global Plastics Treaty](#)<sup>33</sup>, due for draft completion by December 2024, to address this head on. Right now the Treaty is focused on plastic pollution.

**In order to address pollution there needs to be a pledge to reduce plastic production. The Treaty must also encompass the full health implications of plastics. Right now human health and plastics, microplastics and their additive chemicals is a dimension completely lacking in its current provisions.**

Just over 70 years ago we survived living in a world largely free from plastics. We were sold the lie that they were both disposable and

convenient. But they are rarely if ever disposable and if our reliance on plastic is causing harm to the health of our children, perhaps it's high time we seriously reconsider the cost of convenience.

To reduce plastic waste, to end plastic pollution, to stop poisoning ourselves and all other species with microplastics, we need to drastically reduce the volume of plastics we produce. *Why?* Because there is clear evidence plastics, microplastics, and their additive chemicals have serious health implications, on animals, human beings and especially on our children. Yet plastics and health remains a deeply understudied subject. We call for urgent action to address the plastic crisis before it is too late.

## ACTIONS NEEDED

- **We need a strong and enforceable Plastic Treaty:** We ask the **United Nations Environmental Programme (UNEP)** to formally recognize the health implications of exposure to microplastics, plastics, and their additive chemicals to ensure plastics and health are not just included in the Global Plastic Treaty but are at the heart of it. EARTHDAY.ORG has launched a Global Plastic Petition calling for the inclusion of the health implications of plastics: <https://action.earthday.org/global-plastics-treaty><sup>34</sup>
- **Research & Investigation into the Health Implications of Microplastics:** We ask the World Health Organization to fund meaningful public health research into the causal health implications of microplastics on human health with specific attention to their impact on unborn babies, neonates, and infants. This research should inform new laws surrounding the manufacturing and usage of plastics and their additive chemicals.
- **Plastic Production Reduction: 8.3 BILLION Metric Tons (9.1 BILLION US Tons)**<sup>35</sup> of plastic has been produced since plastic was introduced in the 1950s. We are calling for a drastic reduction in the volume of global plastic production so that by 2040, it will be reduced from current levels by 60%. Specifically in the area of single-use plastic, which accounts for nearly 50%<sup>36</sup> of ALL plastic produced.
- **Accountability:** Plastic producers need to be held fiscally accountable for the environmental impacts of plastic pollution. Even more urgently, they must be held accountable for the health consequences of breathing and ingesting microparticles.
- **End Greenwashing:** We call on the plastic industry to be honest and open in rejecting “greenwashing,” the act of making misleading claims about the environmental benefits of a product or a practice. Greenwashing is often associated with claims about plastics recycling.
- **End Plastic Subsidies:** Evidence indicates plastic production is largely subsidized, contributing to and deepening the plastic pollution crisis. To effectively achieve the goals of the Plastics Treaty, many states have recognized the urgency of eliminating these subsidies. We join them in this call. The Center for International Environmental Law (CIEL) and Rambod Behboodi have prepared this brief detailing these subsidies and the issues they provoke: [Tackling Subsidies for Plastic Production: Key Considerations for the Plastics Treaty Negotiations](#)<sup>37</sup>.

- **Plastic Industry Disclosure:**  
We ask the plastic manufacturing industry to tell us what their own internal research knows about plastics and human health.

By July 1977, [EXXON](#)<sup>38</sup>, now ExxonMobile, knew the burning of fossil fuels would impact the global climate through the release of the greenhouse gas carbon dioxide. They hid their research. It would finally be made known by journalists from Inside Climate News in 2015. Exxon and many other fossil fuel companies are now major producers of plastics.

*What do plastic manufacturers know about the impacts of microplastics on human health?*

