CIEL

CENTER for INTERNATIONAL ENVIRONMENTAL LAW

Breathing Plastic

The Health Impacts of Invisible Plastics in the Air

Key Messages

- **Multiple Sources, Same Origin:** Micro- and nanoplastics are ubiquitous in our environment, but they are mainly invisible. They can be intentionally produced or result from the fragmentation of larger plastics. Regardless of the source, they are part of the bigger story of plastics, as they are fundamentally a human creation.
- **Moving through Air:** Airborne micro- and nanoplastics can travel quickly and cover great distances. They can move thousands of kilometers in a matter of days to weeks, affecting even remote populations.
- **Inside the Body:** Humans can breathe airborne micro- and nanoplastics. Small particles can enter the lungs and move through the body, migrating to lymph nodes or other tissues and secondary organs via the bloodstream.
- **A Trojan Horse:** Micro- and nanoplastics act like a "Trojan Horse," hiding harmful substances and carrying them inside bodies via inhalation, absorption, and ingestion. These harmful substances include hormone-disrupting chemicals linked to diabetes, infertility, and hormone-related cancers.
- **Health Impacts:** Studies on the inhalation of micro- and nanoplastics show a series of adverse effects along the respiratory tract and beyond, ranging from irritation to the onset of cancer in cases of chronic exposure. Studies also indicate a potential range of effects in early childhood development.
- **A Toxic Cocktail:** Exposure to airborne micro- and nanoplastics is not happening in a vacuum. Humans are exposed to multiple pollutants and hazardous chemicals daily, including micro- and nanoplastics ingested via other sources, such as food or drink. While research on airborne micro- and nanoplastics is in its infancy, plastic exposure typically happens alongside other toxic substances. Regulators need to apply the precautionary principle to address the risks of combined exposure.
- **The Bigger Picture:** If no action is taken, the volume of airborne microplastic emissions will follow the expected rise in plastic production, resulting in a greater risk of toxic impacts and spreading potentially toxic chemicals. Regulators need to dramatically reduce the production of plastics and phase out hazardous chemicals.

Introduction

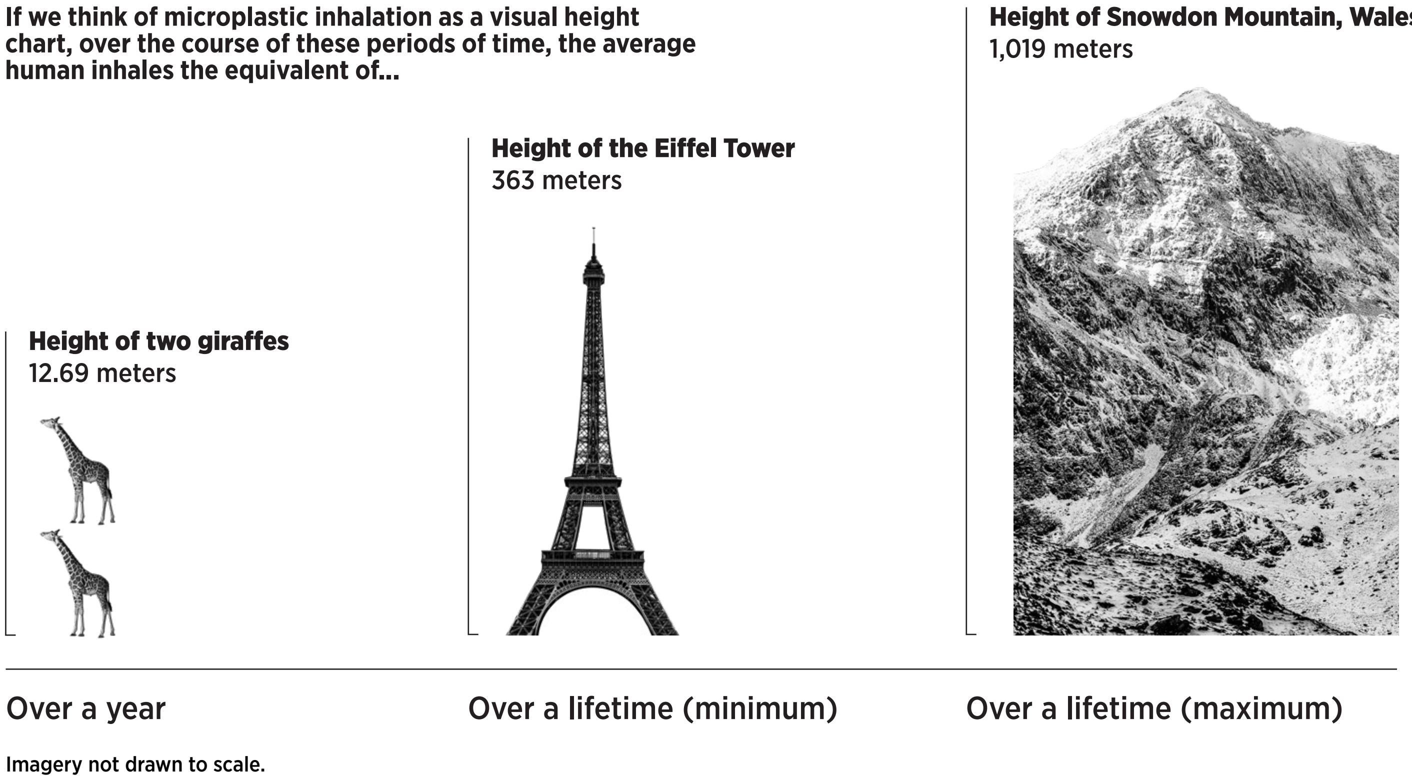
As the world's understanding of the plastics crisis grows, new facets of the problem emerge and reveal impacts on human health and the environment. Recent advances in science are allowing scientists to explore how micro- and nanoplastics form a critical piece of the plastic pollution problem. First thought to be mainly a marine pollution issue, over the last decade, scientists have discovered micro- and nanoplastics exist in every environmental compartment — from freshwater to soil and air — and in thousands of species, including humans.[1] But like climate change and hazardous chemicals, most plastics are invisible to the naked human eye, meaning their impact goes relatively unseen.[2]

Contrary to popular depictions, oceans are not "the final sink"[3] for microplastics. These tiny plastic particles can travel worldwide, ending up in urban, rural, and remote areas. They take an even faster transport pathway than oceanic currents: the atmosphere.[4] Moving through the air, micro- and nanoplastics can cover thousands of kilometers in a matter of days to weeks, creating what could be a "never-ending loop" of plastic transport.[5] The serious potential for long-range transport means that micro- and nanoplastics can affect locations and populations vast distances from the sources of plastic pollution, making microplastics "one of the most ubiquitous pollutants released by anthropogenic activities"[6] and a grave public health issue.[7] While scientists may not yet know the full scope of the health impacts of micro- and nanoplastics, the cause is undeniably clear: the production and use of plastics.

The Problem: Micro- and Nanoplastics Are Ubiquitous, Invisible, and Can Pass through the Human Nose and Lungs

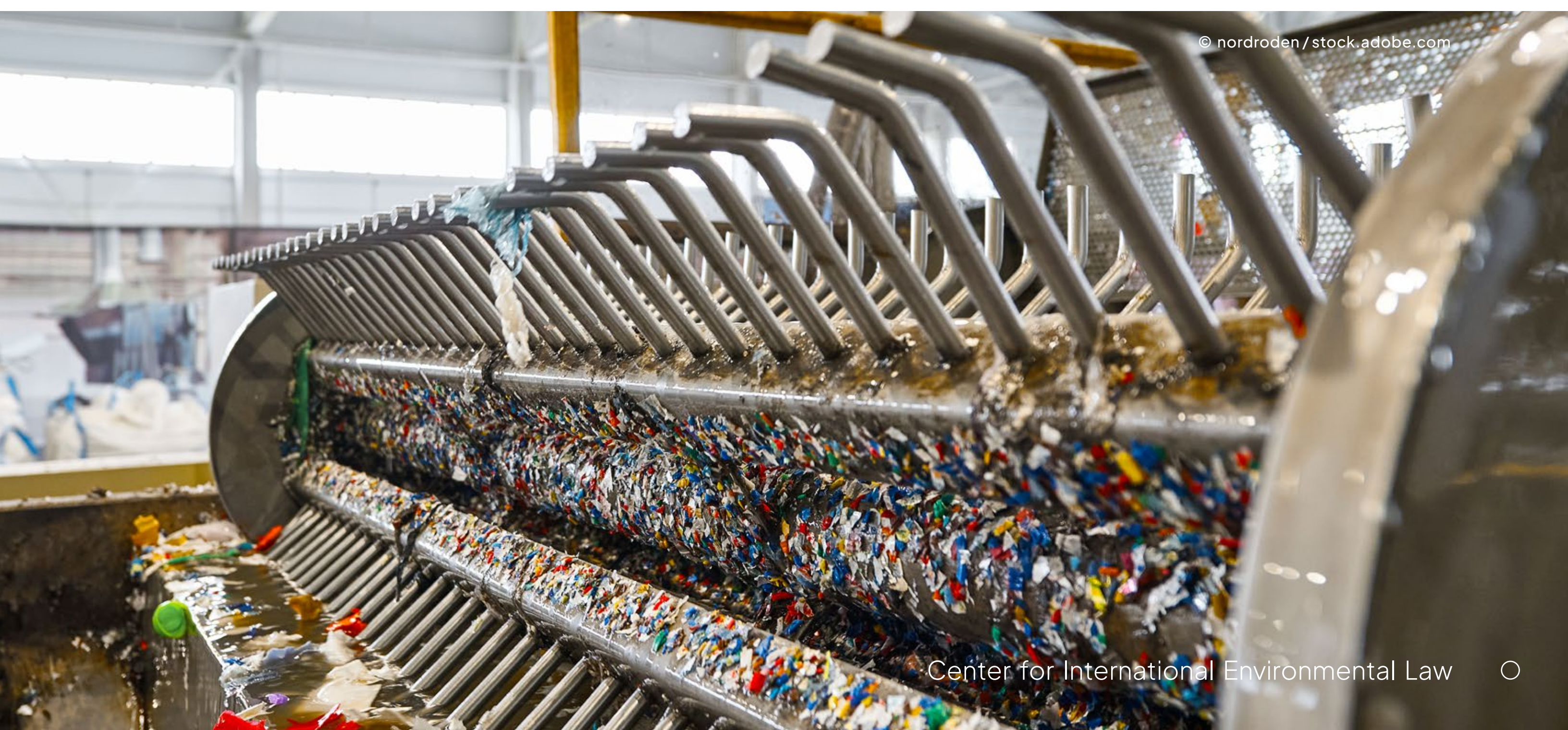
Everywhere they look, scientists are finding microplastics.[8] Often so small that they are invisible to the human eye, these tiny plastic particles are imperceptible as they pass through airways and reach the very bottom of the lungs. Scientists have found that inhalation is a major contributor to human intake of micro- and nanoplastics, and exposure rates — the amount of atmospheric micro- and nanoplastics in an individual's vicinity — can be as high as 5,700 microplastics per cubic meter.[9] It's estimated that humans can inhale up to 22,000,000 micro- and nanoplastics annually.[10] Evidence of inhalation as an uptake pathway of atmospheric microplastics was substantiated in 2022 when a study identified abundant microplastics within human lung tissue samples for the first time.[11] Estimates of human intake increase when they include ingestion of micro- and nanoplastics deposited on food and beverages.[12] Studies show that individuals can ingest up to 1 million pieces of deposited atmospheric microplastics over a year.[13]

