SOWING A PLASTIC PLANET

How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future

CIEL
CENTER for INTERNATIONAL ENVIRONMENTAL LAW

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CENTER for INTERNATIONAL ENVIRONMENTAL LAW

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Executive Summary and Key Findings

Tiny particles of plastic — or microplastic — are accumulating across the planet in even the most remote areas, in the air, in water, in soil, in plants, and in animals, including in our bodies. Humans are ingesting and breathing plastics and the toxins they contain through this continued environmental exposure. One of the least known and most concerning sources of microplastic pollution is their deliberate addition to synthetic fertilizers and pesticides used in industrial agriculture.

Plastics are everywhere in agriculture, from greenhouse films and landscaping fabrics to crop coverings and product packaging. Many of these uses provide pathways for plastic contamination. But the application of plastic-coated agrochemicals to soils and crops directly introduces microplastic into the environment and potentially into the food supply. It also compounds the health and environmental hazards posed by agrochemicals themselves.

Synthetic fertilizers and pesticides, derived primarily from oil- and gas-based feedstocks, are already some of the most toxic substances in use today. Encapsulating them in microplastic, itself fossil fuel in another form, only heightens the risks. By providing a vector that carries toxins, is easily dispersed, and is readily absorbed in the human body, the microplastic coating on fertilizers and pesticides combines the harmful impacts of intentional plastic pollution and the overuse of agrochemicals, aggravating existing threats to human, ecological, and planetary health. One hundred percent of the microplastic applied directly to soil and crops has the potential to pollute. Because of its deliberate and controlled nature, microplastic pollution from plastic-coated agrochemicals is especially egregious, but it is also readily preventable. The only barriers are public awareness of the problem and political will to tackle it at its source by regulating the plastics industry.

This briefing exposes the underrecognized threat presented by the intentional use of microplastics in the agricultural sector and identifies priorities for halting this pervasive but preventable source of pollution. It reveals yet another facet of the toxic triad formed by agrochemicals, plastics, and the fossil fuels used to make them. Exposing critical questions and evidentiary gaps in the industry's portrayal of plastic-coated agrochemicals as efficient or sustainable, the briefing outlines why encapsulating pesticides and fertilizers in plastic only compounds hazards, magnifying environmental and health risks. The briefing concludes with recommendations on ending the use of intentionally added microplastics in agriculture and beyond; enhancing understanding of the harms of microplastics; curbing dependency on industrial agriculture and synthetic fertilizers and pesticides; and adopting a comprehensive global approach to plastics regulation.

Key Findings

- Despite receiving little public attention to date, the agricultural sector is one of the most significant users of intentionally added microplastics.
- The deliberate dispersion of microplastics in the environment through the application of plastic-coated fertilizers and pesticides is one of the most direct and preventable sources of growing microplastic pollution in agricultural soils.
- The use of plastic-coated synthetic fertilizers and pesticides is rising, with producers marketing their "controlled-release" function as key to sustainable, climate-friendly agriculture.
- Encapsulating agrochemicals in plastic and spreading them across soils and crops only compounds the significant health and environmental risks posed by agrochemicals and may exacerbate their harmful impacts.
- Governments should act now to close regulatory gaps and comprehensively ban the intentional use of microplastics in agriculture and other industries.

Introduction

We are increasingly living on a plastic planet. Due to the explosion in plastic production and use, plastic pollution has grown exponentially in recent years. Today, plastic pervades even the most remote areas of the globe, from the top of Mount Everest to the bottom of the Mariana Trench.[1] We now know that plastic pollution extends far beyond oceans, affecting every ecosystem on Earth. Plastics have been detected in drinking water, farm soils, food supplies, and even in the air we breathe.[2] They have also been found in human blood, tissue, and waste. Our bodies are exposed to plastic particles through an array of pathways, some of which scientists are only beginning to understand.[3]

Plastic contamination of the food supply doesn't start with plastic packaging on the grocery store shelf. Rather, it begins with the seeds and soil from which food is grown. Emerging evidence indicates that tiny plastic fragments, or microplastics, are increasingly accumulating in agricultural soils.[4] Nearly one-third of all plastic waste could end up in soil environments.[5] It is estimated that microplastic pollution is four to twenty-three times greater in terrestrial soils than in marine environments.[6]

Plastics enter the soil through multiple channels. Atmospheric deposition plays a large role, as do various agricultural practices, such as the use of plastic mulching films, wastewater irrigation, and the application of biosolids and compost.[7] Yet there is one significant pathway that receives little attention, despite being one of the most direct and controllable sources of microplastics in the environment: the application of synthetic fertilizers and pesticides containing *intentionally added microplastics*. The deliberate deployment of plastic particles in agrochemical products, including those applied to food crops, poses significant risks to health and the environment.