*What if anything are they NOT telling us?*



# END NOTES (SOURCES)

## EXECUTIVE SUMMARY

- 1 <https://www.earthday.org/fast-fashion-our-generations-nuclear-bomb/>
- 2 <https://www.europarl.europa.eu/news/en/headlines/society/20181116STO19217/microplastics-sources-effects-and-solutions>
- 3 <https://www.mdeplastics.com/20-different-types-of-common-plastic-material>
- 4 <https://pubs.acs.org/doi/10.1021/acs.estlett.2c00763>
- 5 <https://www.mdpi.com/1422-0067/23/21/12743>
- 6 <https://www.sciencedirect.com/science/article/abs/pii/S0045653521002745?via%3Dihub>
- 7 <https://onlinelibrary.wiley.com/doi/full/10.1002/bdr2.1776>
- 8 <https://pubmed.ncbi.nlm.nih.gov/35134716/>
- 9 <https://www.sciencedirect.com/science/article/abs/pii/S0890623822000545#:~:text=Increasing%20evidence%20shows%20that%20the,prenatal%20BPA%20exposure%20remains%20unknown.>
- 10 <https://academic.oup.com/jnci/article/114/6/885/6531974?login=false>
- 11 <https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/expert-answers/bpa/faq-20058331#:~:text=Exposure%20to%20BPA%20is%20a,2%20diabetes%20and%20cardiovascular%20disease.>
- 12 <https://www.wired.com/story/baby-poop-is-loaded-with-microplastics/>
- 13 <https://pubs.acs.org/doi/abs/10.1021/acs.estlett.1c00559>
- 14 <https://www.plasticsindustry.org/newsroom/plastics-industry-association-launches-recycling-is-real-advocacy-campaign/>
- 15 <https://www.sciencedaily.com/releases/2016/01/160127083854.htm>
- 16 <https://www.sciencedirect.com/science/article/abs/pii/S2213305416300029>
- 17 <https://www.geochemicalperspectivesletters.org/article1829/#Fig3>
- 18 <https://www.nationalgeographic.com/environment/article/microplastics-found-near-everests-peak-highest-ever-detected-world-perpetual-planet>
- 19 <https://www.sciencenews.org/article/ants-first-insects-ensnared-plastic-pollution#:~:text=Finding%20plastic%20wrapped%20ants%20suggests,volcanic%20island%20of%20La%20Palma.>
- 20 [https://www.sciencedirect.com/science/article/pii/S0025326X18307999?casa\\_token=PRL-Mgw-CYAAAAAA:0OSv5vr4LvZsybQnbZWAQuKciGpCPO0ISiAS5oGMObpGWA\\_pRBGfrc4oCKfZgISRuJYV2qd6Y](https://www.sciencedirect.com/science/article/pii/S0025326X18307999?casa_token=PRL-Mgw-CYAAAAAA:0OSv5vr4LvZsybQnbZWAQuKciGpCPO0ISiAS5oGMObpGWA_pRBGfrc4oCKfZgISRuJYV2qd6Y)
- 20 <https://www.nationalgeographic.com/environment/article/you-eat-thousands-of-bits-of-plastic-every-year#>
- 22 [https://www.sciencedirect.com/science/article/pii/S030438941730763X?ref=pdf\\_download&fr=RR-2&rr=825c0e06b8bc0](https://www.sciencedirect.com/science/article/pii/S030438941730763X?ref=pdf_download&fr=RR-2&rr=825c0e06b8bc0)
- 23 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10413915/#:~:text=As%20well%20as%20being%20a,been%20documented%20in%20the%20literature.>
- 24 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10151227/#B12>
- 25 <https://www.sciencedirect.com/science/article/pii/S2666911021000022>
- 26 <https://www.uq.edu.au/news/article/2022/11/viruses-can-hitchhike%E2%80%99-microplastics>
- 27 <https://www.technologyreview.com/2023/06/02/1073822/microplastics-immune-systems/#:~:text=Yes%2C%20they%20are%20in%20our,deepest%20part%20of%20the%20ocean.>
- 28 <https://www.nationalgeographic.co.uk/environment/2019/06/you-eat-thousands-bits-plastic-every-year>
- 29 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3266016/>
- 30 <https://www.sciencedirect.com/science/article/abs/pii/S026974912201171X?via%3Dihub>
- 31 <https://www.cdc.gov/mmwr/preview/mmwrhtml/lmrk095.htm>
- 32 <https://www.epa.gov/lead/protect-your-family-sources-lead#:~:text=In%201978%2C%20the%20federal%20government,is%20usually%20not%20a%20problem.>
- 33 <https://www.cdc.gov/nceh/features/leadpoisoning/index.html#:~:text=windowsills%2C%20and%20wells.,Exposure%20to%20lead%20can%20seriously%20harm%20a%20child%27s%20health%2C%20including,and%20hearing%20and%20speech%20problems.>
- 34 <https://www.unep.org/news-and-stories/press-release/era-led-petrol-over-eliminating-major-threat-human-and-planetary>
- 35 <https://www.nature.com/articles/s41598-019-45054-w>
- 36 <https://www.nature.com/articles/s41598-019-45054-w>
- 37 <https://www.earthday.org/the-invisible-pollutant-microplastics-in-our-air/>