Microplastic Inhalation over the Average Human Lifetime

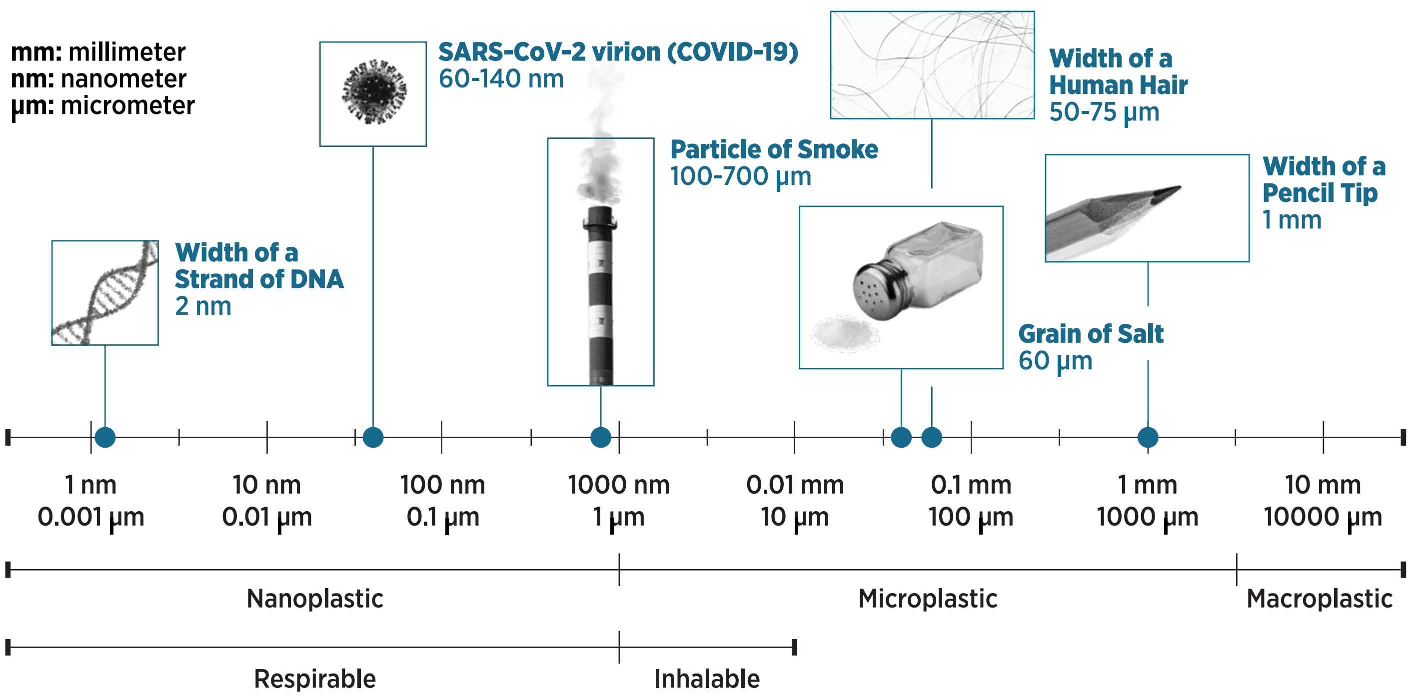


Source: [Data from an investigation by the University of Portsmouth and Good Morning Britain.]

To better understand the issue, it is essential to examine the scales used to classify plastic particles. Microplastics are plastic particles less than 5 millimeters (mm) in diameter, about the size of an orange seed.[14] Airborne microplastics, however, are much smaller — even a 0.5mm (500 micrometer (µm)) particle is considered large. When plastic fragments are below 0.001 mm in size (equivalent to 1 µm or 1,000 nanometers (nm)), they are less than 1/100th of the thickness of a human hair. Particles this small are called nanoplastics and cannot be seen by the naked eye.[15]



The Size of Micro- and Nanoplastics



Source: Based on a visual by Deonie and Steve Allen, presented in a webinar hosted by Plastic Pollution Coalition.

While size matters in assessing the risks and their regulation, the small scale does not change the fact that micro- and nanoplastics are part of a continuum of manufacturing plastic products.[16] Whether inhaled, ingested, or visible as litter, all plastics are part of the same story.

Micro- and Nanoplastics in the Air Originate from Multiple Sources

Fundamentally, atmospheric microplastics come from human creation and use of plastics. Microplastics fall into categories based on their source.[17] Primary microplastics[18] are intentionally produced at microscale for a specific use (such as agrochemicals or pharmaceuticals). In contrast, secondary microplastics result from the mechanical, chemical, and physical fragmentation of larger (macro) plastics, which can include "legacy" plastics disposed of in the environment decades ago. Every stage of the plastics life cycle, from the extraction of feedstocks to production, transport, use, disposal, and remediation, emits both primary and secondary microplastics and other hazardous substances.[19]

Airborne microplastics originate from a variety of sources. They can be found in both outdoor and indoor environments, from the inner city and industrial areas to the most remote locations on the planet — spanning the Arctic to the Antarctic.[20] The sources of primary micro- and nanoplastics include nurdles (the industry term for pellets used to transport plastic resins before production and processing into familiar plastic products),[21] personal care products,[22] pharmaceuticals,[23] their intentional introduction in agricultural seed and fertilizer products,[24] printing ink,[25] and electronics.[26] Secondary microplastics can result from discarded plastic products deteriorating, tire abrasion (including car, truck, and airplane tires),[27] and the wear and tear of synthetic textiles like clothes, carpets, furniture, and household goods.[28] Other sources include tumble dryer exhaust; thermoplastic road markings; artificial turf; waste incineration; landfills; construction; emissions from industrial processes;[29] 3D and laser printing;[30] agricultural materials;[30] degradation of paint, wallpaper, flooring, and furniture; and the opening of plastic packaging.[32]

Beyond primary and secondary forms, microplastics can be transferred from one environment to another. A study published in 2020 examined the potential for the ocean to serve as a genesis for the release of micro- and nanoplastics into the atmosphere. It discovered that microplastics found in marine environments can be released into the atmosphere via sea spray.[33]

Given the *anticipated rise in plastic production,* the volume of **microplastics will only increase** if there is no drastic reduction in plastic manufacturing.

The increase in plastic production corresponds to the presence of microplastic deposits in studies of atmospheric records. When scientists examined ombrotrophic peatlands and high-altitude lake sediments for microplastic pollution, they discovered that an increase in worldwide plastic production and plastic waste management policies over the last several decades corresponds with a rise in atmospheric microplastic deposition.[34] Given the anticipated rise in plastic production, the volume of microplastics will only increase if there is no drastic reduction in plastic manufacturing.

Atmospheric Micro- and Nanoplastics Comprise a Diverse Range of Polymers and Toxic Components

The Diverse Polymer Makeup of Atmospheric Microplastics

So far, all types of plastic polymers in other environments (i.e., soil, marine, or freshwater) have also been found in the atmosphere in micro- or nano-form. Air in living and work spaces continually mixes with outdoor air. It carries micro- and nanoplastics from both close sources (like carpets or clothing) and far-flung sources (after being transported distances up to thousands of kilometers).

Atmospheric microplastics come in a diverse range of polymer types, sizes, and shapes (also called morphologies) and represent the diverse range of plastics created and used globally. Examining microplastics from a variety of locations reveals key information, including:

- While there is an understood relationship between particle quantity and size, there are no clear trends in polymer type.
- As the particle size decreases, there is an exponential to logarithmic increase in particle quantity. For example, there are approximately ten times as many 10 μm (inhalable) microplastics as there are 100 μm microplastics.
- The lack of pattern among polymer types could be due to the cumulative nature, local and long-distance transport of these particles, and the continual creation of micro- and nanoplastics that can potentially be airborne.
- There is some indication that location (city, country, or land use), seasonality, and meteorological conditions play a part in the atmospheric polymer composition.