Commercial pesticides and fertilizers are toxic and ecologically harmful on their own, and their overuse is causing adverse effects on human health and the environment.[8] Adding a plastic casing to pesticides and fertilizers only compounds the negative effects of the chemicals. Plastics adsorb and accumulate toxins, including persistent organic pollutants (POPs) and other "forever chemicals"— substances that do not degrade or disappear, and cause irreparable harm to health and the environment.[9] Consequently, the deliberate use of plastic in the manufacture of agrochemicals increases the presence of contaminated plastic in the environment and food chains.

Addressing the noxious combination of plastics and agrochemicals is just the tip of the iceberg when it comes to understanding and unraveling the linkages between fossil fuels and industrial agriculture. Plastics, like most chemical fertilizers and pesticides, are derived from oil and gas.[10] The use of plastics and agrochemicals in tandem exemplifies overreliance on fossil fuel-based products and highlights its interconnected impacts on climate change, biodiversity loss, and toxic plastic pollution.

This briefing exposes the growing use of microplastics in agrochemical products, the industry's promotion of this practice, and its threats to human health and the environment. It concludes that, in the face of known risks and the significant probability that plastic-coated fertilizers and pesticides only add to existing harm from toxic chemicals and microplastic, their production and use should be banned.

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PART 1

Microplastics: Tiny Plastic Particles That Persist in the Environment — and in Our Bodies

The plastics ubiquitous in the environment come in a variety of shapes and sizes. The tiniest particles — micro- and nanoplastics — are among the hardest to detect and are accumulating in ever-greater amounts. Plastics are synthetic polymers, large chains of repeating molecules derived almost exclusively from fossil fuels. Microplastics are microscopic particles of these polymers smaller than 5 millimeters. They can fragment into even smaller particles called nanoplastics. Because micro- and nanoplastics do not easily degrade, they have the potential to persist in the environment.[11] Widespread, easily ingested through food and drinking water, and potentially transferable within food chains,[12] microplastics constitute what the United Nations Special Rapporteur on toxics has called "an invisible threat"[13] to human rights and the environment.

Primary Microplastics Pollute by Design

Microplastics fall into two categories: "primary" and "secondary." Primary microplastics are deliberately manufactured at the microscale. "Secondary" microplastics result from the fragmentation of larger plastics.[14] Primary microplastics are used in a wide range of industrial and consumer products, such as cosmetics, cleansers, and paints, as well as synthetic fertilizers and pesticides — the subject of this briefing.[15]

The generation of secondary microplastics is an unintended though entirely foreseeable consequence of making, using, and disposing of plastics. Therefore, reducing secondary microplastics requires addressing the plastic pollution problem more broadly. And ultimately, reducing plastic pollution requires dramatically reducing plastic production. But primary microplastics are in a different category. They do not become tiny fragments through degradation over time; they are intentionally manufactured as tiny particles that readily disperse and persist in the environment. As discussed below, their production and use should be banned. Halting the use of microplastics in agrochemicals is a critical step toward that end.

Microplastics Accumulate in Ecosystems and Food Chains

Evidence indicates that the continuous release and increased environmental accumulation of microplastics have adverse environmental and human health impacts.[16] Plastics also emit trace greenhouse gases (ethylene and methane) as they photodegrade, or slowly break down in the presence of sunlight.[17] The growing presence of microplastics in the environment, particularly in agricultural soils, means there is an increased potential for these tiny plastic particles to end up in our food and, ultimately, our bodies. Consuming food and water that have been contaminated with micro- and nanoplastics is the main route of ingestion

Glossary

Controlled-release technology: A method, used with both fertilizers (controlled-release fertilizers or CRFs) and pesticides, in which a physical barrier — typically a polymer coating — slows or modulates the release of the coated chemical ingredient(s).

Microencapsulation: A process in which tiny particles of the active ingredient(s) are surrounded by a coating, generally made of polymers, to create small capsules.

Plastic: Material made of synthetic polymers usually containing additives and non-intentionally added substances (NIAS).

Microplastics: Tiny plastic pieces smaller than 5 mm consisting of synthetic polymers that have low solubility in water and do not easily degrade. Microplastics can fragment into even smaller particles called nanoplastics (usually identified as plastic particles within the 1 to 1,000 nanometer range).