- <sup>38</sup> <https://e360.yale.edu/features/plastic-waste-atmosphere-climate-weather#:~:text=Nearly%20a%20dozen%20studies%20have,meter%20in%20London%20and%20Beijing>
- <sup>39</sup> <https://doi.org/10.1016/j.envres.2023.116411>
- <sup>40</sup> <https://www.sciencedirect.com/science/article/abs/pii/S0013935123016626>
- <sup>41</sup> <https://www.nature.com/articles/s41598-017-18849-y>
- <sup>42</sup> <https://www.nature.com/articles/s41598-017-10813-0.pdf>
- <sup>43</sup> <https://web.archive.org/web/20101203205130/http://www.epa.gov/apti/bces/module3/category/category.htm>
- <sup>44</sup> <https://pubs.acs.org/doi/10.1021/acs.est.0c04032>
- <sup>45</sup> <https://www.uri.edu/news/2023/08/microplastics-infiltrate-all-systems-of-body-cause-behavioral-changes/>
- <sup>46</sup> <https://pubmed.ncbi.nlm.nih.gov/34492918/>
- <sup>47</sup> <https://www.acs.org/pressroom/presspacs/2023/august/microplastics-found-in-human-heart-tissues-before-and-after-surgical-procedures.html#:~:text=A%20pilot%20study%20found%20microplastics,people%20who%20underwent%20cardiac%20surgery.&text=Everywhere%20scientists%20look%20for%20microplastics,parts%20of%20the%20human%20body.>
- <sup>48</sup> <https://www.mdpi.com/2305-6304/11/1/40>
- <sup>49</sup> <https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/#:~:text=The%20worldwide%20production%20of%20plastics,production%20has%20soared%20since%201950s.>
- <sup>50</sup> <https://www.statista.com/topics/5266/plastics-industry/#topicOverview>
- <sup>51</sup> <https://www.oecd.org/environment/plastics/increased-plastic-leakage-and-greenhouse-gas-emissions.htm#:~:text=Throughout%20their%20lifecycle%2C%20plastics%20have,of%20global%20greenhouse%20gas%20emissions>
- <sup>52</sup> [https://www.europarl.europa.eu/thinktank/en/document/EPRS\\_IDA\(2015\)573876#:~:text=The%20precautionary%20principle%20enables%20decision,and%20the%20stakes%20are%20high.](https://www.europarl.europa.eu/thinktank/en/document/EPRS_IDA(2015)573876#:~:text=The%20precautionary%20principle%20enables%20decision,and%20the%20stakes%20are%20high.)
- <sup>53</sup> <https://www.bakerinstitute.org/research/plastics-and-precautionary-principle>
- <sup>54</sup> <https://www.elr.info/sites/default/files/litigation/5.20157.htm>
- <sup>55</sup> <https://www.epa.gov/pfas/pfas-explained>
- <sup>56</sup> <https://nyulangone.org/news/daily-exposure-forever-chemicals-costs-united-states-billions-health-costs>
- <sup>57</sup> <https://www.unep.org/news-and-stories/press-release/plastic-waste-causes-financial-damage-us13-billion-marine-ecosystems>

## CHAPTER 1

- 1 <https://www.google.com/books/edition/Plastic/9LyGHqqlKT4C?hl=en>
- 2 <https://www.sciencehistory.org/education/classroom-activities/role-playing-games/case-of-plastics/history-and-future-of-plastics/>
- 3 <https://www.sciencehistory.org/education/classroom-activities/role-playing-games/case-of-plastics/history-and-future-of-plastics/>
- 4 <https://www.pbs.org/wgbh/americanexperience/features/tupperware-plastics/>
- 5 <https://thisisplastics.com/plastics-101/how-are-plastics-made/>
- 6 <https://www.bpf.co.uk/plastipedia/how-is-plastic-made.aspx#:~:text=Refining%20process%20transforms%20crude%20oil,basic%20building%20blocks%20of%20polymers>
- 7 [https://www.cdc.gov/biomonitoring/Phthalates\\_FactSheet.html#:~:text=Phthalates%20are%20a%20group%20of,%20shampoos%20hair%20sprays\).](https://www.cdc.gov/biomonitoring/Phthalates_FactSheet.html#:~:text=Phthalates%20are%20a%20group%20of,%20shampoos%20hair%20sprays).)
- 8 <https://dceg.cancer.gov/research/what-we-study/pfas>
- 9 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602822/#:~:text=BPA%20can%20mimic%20estrogen%20to,to%20cancer%20development%20and%20progression>
- 10 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602822/#:~:text=BPA%20can%20mimic%20estrogen%20to,to%20cancer%20development%20and%20progression.>
- 11 <https://www.britannica.com/science/plastic/The-polymers>
- 12 <https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm>
- 13 <https://doi.org/10.1021/acs.est.9b04535>
- 14 <https://pubs.acs.org/doi/10.1021/acs.est.9b04535>
- 15 <https://www.openaccessgovernment.org/microplastics-babies/128723/#:~:text=But%20several%20studies%20now%20suggest,This%20makes%20them%20particularly%20vulnerable.>
- 16 <https://www.ciel.org/issue/fossil-fuels-plastic/#:~:text=Over%2099%25%20of%20plastic%20is,in%20the%20US%20and%20beyond.>
- 17 <https://www.niehs.nih.gov/health/topics/agents/sya-bpa/index.cfm>
- 18 <https://www.packagingdigest.com/food-safety/history-bpa>
- 19 <https://www.niehs.nih.gov/health/topics/agents/sya-bpa/index.cfm>
- 20 <https://thisisplastics.com/safety/bpa-is-it-safe/>
- 21 <https://www.fda.gov/food/food-packaging-other-substances-come-contact-food-information-consumers/bisphenol-bpa-use-food-contact-application#:~:text=Steps%20and%20Collaborations-,Summary%20of%20FDA%27s%20Current%20Perspective%20on%20BPA%20in%20Food%20Contact,current%20levels%20occurring%20in%20foods.>
- 22 <https://www.npr.org/sections/thesalt/2012/07/17/156916616/fda-bans-chemical-bpa-in-sippy-cups-and-baby-bottles>
- 23 <https://www.federalregister.gov/documents/2012/07/17/2012-17366/indirect-food-additives-polymers>
- 24 <https://www.americanchemistry.com/better-policy-regulation/plastics/plastics-division-membership>
- 25 <https://www.markey.senate.gov/news/press-releases/markey-petition-to-fda-brings-end-to-use-of-toxic-chemical-in-infant-formula-packaging>
- 26 <https://echa.europa.eu/about-us>
- 27 <https://curia.europa.eu/juris/document/document.jsf?text=&docid=271068&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=1069642>
- 28 <https://www.bcpp.org/resource/bpa-laws-and-regulations/#:~:text=International%20Regulation&text=However%20%20some%20EU%20nation%20states,food%20packaging%20as%20of%202013.>
- 29 <https://www.nationalgeographic.com/environment/article/map-shows-the-complicated-landscape-of-plastic-bans#:~:text=In%20Colorado%20an%20industry%20group,statute%20preempts%20local%20plastics%20bans.&text=New%20York%20State's%20ban%20on,from%20addressing%20bags%20at%20restaurants>
- 30 <https://publicintegrity.org/environment/pollution/pushing-plastic/inside-the-long-war-to-protect-plastic/>
- 31 <https://archive.jsonline.com/watchdog/watchdogreports/54195297.html>
- 32 <https://www.nationalobserver.com/2021/05/13/news/canada-officially-tosses-plastic-toxic-bin>
- 33 <https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html>