In general, some known atmospheric microplastic polymer types evidenced in urban, rural, or remote areas include polyethylene terephthalate/polyester (PET),[35] but also polyethylene (PE), polypropylene (PP), polystyrene (PS),[36] polycarbonate (PC),[37] and about a dozen different petrochemical-based polymers (e.g., polyacrylonitrile (PAN), polyurethane (PUR), polyamide (PA), and polyvinyl chloride (PVC)).[38]

The "Trojan Horse" Problem: Toxic Components of Micro- and Nanoplastics

The very characteristics of microplastics reveal their potential to be a dangerously potent vector for toxics and pathogens. Microplastics often have large specific surface areas and are predominantly hydrophobic, meaning they repel water. These characteristics make airborne microplastics a "Trojan Horse" capable of hiding and carrying harmful substances inside the animals or humans who inhale, absorb, and ingest them.[39] Therefore, knowing what's *inside* plastic is as important as knowing what lies *on* it.[40]

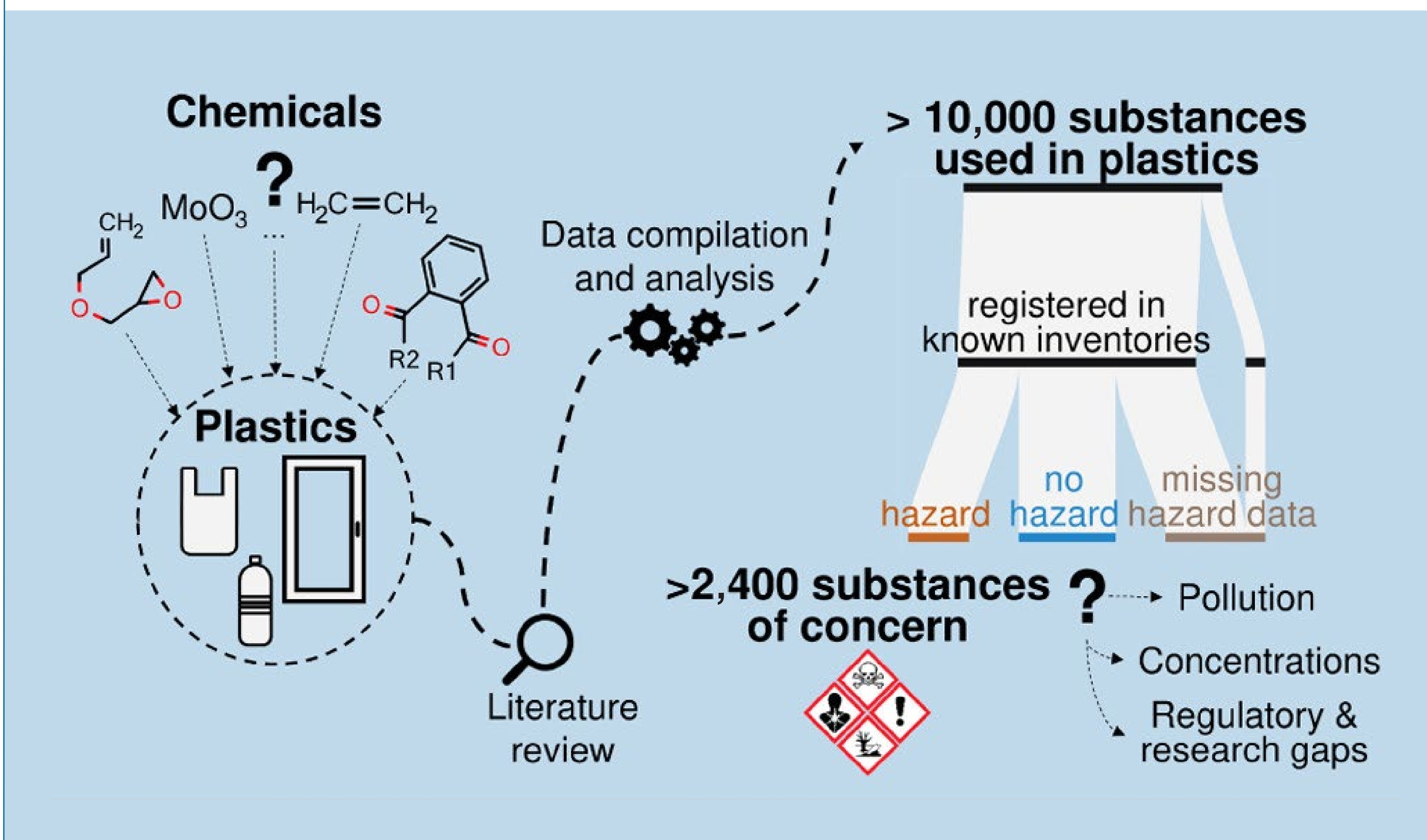
Microplastics can contain "intrinsic" pollutants introduced during manufacturing (additives such as plasticizers and flame retardants,[41] dyes and pigments, and unreacted monomers).[42] More than 10,000 substances have been identified as part of plastic production, with more than 2,400 flagged for potential concern because they meet one or more of the European Union's criteria for persistence, bioaccumulation, and toxicity. Many others have not been adequately tested.[43] Concerningly, most of the substances added to plastics are not (and cannot be) chemically bound and can therefore leach out into the environment or organisms during degradation.[44]

Further, airborne microplastics also carry associated contaminants adsorbed from the surrounding environment. These include heavy metals, persistent organic pollutants (POPs), and polycyclic aromatic hydrocarbons (PAHs).[45] Concerningly, it is not possible to know what "legacy" substances microplastics may contain. A particle may include both unknown contaminants and well-known hazardous chemicals whose uses are currently prohibited or restricted due to their persistence in the environment, such as dichloro-diphenyl-trichloroethane (DDT).[46]

While studies quantifying toxic chemicals sorped on the surface of airborne microplastics are limited,[47] the effects of indoor dust contaminated by hazardous chemicals used in plastic production are well-documented. Studies showing the effects of hazardous chemicals used in plastic production[48] are linked with reproductive toxicity, endocrine disruption, carcinogenicity, and mutagenicity, including bisphenol A (BPA), polybrominated diphenyl ethers (PBDEs), and phthalates.[49]

Alarmingly, microplastics' intrinsic pollutants and adsorbed contaminants are not the only cause for concern. Microplastics can carry antibiotic-resistant genes[50] and bacterial and viral pathogens when in water and soil.[51] Thus, it cannot be excluded that airborne microplastics may also be a carrier of microbial or viral infections[52] and serve as a potential vector for COVID-19.[53]

Chemicals Used in Plastics



Source: Reprinted from a 2021 study by Helene Wiesinger, Zhanyun Wang, and Stefanie Hellweg, titled "Deep Dive into Plastic Monomers, Additives, and Processing Aids."

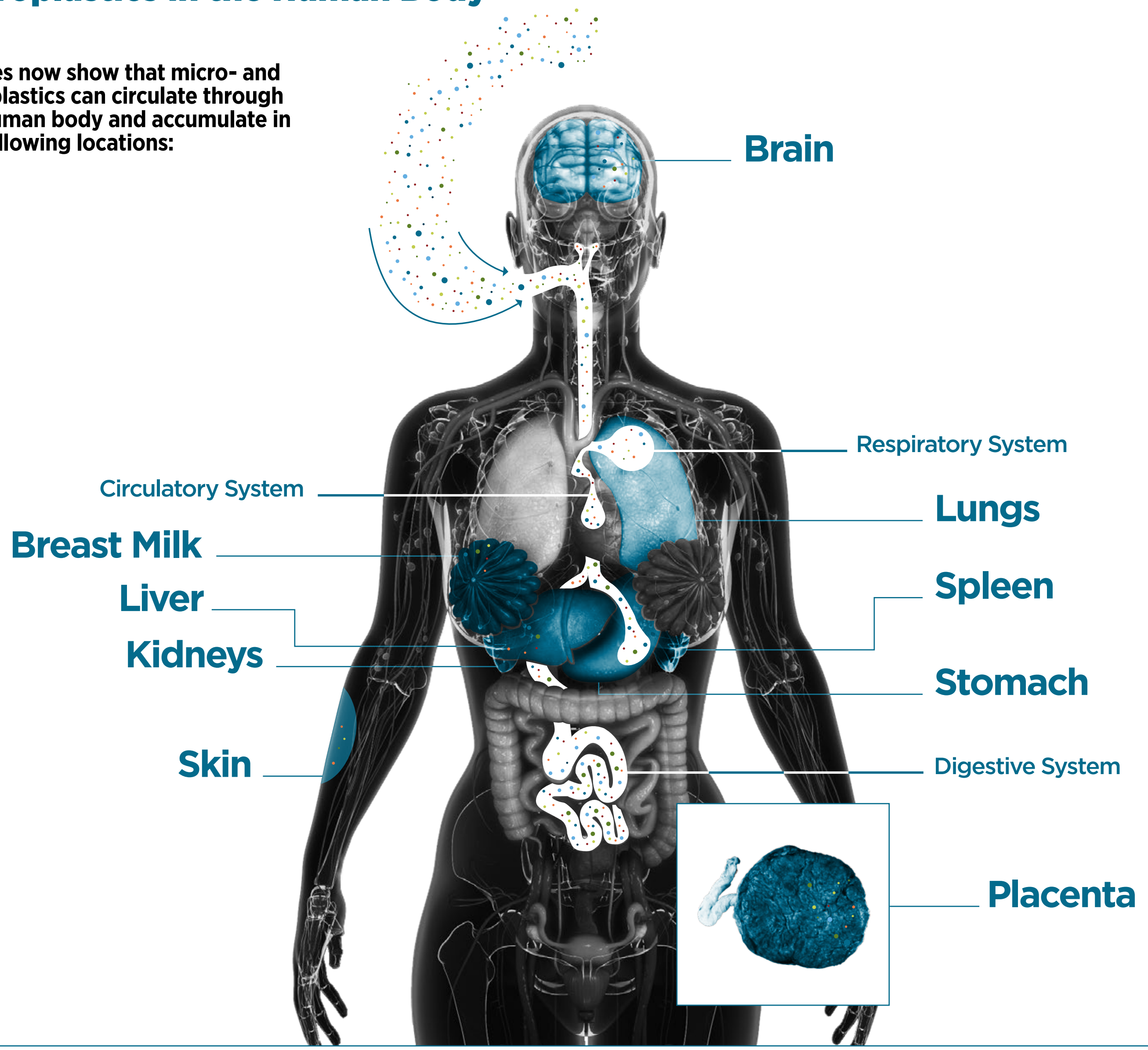
Airborne Micro- and Nanoplastics Enter Human Bodies

The Diverse Polymer Makeup of Atmospheric Microplastics

Exposure to airborne microplastics can occur through inhalation, penetration through skin pores, and ingesting foods that contain them.[54] Microplastics' reach inside the human body depends on their properties, size, shape, and an individual's metabolism, susceptibility, and lung anatomy.[55] They can enter the respiratory system through the nose or mouth before being deposited in the upper airways or deep in the lungs.[56]

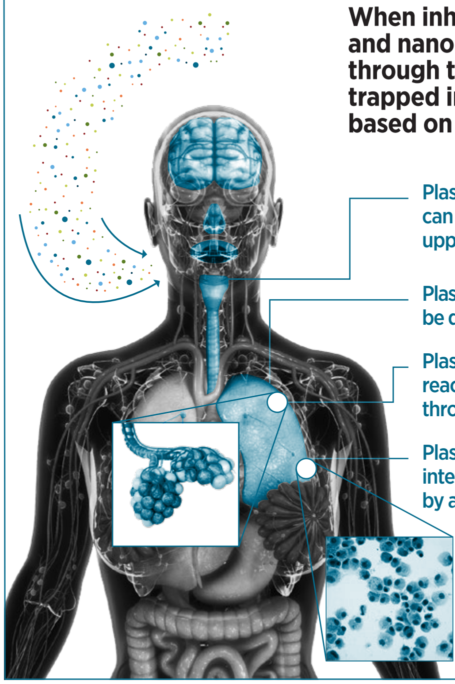
Microplastics in the Human Body

Studies now show that micro- and nanoplastics can circulate through the human body and accumulate in the following locations:



Source: Based on visuals by the United Nations Environment Programme (from the 2021 report, "From Pollution to Solution") & the World Health Organization (from the 2022 report, "Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health").