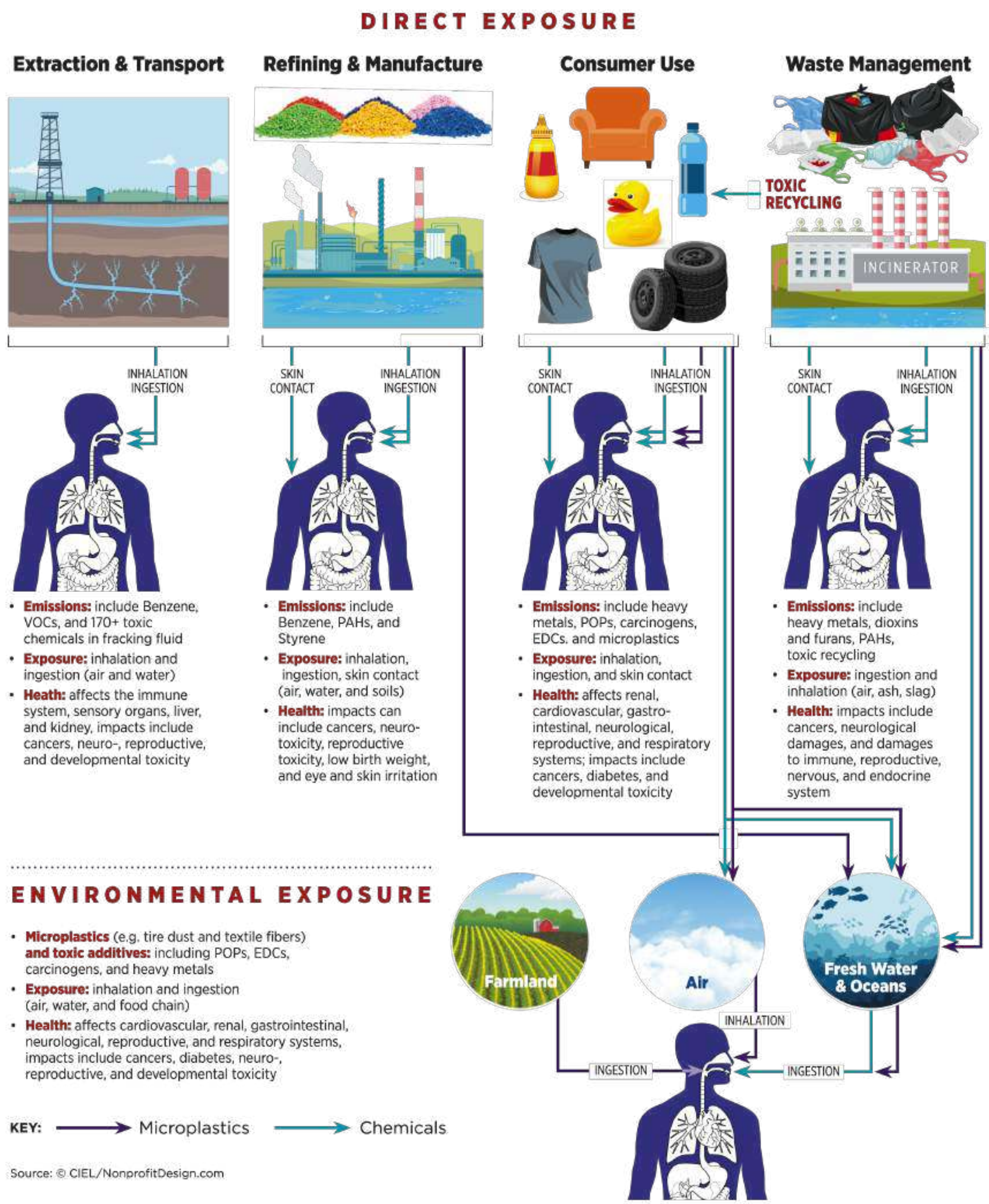
Polymer: Large molecule made up of a chain of repeating units, either natural or synthetic.

exposure for humans.[18] Microplastics, depending on their size and type, can penetrate edible fruits and vegetables, including seeds, roots, and leaves.[19] Therefore, if fruits and vegetables come from soil that has accumulated microplastics, consuming them may result in microplastic intake.[20] Furthermore, studies have detected the presence of microplastics in food and beverage items like sugar, salt, and beer.[21]

Rising public awareness of plastic pollution generally, and of the widespread accumulation of microplastics in particular, has prompted public action, such as campaigns targeting micro-beads in cosmetics.[22] Yet the intentional use of microplastics in other products, including agrochemicals, remains largely out of the public eye.