## CHAPTER 2

- 1 <https://www.babycentre.co.uk/x6721/why-does-my-baby-put-everything-in-her-mouth#>
- 2 <https://www.independent.co.uk/climate-change/babies-infants-adults-microplastics-study-b1925240.html#>
- 3 <https://pubs.acs.org/doi/abs/10.1021/acs.estlett.1c00559>
- 4 <https://www.verywellfamily.com/study-shows-babies-have-more-microplastics-in-their-bodies-than-adults-5205020#:~:text=If%20you%20really%20look%20at,important%20sources%20of%20microplastic%20exposure.>
- 5 <https://www.today.com/health/microplastics-drinking-water-baby-formula-plastic-baby-bottles-shed-particles-t197037#>
- 6 <https://www.nature.com/articles/s43016-020-00171-y>
- 7 [https://www.tcd.ie/news\\_events/articles/bottle-fed-babies-may-consume-millions-of-microplastic-particles-our-research-suggests/](https://www.tcd.ie/news_events/articles/bottle-fed-babies-may-consume-millions-of-microplastic-particles-our-research-suggests/)
- 8 <https://www.theguardian.com/environment/2020/oct/19/bottle-fed-babies-swallow-millions-microplastics-day-study>
- 9 <https://pubs.acs.org/doi/10.1021/acs.est.3c01942>
- 10 <https://pubs.acs.org/doi/10.1021/acs.est.3c01942>
- 11 <https://www.plasticsoupfoundation.org/wp-content/uploads/2022/07/Final-Report-pilot-study-plastic-particles-in-livestock-feed-milk-meat-and-blood-SIGNED.pdf>
- 12 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9269371/>
- 13 <https://www.sciencedirect.com/science/article/abs/pii/S0269749123001999>
- 14 <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/polyethylene-terephthalate>
- 15 <https://plastics-themag.com/Plastic-shakes-up-the-toy-industry>
- 16 [https://health.ucdavis.edu/mindinstitute/resources/resources\\_pdf/Plastics\\_and\\_Plastic\\_Toys\\_7\\_14.pdf](https://health.ucdavis.edu/mindinstitute/resources/resources_pdf/Plastics_and_Plastic_Toys_7_14.pdf)
- 17 [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3327051/#:~:text=A%20model%20example%20of%20carcinogenic,carcinogen%20vinyl%20chloride%20\(VC\).](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3327051/#:~:text=A%20model%20example%20of%20carcinogenic,carcinogen%20vinyl%20chloride%20(VC).)
- 18 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6864600/#:~:text=BPA%20is%20classified%20as%20an,hormones%20%5B2%2C%208%5D.>
- 19 <https://www.cpsc.gov/Newsroom/News-Releases/2018/CPSC-Prohibits-Certain-Phthalates-in-Childrens-Toys-and-Child-Care-Products>
- 20 <https://www.toyassociation.org/PressRoom2/IndustryStatements/statement-on-bisphenol-a.aspx#:~:text=No%20federal%20or%20state%20jurisdiction,highest%20standards%20for%20toy%20safety.>
- 21 <http://changingmarkets.org/wp-content/uploads/2021/06/CM-EX-SUM-FINAL-ENGLISH-SYNTETHIC-ANONYMOUS-WEB-.pdf>
- 22 <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0281596>
- 23 <https://www.nytimes.com/wirecutter/blog/reduce-laundry-microfiber-pollution/>
- 24 <https://www.frontiersin.org/articles/10.3389/fmars.2022.991650/full>
- 25 <https://iopscience.iop.org/article/10.1088/1755-1315/631/1/012006/pdf#:~:text=Influence%20of%20Microplastics%20on%20Marine%20Fishes&text=The%20microplastics%20can%20have%20a,oxidative%20damage%20and%20abnormal%20behavior.>
- 26 <https://www.mdpi.com/2073-4441/14/23/3797>
- 27 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8987311/>
- 28 <https://www.sciencedirect.com/science/article/abs/pii/S0166445X21000072>
- 29 <https://www.epa.gov/pfas/pfas-explained>
- 30 <https://www.ewg.org/news-insights/news/2022/11/new-baby-textile-product-tests-show-concerning-levels-toxic-forever>
- 31 <https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas>
- 32 <https://pubmed.ncbi.nlm.nih.gov/35816333/>
- 33 <https://vivo.brown.edu/display/jb93>
- 34 <https://www.parents.com/there-are-probably-toxins-in-your-child-s-clothing-here-s-what-you-need-to-know-7629291#:~:text=According%20to%20new%20research%20by,kids%27%20health%20long%2Dterm.&text=Staying%20on%20top%20of%20a,like%20a%20full%2Dtime%20job.>
- 35 <https://www.sciencedirect.com/science/article/abs/pii/S0048969722059654#:~:text=Built%2Din%20plastic%20structures%20might,found%20on%20leaves%20inside%20playgrounds.>
- 36 <https://pubmed.ncbi.nlm.nih.gov/36126714/>
- 37 <https://doi.org/10.1016/j.scitotenv.2020.142566>
- 38 <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/scrap-tyre>
- 39 <https://www.parksandrecbusiness.com/articles/the-microplastics-crisis>
- 40 <https://pubmed.ncbi.nlm.nih.gov/29053641/>