Where Microplastics Get Trapped in the Human Body



Source: Based on a visual from a 2021 paper by Alessio Facciolà et al., titled "Newly Emerging Airborne Pollutants: Current Knowledge of Health Impact of Micro and Nanoplastics."

Once there, evidence shows that micro- and nanoplastics can be transferred from the lung epithelial surface to lung tissue,[57] potentially to internal organs and the vascular system, and beyond.[58]

The Respiratory System

Particles that enter the respiratory system and can deposit in the upper airways are referred to as "inhalable" microplastics. These are typically between 5–30 µm and are small enough that they can undergo clearance, including through: (1) mucous, leading to gastrointestinal exposure,[59] (2) alveolar macrophage phagocytosis, and (3) migration through the lymphatic system.[60]

> It is *not only* microplastics' reach into the human body that is concerning; it is *also* the potential for **damage.**

Removing particles can occur through regular bodily functions like sneezing, but there may be greater difficulty if particles have particularly large surface areas[61] or if an individual has a compromised clearing mechanism.[62] The latter can occur if an individual is immunocompromised, has a pre-existing lung condition (e.g., cancer, viral infections), or experiences particle overload due to exceptionally elevated exposure.[63]

Studies in rats show that ultrafine particles ranging from <100 nm to 0.1 µm move from the nasal cavity through the olfactory bulb located in the forebrain — the more direct connection between air and internal organs bypassing the lungs.[64] This movement suggests that micro- and nanoplastics have a direct route along the upper respiratory tract to blood and the brain.[65]

Microplastics with lower density and smaller particle size have "a greater probability of reaching deep airways,"[66] including lungs. These are referred to as "respirable" microplastics.[67] Once there, microplastics likely persist and eventually accumulate, leaching any chemicals they have carried into a warm, wet, and conducive environment.[68] There is also evidence that particles transfer from the lungs to lung tissue, into cells, and through the cell barrier.[69]

It is not only microplastics' reach into the human body that is concerning; it is also the potential for damage. In smaller particles, the surface area takes up a large percentage of the overall volume, making them more reactive.[70] Therefore, it is particularly concerning that most of the plastics humans breathe in are not food grade. They originate from objects such as car tires, carpets, and clothing that do not guarantee safety standards or come with easily accessible ingredient lists for the plastics themselves, additives, or the substances carried on their surface.

Beyond the Respiratory System

Once inhaled nanoplastics overcome the pulmonary cells barrier,[71] they can move across the body, migrating to lymph nodes or other tissues and secondary organs via the bloodstream.[72] Studies in pregnant and fetal rats have found microplastics in the adult placenta, heart, spleen, fetal liver, heart, kidney, lung, and brain.[73] A recent study on humans also found microplastics in breastmilk.[74]

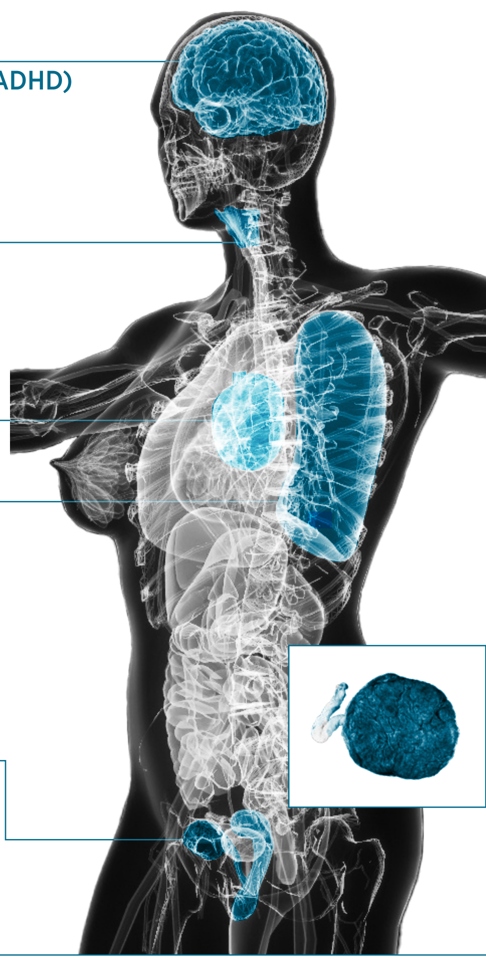
There are few targeted studies on micro- and nanoplastics' translocation to secondary organs and their consequences. Nevertheless, existing studies on metallic and carbonaceous nanoparticles highlighted their impact on the neurological, reproductive, cardiovascular, immune, and other systems.[75]

Inhalation of Airborne Micro- and Nanoplastics Presents Health Impacts

While airborne microplastics research is in its infancy, studies on the inhalation of micro- and nanoparticles of plastics show a series of adverse effects along the respiratory tract and beyond, ranging from irritation to the onset of cancer in cases of chronic exposure.[76] These adverse effects include:

- immediate asthma-like reactions;
- inflammatory reactions and fibrotic changes, like chronic bronchitis;
- lung disorders such as extrinsic allergic alveolitis and chronic pneumonia;
- pulmonary emphysema;[77]
- the development of interstitial lung diseases,[78] resulting in coughing, difficulty breathing, and a reduction in lung capacity;[79]
- oxidative stress and the formation of reactive oxygen species (ROS) and thus the ability to damage cells (cytotoxic effects);[80] and
- autoimmune diseases.[81]

Human Health Impacts of Exposure to Chemicals in Microplastics



Source: Based on visuals from a 2021 report by the United Nations Environment Programme, titled "From Pollution to Solution").

These health risks are particularly concerning for at-risk and vulnerable people and those who come into frequent contact with airborne microplastics, including workers. Exemplar studies of PVC and flock[i] workers showed how their exposure can cause persistent inflammatory stimulation and lead to pulmonary fibrosis or even cancer.[82]

The presence of micro- and nanoplastics can also concur with *other airborne pollutants,* exposing people to a **cocktail of toxins.**

Exposure to chemicals and plastics also has gender-differentiated impacts: Women and individuals assigned female at birth are generally more disproportionately impacted by toxic exposures.[83] Pregnancy and childhood are particularly susceptible to harm from airborne plastic due to the increased immune, vascular, and organ stress from growth rates. On the one hand, the impact of translocation of the *chemicals* associated with plastic and the other pollutants (e.g., BPA, PFAS, lead, and arsenic, etc.) that the particles could transform are known. On the other, it is plausible that nanoplastic particles that cross the placental barrier are taken up by the fetus and remain after birth. However, the potential translocation of the particle to the fetus and its impacts are not yet known.

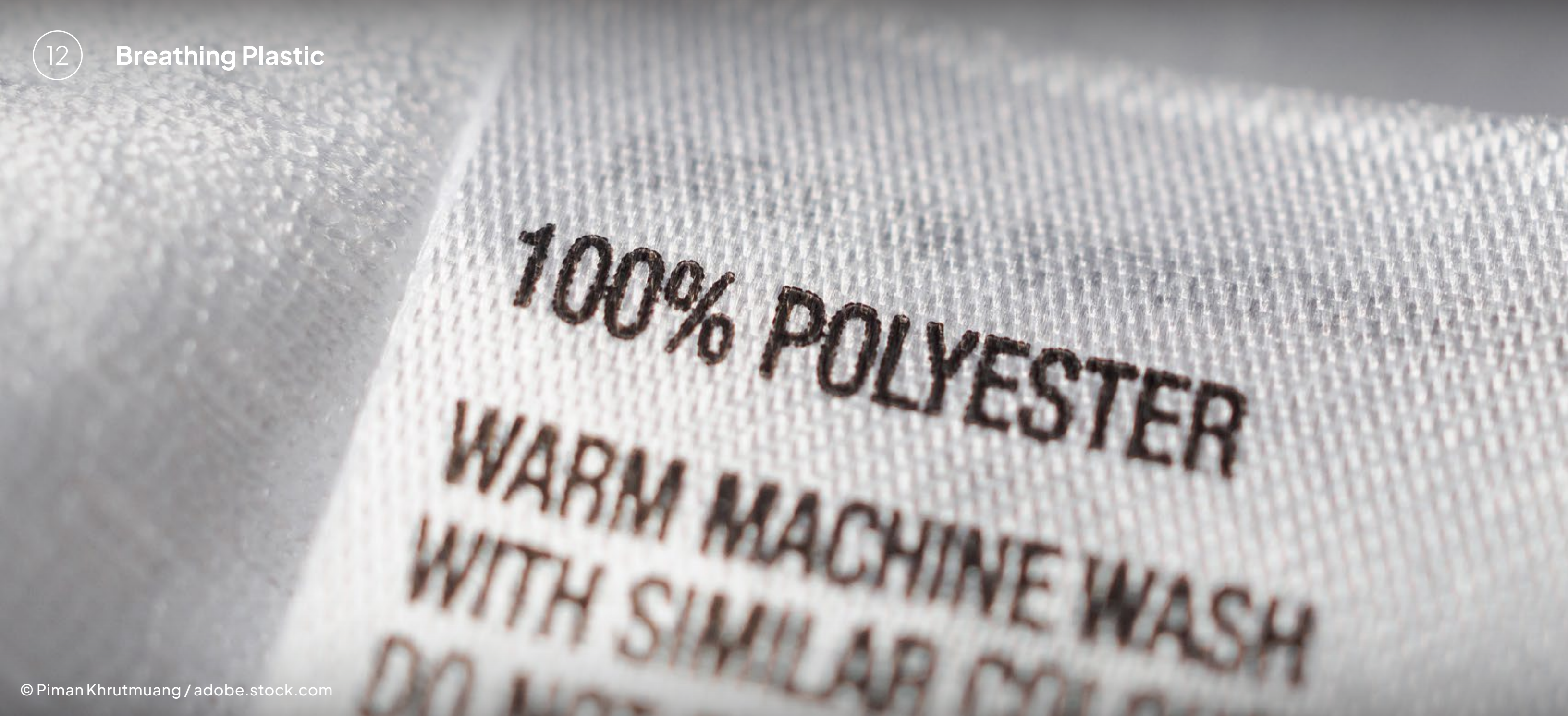
Studies indicate the potential range of effects in early childhood development. When pregnant people (and therefore fetuses) are exposed to a greater amount of phthalates, they experience shorter gestation periods, and children are born with lower birth weights.[84] In a different study, researchers observed reduced fetal and placental weight 24 hours after pulmonary exposure to nanoplastic particles.[85] Given that low birth weight is associated with a high risk of complications, in-utero exposure to plastics and chemicals may have long-term developmental effects.

While epidemiological studies have usually focused on adults,[86] the threats associated with exposure to micro- and nanoplastics are also present in childhood and adolescence. One study followed the powdering of a plastic polymer-based floor polish at a secondary school: Young teenage students exposed to the floor dust reported irritation of eyes and airways.[87]

The presence of micro- and nanoplastics can also concur with other airborne pollutants, exposing people to a cocktail of toxins. Air quality is often measured by particulate matter (PM), a figure that encompasses everything from dust to dirt, airborne pollutants, and other toxins. Because airborne microplastics appear to be so prevalent, PM10, PM2.5, and PM1 (inhalable, fine particulate, and ultrafine matter, respectively) may include some percentage of airborne micro- and nanoplastics.

In 2019, air quality, exhaust, and non-exhaust pollution were shown to be the primary cause of 6.7 million deaths worldwide.[88] Tragically, in 2020, a nine-year-old child in London died in what has been called the first certified death caused by air pollution.[89] Given the prevalence of airborne micro- and nanoplastics and their potential to act as a carrier for PAHs, metals, viruses and bacteria, organics, and other toxins,[90] it is not known how many deaths are directly related to atmospheric micro- and nanoplastics. However, the number of global deaths that are attributed to air quality should be cause for concern over the microplastics and nanoplastics contribution to this human health and premature mortality issue.

i. **Flocking** is a method to apply very short (1/10 to 1/4 inch) fibers called flock to a substrate, such as fabric, foam, or film, coated with an adhesive. Flocking is an inexpensive method of producing an imitation extra yarn fabric, flocked in a design, or a pile-like fabric where the flock has an overall pattern. See Robyne Williams, Flocking, Love to Know, https://fashion-history.lovetoknow.com/fabrics-fibers/flocking (last visited April 26, 2022).



Global Trends: Growing Emissions and Long-Range Transport of Micro- and Nanoplastics

Since air is a strong environmental media, the spread and effects of airborne microplastics can remain localized or extend far beyond the point of release. While concentration levels vary, no location remains untouched. Airborne microplastics have been collected worldwide, but especially in the Northern Hemisphere, including France, Iran, China, Japan, Vietnam, Nepal, the United States, Colombia, Saudi Arabia, South Korea, Kuwait, Greece, Romania, Pakistan, and India.[91]

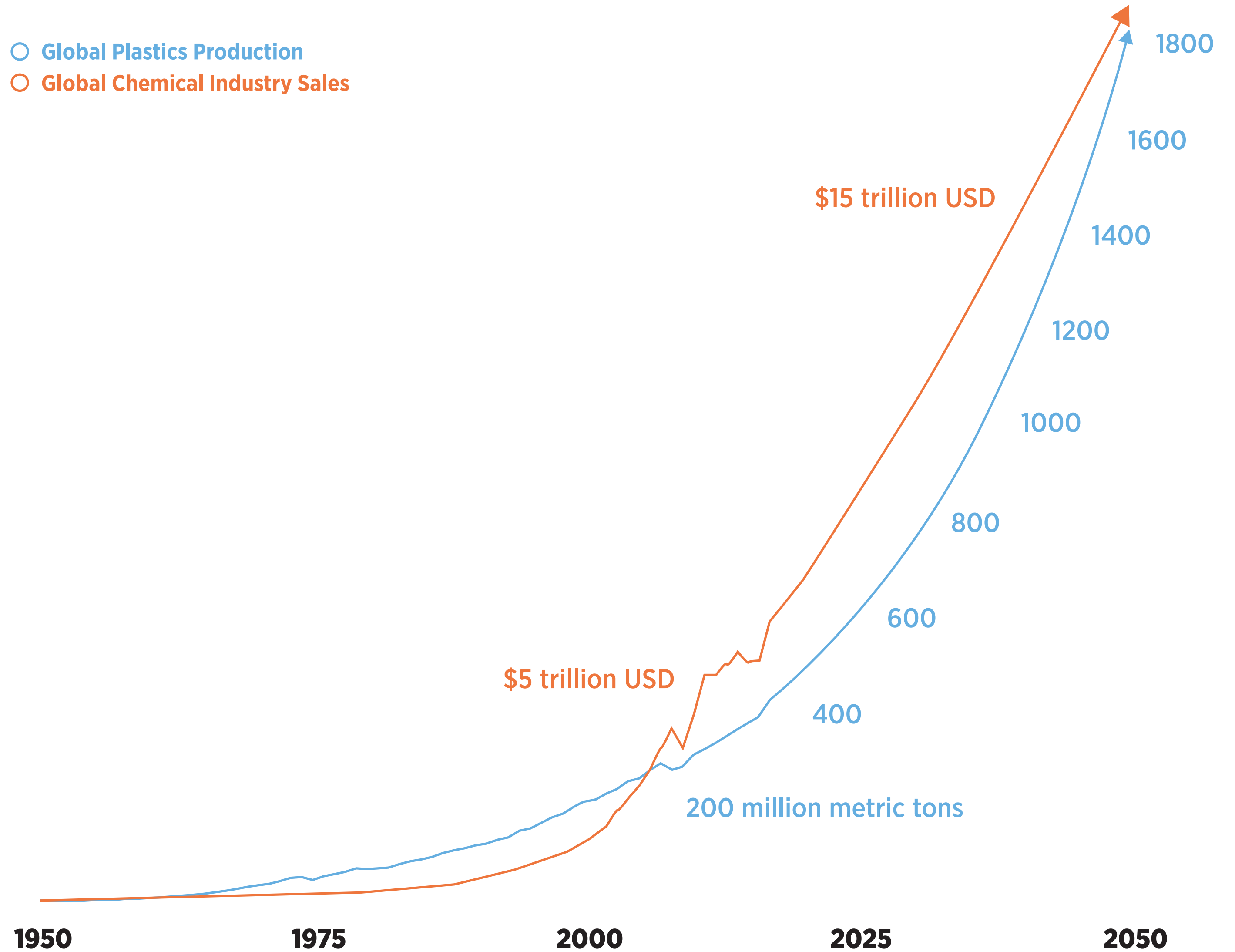
Close sources of micro- and nanoplastics, including, but not limited to, packaging, clothing, and carpets, help contribute to the substantial indoor deposition of airborne particles. Research shows that the concentration of indoor plastic particles could be even higher than what is found in the open air. This concentration is particularly concerning considering that humans (especially Americans and Europeans)[92] spend an estimated 70 to 90 percent of their time indoors.[93]

For particles released outdoors, the atmosphere can serve as an efficient and rapid transport pathway for microplastics to travel great distances.[94] The long-distance transport complicates source management as exposure within a specific location (e.g., a city street) will be a mixture of micro- and nanoplastics from local emissions, the regional atmosphere, and those traveling from outside the region (including from other countries with different management regimes). The relative speed of atmospheric transport differentiates it from slower transport seen in the marine environment.[95] Therefore, plastic released in one country could be inhaled by citizens from a neighboring or distant country relatively quickly, with smaller particles potentially transported even further and in greater quantities.

The effects of airborne microplastics are not limited to inhalation. Air can also be a vector for microplastics to contaminate soils, foods, and water.[96] Micro- and nanoplastics have been detected in drinking water,[97] and scientists discovered that they can also penetrate edible fruits and vegetables, including seeds, roots, and leaves.[98] Therefore, consuming water and food, including fruits and vegetables, may result in microplastic intake.[99]

Global trends show that the dimension of the threat will continue to grow. The production of plastic, including primary microplastics, is projected to increase in the coming decades, from 9.2 billion metric tons in 2017 to 34 billion metric tons by 2050.[100] The estimated emissions of plastic waste into aquatic ecosystems are also projected to nearly triple between 2016 and 2040[101] under "business-as-usual" practices.[102] Relatedly, chemical production growth nearly doubled between 2000 and 2017, and sales are estimated to double again before 2030.[103] The volume of airborne microplastic emissions will follow the expected rise in plastic production, use, and waste, providing greater opportunities to spread an increase of potentially toxic chemicals. The result is that every human and ecosystem will be susceptible to harm.[104]

Projected Growth in Chemicals and Plastics Production



Source: Based on a graph from a 2021 report by the International Pollutants Elimination Network, titled "Plastic's Toxic Chemical Problem").