- 41 <https://www.iucn.org/news/secretariat/201702/invisible-plastic-particles-textiles-and-tyres-major-source-ocean-pollution-%E2%80%93-iucn-study>
- 42 <https://www.epa.gov/chemical-research/july-2019-report-tire-crumb-rubber-characterization-0>
- 43 [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_23\\_4581](https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4581)
- 44 <https://www.google.com/url?q=https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4711263/%23:-:text%3DThe%2520patients%2520with%2520conjugated%2520BPA,women%2520in%2520the%2520lowest%2520quartile&sa=D&source=docs&ust=1699387983108015&usg=AOvVaw3Yki7fSbSilsfA9-BN4Ycl>
- 45 <https://academic-accelerator.com/encyclopedia/laser-direct-infrared-imaging>
- 46 <https://doi.org/10.1016/j.scitotenv.2022.158699>
- 47 <https://www.sciencedirect.com/topics/neuroscience/raman-spectroscopy>
- 48 <https://pubmed.ncbi.nlm.nih.gov/33395930/#:~:text=In%20total%2C%2012%20microplastic%20fragments,of%20morphology%20and%20chemical%20composition.>
- 49 <https://www.mdpi.com/1422-0067/23/21/12743>
- 50 <https://my.clevelandclinic.org/health/diseases/17952-preeclampsia>
- 51 <https://www.sciencedirect.com/science/article/pii/S0160412020322297?via%3Dihub>
- 52 <https://doi.org/10.1007/s11356-021-13911-9>
- 53 <https://www.medicalnewstoday.com/articles/320160>
- 54 <https://www.sciencedirect.com/science/article/abs/pii/S0269749118345858?via%3Dihub>
- 55 <https://www.sciencedirect.com/science/article/abs/pii/S0045653515006517>
- 56 <https://pubs.acs.org/doi/full/10.1021/es504525u>