Taking Action

While research on the human health impacts of microplastics is continuing to evolve and grow (for example, five newly-funded projects on micro- and nanoplastics and health in the European Union),[105] the existing information combined with the growing trends is enough to warrant taking action and adopting precautionary measures.

Some countries have banned specific plastic items or plan to restrict certain types of intentionally added microplastics into products. Still, no comprehensive national or regional regulation covers intentional and unintentional releases of microplastics. Specific legally binding measures could target different sources of airborne microplastics. For instance, in the case of tire dust, there should be standards and minimum requirements for tire abrasions, combined with a general objective to reduce road transport. In the case of synthetic textiles, measures should include maximum thresholds on the release of microplastics, a mandatory industrial pre-washing of garments, and the use of filters to capture microplastic releases (with a funded management process for the collection and control of the waste). These should be combined with efforts to incentivize eco-design and provide quantitative targets to reduce synthetic textile products (rather than redesign products to support the ongoing use of plastics or a proportion of recycled plastic material).

> No comprehensive *national* or *regional* regulation covers intentional and unintentional releases of microplastics.

Individual-facing mitigation actions can include wiping off the deposited dust and microplastics from floors and tables; use of high-efficiency particulate air (HEPA) filters in the home and work environments; ensuring minimal use of plastic in food preparation, cooking, and storage (including freezing and microwaving); covering a cup during drinking and rinsing dishware before use; and avoiding plastic packaging.[106] However, these mitigation measures are a temporary bandage for a systemic problem. Micro- and nanoplastic fibers will continue to shed from textile products, legacy plastics, tire dust, and air deposits,[107] resulting in the urgent need for more sustainable and longer-term solutions.

Recommendations

1. **Consider the combined "cocktail" effect.** Exposure to micro- and nanoplastics is a multi-faceted problem touching on air, water, terrestrial environments, food, and more. Regardless of how exposure occurs, it typically happens alongside other toxics. Humans are exposed to multiple pollutants and hazardous chemical compounds daily, including endocrine disruptors and POPs linked to diabetes, infertility, and hormone-related cancers. Regulators need to apply the precautionary principle to address the risks of combined exposure. Such an approach should include ensuring access to information on the petrochemical compounds in plastics products and processes (both voluntary and non-intentionally added) for ALL plastic products, not just food-grade plastics.
2. **Adopt legally binding measures without any further delay.** Self-regulation and voluntary approaches have failed to reduce plastic and microplastic pollution. Banning intentionally added microplastics is the first step. Mandatory regulations will need to reduce the production and release of plastic and its associated compounds and reduce human exposure to plastics, microplastics, and nanoplastics.
3. **Address the full life cycle of plastics.** Airborne micro- and nanoplastics are part of the bigger story of plastics. Thus, a systemic effort is needed to address the full issue, beginning with the extraction of fossil fuels and associated chemicals used in plastic production. Decision makers should further support action at the global level, supporting ambitious and effective provisions, including strict enforcement measures, in the future international legally binding agreement on plastic that will be negotiated before the end of 2024.

Endnotes

1. Steve Allen et al., "Micro(Nano)Plastics Sources, Fate, and Effects: What We Know after Ten Years of Research," Journal of Hazardous Materials Advances 6 (May 1, 2022): 1, https://doi.org/10.1016/j.hazadv.2022.100057.
2. Allen et al., 2.
3. Allen et al., 6.
4. Allen et al., 6; Deonie Allen et al., "Microplastics and Nanoplastics in the Marine-Atmosphere Environment," Nature Reviews Earth & Environment 3, no. 6 (June 2022): 393, https://doi.org/10.1038/s43017-022-00292-x.
5. Allen et al., "Micro(Nano)Plastics Sources, Fate, and Effects," 6.
6. Yulan Zhang et al., "Atmospheric Microplastics: A Review on Current Status and Perspectives," Earth-Science Reviews 203 (April 1, 2020): 11, https://doi.org/10.1016/j.earscirev.2020.103118.
7. A. Dick Vethaak and Juliette Legler, "Microplastics and Human Health," Science 371, no. 6530 (February 12, 2021): 672–74, https://doi.org/10.1126/science.abe5041.
8. "Nanoplastics -- an underestimated problem?," ScienceDaily, accessed November 6, 2021, https://www.sciencedaily.com/releases/2021/05/210504112641.htm; Albert A. Koelmans et al., "Risk Assessment of Microplastic Particles," Nature Reviews Materials 7, no. 2 (February 2022): 138–52, https://doi.org/10.1038/s41578-021-00411-y.
9. Yaowei Li et al., "Airborne Fiber Particles: Types, Size and Concentration Observed in Beijing," Science of The Total Environment 705 (February 25, 2020): 5, https://doi.org/10.1016/j.scitotenv.2019.135967; S. Allen et al., "Evidence of Free Tropospheric and Long-Range Transport of Microplastic at Pic Du Midi Observatory," Nature Communications 12, no. 1 (December 21, 2021): 5, https://doi.org/10.1038/s41467-021-27454-7; An Xu et al., "Status and Prospects of Atmospheric Microplastics: A Review of Methods, Occurrence, Composition, Source and Health Risks," Environmental Pollution 303 (June 15, 2022): 5, https://doi.org/10.1016/j.envpol.2022.119173.
10. Kieran D. Cox et al., "Human Consumption of Microplastics," Environmental Science & Technology 53, no. 12 (June 18, 2019): 7071, https://doi.org/10.1021/acs.est.9b01517; Kurunthachalam Kannan and Krishnamoorthi Vimalkumar, "A Review of Human Exposure to Microplastics and Insights Into Microplastics as Obesogens," Frontiers in Endocrinology 12 (2021): 978, https://doi.org/10.3389/fendo.2021.724989; Zhang et al., "Atmospheric Microplastics," 12; Qun Zhang et al., "A Review of Microplastics in Table Salt, Drinking Water, and Air: Direct Human Exposure," Environmental Science & Technology 54, no. 7 (April 7, 2020): 3747, https://doi.org/10.1021/acs.est.9b04535; See also Alvise Vianello et al., "Simulating Human Exposure to Indoor Airborne Microplastics Using a Breathing Thermal Manikin," Scientific Reports 9, no. 1 (June 17, 2019): 8670, https://doi.org/10.1038/s41598-019-45054-w; "World-First Investigation Finds People Are Breathing in 100 Times More Microplastics," accessed November 12, 2021, https://www.portsmouth.co.uk/news/people/world-first-investigation-by-university-of-portsmouth-and-good-morning-britain-finds-people-are-breathing-in-100-times-more-microplastics-in-homes-than-thought-3449090.
11. Lauren C. Jenner et al., "Detection of Microplastics in Human Lung Tissue Using MFTIR Spectroscopy," Science of The Total Environment 831 (July 20, 2022): 4, https://doi.org/10.1016/j.scitotenv.2022.154907.
12. Cox et al., "Human Consumption of Microplastics"; Mingzhu Fang et al., "Microplastic Ingestion from Atmospheric Deposition during Dining/Drinking Activities," Journal of Hazardous Materials 432 (June 15, 2022): 7, https://doi.org/10.1016/j.jhazmat.2022.128674.
13. Fang et al., "Microplastic Ingestion from Atmospheric Deposition during Dining/Drinking Activities," 7.
14. Richard C. Thompson et al., "Lost at Sea: Where Is All the Plastic?," Science 304, no. 5672 (May 7, 2004): 838–838, https://doi.org/10.1126/science.1094559; C. Arthur, "Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris" (University of Washington Tacoma, Tacoma, WA, USA: National Oceanic and Atmospheric Administration (NOAA), 2008), 10; Nanna B. Hartmann et al., "Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris," Environmental Science & Technology 53, no. 3 (February 5, 2019): 1040, https://doi.org/10.1021/acs.est.8b05297.
15. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), "Proceedings of the GESAMP International Workshop on Assessing the Risks Associated with Plastics and Microplastics in the Marine Environment," 2020, 26, http://www.gesamp.org/publications/gesamp-international-workshop-on-assessing-the-risks-associated-with-plastics-and-microplastics-in-the-marine-environment.
16. Denise M. Mitrano, Peter Wick, and Bernd Nowack, "Placing Nanoplastics in the Context of Global Plastic Pollution," Nature Nanotechnology 16, no. 5 (May 2021): 491, https://doi.org/10.1038/s41565-021-00888-2.
17. GESAMP, "Sources, Fate and Effects of Microplastics in the Marine Environment (Part 1)," GESAMP Reports and Studies (International Maritime Organization (IMO), 2015), 18, http://www.gesamp.org/publications/reports-and-studies-no-90.
18. "Nanoplastics Are Neither Microplastics nor Engineered Nanoparticles | Nature Nanotechnology," accessed July 16, 2022, https://www.nature.com/articles/s41565-021-00886-4 Figure 2.
19. Center for International Environmental Law (CIEL) et al., "Plastic & Health: The Hidden Costs of a Plastic Planet," accessed November 1, 2021, https://www.ciel.org/reports/plastic-health-the-hidden-costs-of-a-plastic-planet-february-2019/.
20. Yi Wang et al., "Airborne Microplastics: A Review on the Occurrence, Migration and Risks to Humans," Bulletin of Environmental Contamination and Toxicology 107, no. 4 (October 2021): 657, https://doi.org/10.1007/s00128-021-03180-0; Alex R. Aves et al., "First Evidence of Microplastics in Antarctic Snow," The Cryosphere Discussions, January 4, 2022, 7, https://doi.org/10.5194/tc-2021-385; Melanie Bergmann et al., "White and Wonderful? Microplastics Prevail in Snow from the Alps to the Arctic," Science Advances 5, no. 8 (August 14, 2019): 1, https://doi.org/10.1126/sciadv.aax1157; Alex R. Aves et al., "First Evidence of Microplastics in Antarctic Snow," The Cryosphere 16, no. 6 (June 7, 2022): 2131, https://doi.org/10.5194/tc-16-2127-2022.
21. Alice A. Horton and Simon J. Dixon, "Microplastics: An Introduction to Environmental Transport Processes," WIREs Water 5, no. 2 (2018): 1, https://doi.org/10.1002/wat2.1268.
22. Laura M. Hernandez, Nariman Yousefi, and Nathalie Tufenkji, "Are There Nanoplastics in Your Personal Care Products?," Environmental Science & Technology Letters 4, no. 7 (July 11, 2017): 283, https://doi.org/10.1021/acs.estlett.7b00187.
23. Matthew Cole et al., "Microplastics as Contaminants in the Marine Environment: A Review," Marine Pollution Bulletin 62, no. 12 (December 1, 2011): 2589, https://doi.org/10.1016/j.marpolbul.2011.09.025.
24. "Sowing a Plastic Planet: How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future (May 2022)," Center for International Environmental Law, 7, accessed July 26, 2022, https://www.ciel.org/reports/microplastics-in-agrochemicals/.
25. Mauro Scungio et al., "Characterization of Particle Emission from Laser Printers," Science of The Total Environment 586 (May 15, 2017): 626–27, https://doi.org/10.1016/j.scitotenv.2017.02.030.
26. Dae-Hyeong Kim et al., "Inorganic Semiconductor Nanomaterials for Flexible and Stretchable Bio-Integrated Electronics," NPG Asia Materials 4, no. 4 (April 2012): 1, https://doi.org/10.1038/am.2012.27.
27. Luís Fernando Amato-Lourenço et al., "An Emerging Class of Air Pollutants: Potential Effects of Microplastics to Respiratory Human Health?," Science of The Total Environment 749 (December 20, 2020): 3, https://doi.org/10.1016/j.scitotenv.2020.141676; Canada, Environment and Climate Change, Science Assessment of Plastic Pollution., 2020, 24, https://www.canada.ca/content/dam/eccc/documents/pdf/pded/plastic-pollution/Science-assessment-plastic-pollution.pdf; Pieter Jan Kole et al., "Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment," International Journal of Environmental Research and Public Health 14, no. 10 (October 2017): 3, https://doi.org/10.3390/ijerph14101265.
28. Canada, Environment and Climate Change, Science Assessment of Plastic Pollution, 24.
29. Canada, Environment and Climate Change, 24.
30. Qian Zhang et al., "Chemical Composition and Toxicity of Particles Emitted from a Consumer-Level 3D Printer Using Various Materials," Environmental Science & Technology 53, no. 20 (October 15, 2019): 12054–61, https://doi.org/10.1021/acs.est.9b04168.
31. Alessio Facciolà et al., "Newly Emerging Airborne Pollutants: Current Knowledge of Health Impact of Micro and Nanoplastics," International Journal of Environmental Research and Public Health 18, no. 6 (January 2021): 3, https://doi.org/10.3390/ijerph18062997.
32. Zahra Sobhani et al., "Microplastics Generated When Opening Plastic Packaging," Scientific Reports 10 (March 19, 2020): 4841, https://doi.org/10.1038/s41598-020-61146-4.
33. Steve Allen et al., "Examination of the Ocean as a Source for Atmospheric Microplastics," PLOS ONE 15, no. 5 (May 12, 2020): e0232746, https://doi.org/10.1371/journal.pone.0232746.
34. D. Allen et al., "Temporal Archive of Atmospheric Microplastic Deposition Presented in Ombrotrophic Peat," Environmental Science & Technology Letters 8, no. 11 (November 9, 2021): 955, https://doi.org/10.1021/acs.estlett.1c00697.
35. Kannan and Vimalkumar, "A Review of Human Exposure to Microplastics and Insights Into Microplastics as Obesogens," 4; Vianello et al., "Simulating Human Exposure to Indoor Airborne Microplastics Using a Breathing Thermal Manikin," 4; Dušan Materić et al., "Micro- and Nanoplastics in Alpine Snow: A New Method for Chemical Identification and (Semi)Quantification in the Nanogram Range," Environmental Science & Technology 54, no. 4 (February 18, 2020): 2357, https://doi.org/10.1021/acs.est.9b07540.