## CHAPTER 3

- 1 <https://www.mdpi.com/2305-6304/11/1/40>
- 2 <https://www.mcgill.ca/newsroom/channels/news/microplastics-are-harming-gut-health-348329#:~:text=%E2%80%9CThe%20more%20microplastics%20found%20in,the%20host%2C%E2%80%9D%20says%20Fackelmann.>
- 3 <https://www.sciencedirect.com/science/article/pii/S0160412022001258>
- 4 <https://www.acs.org/pressroom/presspacs/2023/august/microplastics-found-in-human-heart-tissues-before-and-after-surgical-procedures.html#:~:text=A%20pilot%20study%20found%20microplastics,people%20who%20underwent%20cardiac%20surgery.&text=Everywhere%20scientists%20look%20for%20microplastics,parts%20of%20the%20human%20body.>
- 5 <https://pubmed.ncbi.nlm.nih.gov/34492918/>
- 6 <https://www.mdpi.com/1422-0067/24/15/12308>
- 7 [https://www.smithsonianmag.com/smart-news/microplastics-found-lurking-human-stool-first-time-180970613/?fbclid=IwAR2EqHUvO18Xk6K8le2tAReLuTFj-1SuPqq\\_yvh5MCunllbXyODu3wm\\_bPA](https://www.smithsonianmag.com/smart-news/microplastics-found-lurking-human-stool-first-time-180970613/?fbclid=IwAR2EqHUvO18Xk6K8le2tAReLuTFj-1SuPqq_yvh5MCunllbXyODu3wm_bPA)
- 8 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9611505/>
- 9 <https://www.sciencedaily.com/releases/2021/09/210922090835.htm>
- 10 <https://doi.org/10.1016/j.chemosphere.2022.134261>
- 11 <https://pubs.acs.org/doi/abs/10.1021/acs.estlett.1c00559>
- 12 <https://pubs.acs.org/journal/estlcu>
- 13 <https://www.acs.org/>
- 14 <https://www.sciencedirect.com/science/article/pii/S1438463919308478?via%3Dihub>
- 15 <https://www.sciencedirect.com/science/article/pii/S1438463919308478?via%3Dihub>
- 16 <https://www.mayoclinic.org/tests-procedures/bone-marrow-transplant/in-depth/stem-cells/art-20048117#:~:text=What%20are%20stem%20cells%3F,more%20cells%20called%20daughter%20cells.>
- 17 <https://www.sciencedirect.com/science/article/pii/S0160412022001258>
- 18 <https://vu.nl/en/news/2022/microplastics-found-in-human-bloodstream>
- 19 [https://en.wikipedia.org/wiki/Polyethylene\\_terephthalate](https://en.wikipedia.org/wiki/Polyethylene_terephthalate)
- 20 <https://www.niehs.nih.gov/health/topics/agents/styrene/index.cfm>
- 21 <https://www.smithsonianmag.com/smart-news/microplastics-detected-in-human-blood-180979826/>
- 22 <https://www.acs.org/pressroom/presspacs/2023/august/microplastics-found-in-human-heart-tissues-before-and-after-surgical-procedures.html#:~:text=A%20pilot%20study%20found%20microplastics,people%20who%20underwent%20cardiac%20surgery.&text=Everywhere%20scientists%20look%20for%20microplastics,parts%20of%20the%20human%20body.>
- 23 <https://www.sciencedirect.com/science/article/pii/S0048969722020009#:~:text=Highlights&text=Microplastics%20were%20identified%20in%20all,human%20lungs%20using%20%CE%BCFTIR%20analysis.&text=Polypropylene%20and%20polyethylene%20terephthalate%20fibres%20were%20the%20most%20abundant.&text=The%20results%20support%20inhalation%20as%20a%20route%20of%20MP%20exposure.>
- 24 <https://www.lung.org/lung-health-diseases/lung-procedures-and-tests/lung-volume-reduction-surgery>
- 25 <http://www.medicalnewstoday.com/articles/323701>
- 26 <https://www.medicalnewstoday.com/articles/microplastics-in-humans-after-blood-scientists-find-traces-in-the-lungs#Microplastics-in-human-tissues>
- 27 <https://pubs.acs.org/doi/10.1021/acs.est.9b04535>
- 28 <https://www.ninds.nih.gov/health-information/public-education/brain-basics/brain-basics-know-your-brain>
- 29 <https://www.mdpi.com/1422-0067/24/15/12308>
- 30 <https://doi.org/10.1016/j.chemosphere.2022.134261>
- 31 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2951017/#:~:text=Microglia%20can%20become%20chronically%20activated,cumulative%20neuronal%20loss%20with%20time.>