36. Liqi Cai et al., "Characteristic of Microplastics in the Atmospheric Fallout from Dongguan City, China: Preliminary Research and First Evidence," Environmental Science and Pollution Research 24, no. 32 (November 1, 2017): 24928–35, https://doi.org/10.1007/s11356-017-0116-x; Chunguang Liu et al., "Widespread Distribution of PET and PC Microplastics in Dust in Urban China and Their Estimated Human Exposure," Environment International 128 (July 2019): 116–24, https://doi.org/10.1016/j.envint.2019.04.024.

37. Liu et al., "Widespread Distribution of PET and PC Microplastics in Dust in Urban China and Their Estimated Human Exposure."

38. S. L. Wright et al., "Atmospheric Microplastic Deposition in an Urban Environment and an Evaluation of Transport," Environment International 136 (March 1, 2020): 4, https://doi.org/10.1016/j.envint.2019.105411.

39. Wang et al., "Airborne Microplastics," 662; Jacky Bhagat, Norihiro Nishimura, and Yasuhito Shimada, "Toxicological Interactions of Microplastics/Nanoplastics and Environmental Contaminants: Current Knowledge and Future Perspectives," Journal of Hazardous Materials 405 (March 5, 2021): 4, https://doi.org/10.1016/j.jhazmat.2020.123913.

40. Koelmans et al., "Risk Assessment of Microplastic Particles," 3.

41. Wang et al., "Airborne Microplastics," 662.

42. Johnny Gasperi et al., "Microplastics in Air: Are We Breathing It In?," Current Opinion in Environmental Science & Health, Micro and Nanoplastics Edited by Dr. Teresa A.P. Rocha-Santos, 1 (February 1, 2018): 4, https://doi.org/10.1016/j.coesh.2017.10.002.

43. Helene Wiesinger, Zhanyun Wang, and Stefanie Hellweg, "Deep Dive into Plastic Monomers, Additives, and Processing Aids," Environmental Science & Technology 55, no. 13 (July 6, 2021): 9339–51, https://doi.org/10.1021/acs.est.1c00976.

44. A Scientific Perspective on Microplastics in Nature and Society (DE: Science Advice for Policy by European Academies, 2019), 47, https://doi.org/10.26356/microplastics.

45. Gasperi et al., "Microplastics in Air," 4; Rafael Trevisan, Daniel Uzochukwu, and Richard T. Di Giulio, "PAH Sorption to Nanoplastics and the Trojan Horse Effect as Drivers of Mitochondrial Toxicity and PAH Localization in Zebrafish," Frontiers in Environmental Science 8 (2020): 2, 12, https://www.frontiersin.org/articles/10.3389/fenvs.2020.00078; Elisabeth S. Gruber et al., "To Waste or Not to Waste: Questioning Potential Health Risks of Micro- and Nanoplastics with a Focus on Their Ingestion and Potential Carcinogenicity," Exposure and Health, March 22, 2022, 9, https://doi.org/10.1007/s12403-022-00470-8; Ming Zhang and Liheng Xu, "Transport of Micro- and Nanoplastics in the Environment: Trojan-Horse Effect for Organic Contaminants," Critical Reviews in Environmental Science and Technology 52, no. 5 (March 4, 2022): 833, https://doi.org/10.1080/10643389.2020.1845531.

46. Bhagat, Nishimura, and Shimada, "Toxicological Interactions of Microplastics/Nanoplastics and Environmental Contaminants," 2; Shuqin Liu et al., "Combined Effect of Microplastics and DDT on Microbial Growth: A Bacteriological and Metabolomics Investigation in Escherichia Coli," Journal of Hazardous Materials 407 (April 5, 2021): 4, https://doi.org/10.1016/j.jhazmat.2020.124849.

47. Christian Ebere Enyoh et al., "Airborne Microplastics: A Review Study on Method for Analysis, Occurrence, Movement and Risks," Environmental Monitoring and Assessment 191, no. 11 (October 24, 2019): 668, https://doi.org/10.1007/s10661-019-7842-0.

48. Gasperi et al., "Microplastics in Air."

49. Gasperi et al., "Microplastics in Air," 4.

50. Yi Liu et al., "Microplastics Are a Hotspot for Antibiotic Resistance Genes: Progress and Perspective," Science of The Total Environment 773 (June 2021): 145643, https://doi.org/10.1016/j.scitotenv.2021.145643.

51. Renjith VishnuRadhan et al., "Atmospheric Plastics- a Potential Airborne Fomite with an Emerging Climate Signature," The Journal of Climate Change and Health 3 (August 1, 2021): 100037, https://doi.org/10.1016/j.joclim.2021.100037.

52. VishnuRadhan et al.

53. Qingyang Liu and James Schauer, "Airborne Microplastics from Waste as a Transmission Vector for COVID-19," Aerosol and Air Quality Research 21 (2021): 200439, https://doi.org/10.4209/aaqr.2020.07.0439; Enyoh Ebere et al., "Novel Coronavirus (SARS-CoV-2) and Airborne Microplastics," Journal of Materials and Environmental Science, August 5, 2020.

54. Enyoh et al., "Airborne Microplastics."

55. Enyoh et al.

56. Gasperi et al., "Microplastics in Air," 3; Joanne M. Donkers et al., "Advanced Epithelial Lung and Gut Barrier Models Demonstrate Passage of Microplastic Particles," Microplastics and Nanoplastics 2, no. 1 (January 28, 2022): 2, https://doi.org/10.1186/s43591-021-00024-w.

57. J. L. Pauly et al., "Inhaled Cellulosic and Plastic Fibers Found in Human Lung Tissue.," Cancer Epidemiology and Prevention Biomarkers 7, no. 5 (May 1, 1998): 425, https://cebp.aacrjournals.org/content/7/5/419.

58. Heather A. Leslie et al., "Discovery and Quantification of Plastic Particle Pollution in Human Blood," Environment International, March 24, 2022, 5–7, https://doi.org/10.1016/j.envint.2022.107199.

59. Gasperi et al., "Microplastics in Air," 3.

60. Facciolà et al., "Newly Emerging Airborne Pollutants," 5.

61. Wang et al., "Airborne Microplastics," 662.

62. Gasperi et al., "Microplastics in Air," 6.

63. Joana Correia Prata, "Airborne Microplastics: Consequences to Human Health?," Environmental Pollution 234 (March 1, 2018): 119, https://doi.org/10.1016/j.envpol.2017.11.043; Canada, Environment and Climate Change, Science Assessment of Plastic Pollution, 67.