## CHAPTER 4

- 1 <https://www.hopkinsmedicine.org/health/wellness-and-prevention/anatomy-of-the-endocrine-system>
- 2 <https://www.niehs.nih.gov/health/topics/agents/endocrine/index.cfm>
- 3 [https://ipen.org/sites/default/files/documents/edc\\_guide\\_2020\\_v1\\_6ew-en.pdf](https://ipen.org/sites/default/files/documents/edc_guide_2020_v1_6ew-en.pdf)
- 4 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5913002/#R25>
- 5 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8910189/#:~:text=All%20three%20human%20studies%20showed%20significant%20effects%20of%20BPA%20on%20hyperactivity.&text=OR%20for%20ADHD%20diagnosis%20associated,ADHD%20with%20phthalates%2Fplasticizers%20exposure.>
- 6 <https://www.diabetesaustralia.com.au/blog/bpa-linked-to-type-2-diabetes/#:~:text=Research%20from%20the%20Baker%20Heart,of%20developing%20type%20%20diabetes.>
- 7 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9134445/>
- 7 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602822/>
- 9 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6864600/#:~:text=BPA%20is%20classified%20as%20an,hormones%20%5B2%2C%208%5D.>
- 10 <https://www.statnews.com/2023/03/23/autism-epidemic-cdc-numbers/#:~:text=In%20a%20pair%20of%20new,This%20increase%20may%20sound%20scary.>
- 11 [https://www.cdc.gov/mmwr/volumes/72/ss/ss7202a1.htm?s\\_cid=ss7202a1\\_w](https://www.cdc.gov/mmwr/volumes/72/ss/ss7202a1.htm?s_cid=ss7202a1_w)
- 12 <https://www.prnewswire.com/news-releases/autism-prevalence-is-now-1-in-44-signifying-the-eighth-increase-in-prevalence-rates-reported-by-the-cdc-since-2000-301436766.html>
- 13 <http://www.cnn.com/2009/HEALTH/12/17/autism.new.numbers/index.html>
- 14 <https://www.sciencedirect.com/science/article/pii/S0160412022000472?via%3Dihub>
- 15 <https://www.niehs.nih.gov/health/topics/science/microbiome/index.cfm#:~:text=The%20microbiome%20is%20the%20collection,to%20human%20health%20and%20wellness.>
- 16 <https://doi.org/10.1038/s41598-019-42183-0>
- 17 <https://doi.org/10.1002/bdr2.1776>
- 18 <https://www.ncbi.nlm.nih.gov/books/NBK542179/#:~:text=The%20central%20nervous%20system%20is,and%20responding%20to%20sensory%20information.>
- 19 <https://www.cdc.gov/ncbddd/adhd/data.html>
- 20 <https://doi.org/10.3390%2Fijerph19052849>
- 21 <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0289841>
- 22 <https://academic.oup.com/jnci/advance-article/doi/10.1093/jnci/djad115/7219716?searchresult=1&login=false>
- 23 [https://www.med.uvm.edu/home/2022/03/16/uvm\\_cancer\\_center\\_research\\_phthalates](https://www.med.uvm.edu/home/2022/03/16/uvm_cancer_center_research_phthalates)
- 24 <https://pubmed.ncbi.nlm.nih.gov/35179607/>
- 25 [https://www.med.uvm.edu/home/2022/03/16/uvm\\_cancer\\_center\\_research\\_phthalates](https://www.med.uvm.edu/home/2022/03/16/uvm_cancer_center_research_phthalates)
- 26 <https://www.sciencedirect.com/science/article/abs/pii/S0045653521002745?via%3Dihub>
- 27 <https://www.genome.gov/genetics-glossary/Lymphocyte#:~:text=A%20lymphocyte%20is%20a%20type,bacteria%2C%20viruses%2C%20and%20toxins.>
- 28 <https://www.scientificamerican.com/article/bpa-exposure-linked-to-prostate-cancer/>
- 29 <https://pubs.acs.org/doi/abs/10.1021/es402764d>
- 30 <https://www.uclahealth.org/cancer/cancer-services/prostate-cancer/what-prostate-cancer>
- 31 <https://www.mdpi.com/2079-4991/9/9/1299>
- 32 <https://annalsfglobalhealth.org/articles/10.5334/aogh.4056#section-2the-plastic-life-cycle-and-its-hazards-to-human-health>
- 33 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240435/>