64. G Oberdörster et al., "Translocation of Inhaled Ultrafine Particles to the Brain," Inhalation Toxicology 16 (June 1, 2004): 437–45, https://doi.org/10.1080/08958370490439597.

65. Sijia Liu et al., "Size-Dependent Neurotoxicity of Micro- and Nanoplastics in Flowing Condition Based on an in Vitro Microfluidic Study," SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, April 19, 2022), https://doi.org/10.2139/ssrn.4087423; Xiaoyan Liu et al., "Bioeffects of Inhaled Nanoplastics on Neurons and Alteration of Animal Behaviors through Deposition in the Brain," Nano Letters 22, no. 3 (February 9, 2022): 1091–99, https://doi.org/10.1021/acs.nanolett.1c04184.

66. Facciolà et al., "Newly Emerging Airborne Pollutants," 5.

67. Gasperi et al., "Microplastics in Air," 3; Joanne M. Donkers et al., "Advanced Epithelial Lung and Gut Barrier Models Demonstrate Passage of Microplastic Particles," Microplastics and Nanoplastics 2, no. 1 (January 28, 2022): 2, https://doi.org/10.1186/s43591-021-00024-w.

68. Gasperi et al., "Microplastics in Air," 3.

69. Pauly et al., "Inhaled Cellulosic and Plastic Fibers Found in Human Lung Tissue;" Jenner et al., "Detection of Microplastics in Human Lung Tissue Using MFTIR Spectroscopy."

70. Canada, Environment and Climate Change, Science Assessment of Plastic Pollution, 68.

71. Facciolà et al., "Newly Emerging Airborne Pollutants," 2.

72. Wang et al., "Airborne Microplastics," 662.

73. Sara B. Fournier et al., "Nanopolystyrene Translocation and Fetal Deposition after Acute Lung Exposure during Late-Stage Pregnancy," Particle and Fibre Toxicology 17, no. 1 (October 24, 2020): 55, https://doi.org/10.1186/s12989-020-00385-9; Facciolà et al., "Newly Emerging Airborne Pollutants."

74. Antonio Ragusa et al., "Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk," Polymers 14, no. 13 (January 2022): 2700, https://doi.org/10.3390/polym14132700.

75. P. A. Stapleton, "Microplastic and Nanoplastic Transfer, Accumulation, and Toxicity in Humans," Current Opinion in Toxicology 28 (December 1, 2021): 62–69, https://doi.org/10.1016/j.cotox.2021.10.001.

76. Facciolà et al., "Newly Emerging Airborne Pollutants," 7.

77. Facciolà et al., 9.

78. Amato-Lourenço et al., "An Emerging Class of Air Pollutants."

79. Gasperi et al., "Microplastics in Air," 3.

80. Amato-Lourenço et al., "An Emerging Class of Air Pollutants."

81. Facciolà et al., "Newly Emerging Airborne Pollutants," 7.

82. Facciolà et al., "Newly Emerging Airborne Pollutants," 7; Guanglong Chen, Qingyuan Feng, and Jun Wang, "Mini-Review of Microplastics in the Atmosphere and Their Risks to Humans," Science of The Total Environment 703 (February 10, 2020): 5, https://doi.org/10.1016/j.scitotenv.2019.135504.

83. Marie Vahter et al., "Implications of Gender Differences for Human Health Risk Assessment and Toxicology," Environmental Research 104 (June 1, 2007): 70–84, https://doi.org/10.1016/j.envres.2006.10.001; Sara Brosché, "Women, Chemicals and the SDGs," December 4, 2020, https://saicmknowledge.org/library/women-chemicals-and-sdgs; Women Engage for a Common Future (WECF), "Plastics, Gender and the Environment," November 2017, https://bit.ly/3FJgWV7.

84. Fournier et al., "Nanopolystyrene Translocation and Fetal Deposition after Acute Lung Exposure during Late-Stage Pregnancy"; Giuseppe Latini et al., "In Utero Exposure to Di-(2-Ethylhexyl)Phthalate and Duration of Human Pregnancy.," Environmental Health Perspectives 111, no. 14 (November 2003): 1784, https://doi.org/10.1289/ehp.6202.

85. Fournier et al., "Nanopolystyrene Translocation and Fetal Deposition after Acute Lung Exposure during Late-Stage Pregnancy."

86. Kam Sripada et al., "A Children's Health Perspective on Nano- and Microplastics," Environmental Health Perspectives 130, no. 1: 015001, accessed February 2, 2022, https://doi.org/10.1289/EHP9086.

87. B. Malmberg et al., "Powdering Floor Polish and Mucous Membrane Irritation in Secondary School Pupils," International Archives of Occupational and Environmental Health 73, no. 7 (September 1, 2000): 498–502, https://doi.org/10.1007/s004200000176.

88. Philip J. Landrigan, "Air Pollution and Health," The Lancet Public Health 2, no. 1 (January 1, 2017): e4–5, https://doi.org/10.1016/S2468-2667(16)30023-8; Richard Fuller et al., "Pollution and Health: A Progress Update," The Lancet Planetary Health 6, no. 6 (June 1, 2022): e535–47, https://doi.org/10.1016/S2542-5196(22)00090-0.

89. Assistant Coroner Philip Barlow, “Regulation 28: Report to Prevent Future Deaths. Annex A.,” https://www.judiciary.uk/wp-content/uploads/2021/04/Ella-Kissi-Debrah-2021-0113-1.pdf, April 20, 2021.

90. Razegheh Akhbarizadeh et al., “Suspended Fine Particulate Matter (PM2.5), Microplastics (MPs), and Polycyclic Aromatic Hydrocarbons (PAHs) in Air: Their Possible Relationships and Health Implications,” Environmental Research 192 (January 1, 2021): 110339, https://doi.org/10.1016/j.envres.2020.110339.

91. Junjie Zhang, Lei Wang, and Kurunthachalam Kannan, “Microplastics in House Dust from 12 Countries and Associated Human Exposure,” Environment International 134 (January 1, 2020): 105314, https://doi.org/10.1016/j.envint.2019.105314; Wang et al., “Airborne Microplastics,” 657.

92. Amato-Lourenço et al., “An Emerging Class of Air Pollutants.”

93. Stapleton, “Microplastic and Nanoplastic Transfer, Accumulation, and Toxicity in Humans.”Luís Fernando Amato-Lourenço et al., “An Emerging Class of Air Pollutants: Potential Effects of Microplastics to Respiratory Human Health?,” Science of The Total Environment 749 (December 20, 2020): 141676, https://doi.org/10.1016/j.scitotenv.2020.141676.

94. Allen et al., “Micro(Nano)Plastics Sources, Fate, and Effects,” 6; Allen et al., “Microplastics and Nanoplastics in the Marine-Atmosphere Environment,” 393.

95. Allen et al., “Microplastics and Nanoplastics in the Marine-Atmosphere Environment,” 393.

96. Qun Zhang et al., “Microplastic Fallout in Different Indoor Environments,” Environmental Science & Technology 54, no. 11 (June 2, 2020): 6530–39, https://doi.org/10.1021/acs.est.0c00087.

97. Zhang et al., “A Review of Microplastics in Table Salt, Drinking Water, and Air.”

98. Gea Oliveri Conti et al., “Micro- and Nano-Plastics in Edible Fruit and Vegetables. The First Diet Risks Assessment for the General Population,” Environmental Research 187 (August 1, 2020): 4, https://doi.org/10.1016/j.envres.2020.109677; Gustavo Führ Hartmann et al., “Phytotoxic Effects of Plastic Pollution in Crops: What Is the Size of the Problem?,” Environmental Pollution 292 (January 1, 2022): 118420, https://doi.org/10.1016/j.envpol.2021.118420; Lianzhen Li et al., “Effective Uptake of Submicrometre Plastics by Crop Plants via a Crack-Entry Mode,” Nature Sustainability 3, no. 11 (November 2020): 929–37, https://doi.org/10.1038/s41893-020-0567-9.

99. Claudia Campanale et al., “A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health,” International Journal of Environmental Research and Public Health 17, no. 4 (February 13, 2020): 15, https://doi.org/10.3390/ijerph17041212; Li et al., “Effective Uptake of Submicrometre Plastics by Crop Plants via a Crack-Entry Mode.”

100. United Nations Environment Programme, “From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution,” UNEP - UN Environment Programme, October 20, 2021, 17, http://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution.

101. UNEP, “From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution;” Lau et al., “Evaluating Scenarios toward Zero Plastic Pollution,” 3.

102. Winnie W. Y. Lau et al., “Evaluating Scenarios toward Zero Plastic Pollution,” Science 369, no. 6510 (September 18, 2020): 3, https://doi.org/10.1126/science.aba9475.

103. UN Environment, “Global Chemicals Outlook II: From Legacies to Innovative Solutions,” UNEP - UN Environment Programme, November 3, 2019, 24, http://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions.

104. VishnuRadhan et al., “Atmospheric Plastics- a Potential Airborne Fomite with an Emerging Climate Signature.”

105. See, for instance, the EU-funded research CUSP: “About - CUSP Cluster,” accessed January 13, 2022, https://cusp-research.eu/about/.

106. Fang et al., “Microplastic Ingestion from Atmospheric Deposition during Dining/Drinking Activities,” 4.

107. Zhang et al., “Microplastic Fallout in Different Indoor Environments.”

This issue brief was authored by Giulia Carlini. It was edited by Cate Bonacini, with support from Lani Furbank. The research and analysis for the brief benefitted from the expertise of Dr. Deonie Allen and Dr. Steve Allen. Special thanks to David Azoulay and Dr. Therese Karlsson, for their reviews and/or insights.

Please send comments or questions to gcarlini@ciel.org.

Design & Layout: Tyler Unger

Cover Photo: struvictory / stock.adobe.com

ciel.org

@ciel_org

@ciel_tweets

facebook.com/ciel.org

CENTER for INTERNATIONAL ENVIRONMENTAL LAW