## CHAPTER 5

- 1 <https://link.springer.com/article/10.1007/s12403-022-00496-y>
- 2 [https://www.cdc.gov/biomonitoring/PFAS\\_FactSheet.html#:~:text=Print-,Per%2D%20and%20Polyfluorinated%20Substances%20\(PFAS\),in%20a%20variety%20of%20products.](https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html#:~:text=Print-,Per%2D%20and%20Polyfluorinated%20Substances%20(PFAS),in%20a%20variety%20of%20products.)
- 3 <https://nyulangone.org/news/daily-exposure-forever-chemicals-costs-united-states-billions-health-costs>
- 4 <https://www.unep.org/news-and-stories/press-release/plastic-waste-causes-financial-damage-us13-billion-marine-ecosystems>
- 5 <https://www.sustainableplastics.com/news/ocean-plastics-150b-problem>
- 6 <https://www.earthday.org/60x40-a-global-wave-to-halt-plastic-production-and-save-our-planet/#:~:text=EARTHDAY,future%20for%20generations%20to%20come.>
- 7 <https://doi.org/10.3390/bioengineering9020074>
- 8 <https://www.mdpi.com/2309-608X/9/2/210>
- 9 <https://www.micropia.nl/en/discover/microbiology/mycelium/#:~:text=A%20mycelium%20is%20a%20network,can%20sprout%20from%20a%20mycelium.>
- 10 <https://www.theverge.com/23610087/mushroom-plastic-waste-research>
- 11 [https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm#:~:text=Only%209%25%20of%20plastic%20waste%20is%20recycled%20\(15%25%20is,is%20disposed%20of%20as%20residues\).](https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm#:~:text=Only%209%25%20of%20plastic%20waste%20is%20recycled%20(15%25%20is,is%20disposed%20of%20as%20residues).)
- 12 <https://www.wbur.org/hereandnow/2023/09/05/unrecyclable-plastic-pollution#>
- 13 <https://www.afandpa.org/news/2022/unpacking-continuously-high-paper-recycling-rates>
- 14 <https://www.colorado.edu/ecenter/2020/10/26/resin-identifications-code>
- 15 <https://calrecycle.ca.gov/plastics/resins/>
- 16 <https://rethinkwaste.org/2020/08/31/why-recycling-is-not-the-same-everywhere/>
- 17 <https://cmr.berkeley.edu/2023/05/america-s-broken-recycling-system/>
- 18 <https://www.pbs.org/wgbh/frontline/documentary/plastic-wars/?>
- 19 <https://pubs.acs.org/doi/10.1021/acssuschemeng.2c05497>
- 20 <https://www.theatlantic.com/ideas/archive/2022/05/single-use-plastic-chemical-recycling-disposal/661141/>
- 21 <https://www.theatlantic.com/ideas/archive/2022/05/single-use-plastic-chemical-recycling-disposal/661141/>
- 22 <https://doi.org/10.1016/j.hazadv.2023.100309>
- 23 <https://www.frontiersin.org/articles/10.3389/frsus.2023.1092107/full#B44>
- 24 <https://www.newtimes.co.rw/article/141095/News/eala-votes-to-ban-polythene-bags>
- 25 <https://piib.gov.in/PressReleasePage.aspx?PRID=1882855#:~:text=Plates%2C%20cups%2C%20glasses%2C%20cutlery,less%20than%20100%20micron%2C%20stirrers.>
- 26 <https://www.nytimes.com/2022/07/31/world/asia/india-plastic-ban.html>
- 27 [https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics\\_en#:~:text=The%20EU%20is%20acting%20against,of%20the%20EU%20Member%20States.](https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics_en#:~:text=The%20EU%20is%20acting%20against,of%20the%20EU%20Member%20States.)
- 28 [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_23\\_3635](https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3635)
- 29 <https://www.un.org/en/climatechange/nations-agree-end-plastic-pollution>
- 30 <https://ohioline.osu.edu/factsheet/SAG-16>
- 31 <https://link.springer.com/article/10.1007/s10311-022-01552-4>
- 32 [https://www.sciencedirect.com/science/article/abs/pii/S2214799320300680?fr=RR-2&ref=pdf\\_download&rr=819a2778af187fff](https://www.sciencedirect.com/science/article/abs/pii/S2214799320300680?fr=RR-2&ref=pdf_download&rr=819a2778af187fff)
- 33 <https://www.un.org/en/climatechange/nations-agree-end-plastic-pollution>
- 34 <https://action.earthday.org/global-plastics-treaty>
- 35 <https://www.earthday.org/fact-sheet-single-use-plastics/>
- 36 <https://www.unep.org/interactives/beat-plastic-pollution/>
- 37 [https://linkprotect.cudasvc.com/url?a=https%3a%2f%2fwww.ciel.org%2fwp-content%2fuploads%2f2023%2f10%2fTackling-Subsidies-for-Plastic-Production\\_FINAL.pdf&c=E,1,bi0aDp7IAsLMypzhCKYKGC5YW5gisELw4y9R82sUOp8Lsbuxv3FwyWP8qVRORZ8pbLNtX-J4i-\\_xx3rvvDk1B3TthW92nm7eSfUE\\_4GppOEPa4UQ&typo=1](https://linkprotect.cudasvc.com/url?a=https%3a%2f%2fwww.ciel.org%2fwp-content%2fuploads%2f2023%2f10%2fTackling-Subsidies-for-Plastic-Production_FINAL.pdf&c=E,1,bi0aDp7IAsLMypzhCKYKGC5YW5gisELw4y9R82sUOp8Lsbuxv3FwyWP8qVRORZ8pbLNtX-J4i-_xx3rvvDk1B3TthW92nm7eSfUE_4GppOEPa4UQ&typo=1)
- 38 <https://www.scientificamerican.com/article/exxon-knew-about-climate-change-almost-40-years-ago/>