Plastic & Health: The Hidden Costs of a Plastic Planet

Humans are exposed to a large variety of toxic chemicals and microplastics through inhalation, ingestion, and direct skin contact, all along the plastic lifecycle.



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PART 2

The Agrochemical Industry: A Large and Growing User of Intentionally Added Microplastics

According to agrochemical producers, microplastics are deliberately added to some pesticides and fertilizers to allow for a controlled release of chemicals or nutrients in the product.[23] Manufacturers accomplish this through microencapsulation, the process of wrapping a nutrient or chemical in a polymer material to form a small capsule. Controlled-release fertilizers (CRFs) use these coatings, typically made of plastics such as polyolefin and polyvinylidene chloride,[24] to dispense fertilizer contents over time through osmotic pressure.[25] Likewise, some pesticide formulations enclose the active chemical ingredient in a microplastic coating.[26] Industry sources describe this "micro-capsule technology" as involving the intentional addition of "micron-sized hollow spheres (typically in the range of 1-50 µm) consisting of a thin polymer shell," most often made of polyureas and filled with the active chemical ingredient.[27] Beyond their use in controlled-release agrochemical products, microplastics are also used as fertilizer additives (like anti-caking agents), soil conditioners, and seed coatings.[28]

Comprehensive figures on the use of these intentionally added microplastics in agriculture are difficult to obtain. Publicly available data about microplastic use is limited, and most pertains to cosmetics and personal care products.[29] The failure of some plastic pollution data to distinguish between primary and secondary microplastics further complicates efforts to assess the contribution of intentionally added microplastics to overall global microplastic pollution.[30] Moreover, even available data may not capture the full scope or severity of the problem. Because microplastic particles themselves are astoundingly small, tonnage alone does not adequately represent the scale of their deployment in the sector, the scope of their release into the environment, or the full magnitude of the impacts from either.

Available Data Indicate That Agriculture Is One of the Largest Users of Intentionally Added Microplastics

According to a 2019 report from the European Chemicals Agency (ECHA), intentionally added microplastics in fertilizers, pesticides, and seed coatings account for almost *half* of the estimated 51,500 tonnes (metric tons) of microplastic used each year in the European Economic Area (EEA).[31] This figure includes an estimated 22,500 tonnes of microplastics in fertilizers and 500 tonnes used in pesticides (capsule-suspended "plant protection products").[32] This means that in the EEA, the agriculture sector uses more microplastics than any other sector, including cosmetics.

Global estimates of the quantity of intentionally added microplastics used in the fertilizer sector vary widely. A major United Nations Food and Agriculture Organization (FAO) report on agricultural plastics published in 2021 estimates that fertilizer coatings account for approximately 100,000 tonnes of plastic used in agriculture globally each year.[33] Extrapolating from figures reflecting the use of polymer-coated fertilizers in the EU, the FAO estimates that 440,000 tonnes of such fertilizer are used globally each year.[34] However, self-reported data from some of the world's largest nitrogen fertilizer manufacturers suggest this FAO figure is a gross underestimate. For example, Nutrien alone claims to produce over 400,000 tonnes of polymer-coated fertilizer annually.[35] ICL Specialty Fertilizers' reported annual production capacity for CRFs is approximately 200,000 short tons.[36] Another producer, Kingenta, stated in 2015 that it had a production capacity of around 1.7 million tonnes of

CRFs.[37] Together, the reported annual production totals from just these three companies would far exceed FAO's estimate, suggesting that the global production and use of intentionally added microplastics may be much greater than recognized to date. The inconsistency in the figures reflects the shortcomings of current disclosure and reporting requirements across the industry. It also underscores that, short of a ban, more consistent and robust data collection efforts across governments are needed to track the use and impacts of primary microplastics.

Market Trends Show the Use of Agrochemicals with Intentionally Added Microplastics Is on the Rise

According to a pre-pandemic market analysis, the global market for microencapsulated pesticides is expected to reach over $817 million by 2025, growing more than 11 percent between 2018 and 2025.[38] Global usage of slow- and controlled-release fertilizers (SRFs and CRFs), including those manufactured with synthetic polymers, has likewise grown significantly in recent years. A book published by the International Fertilizer Industry Association (IFA) states that between 1996 and 2005, the use of CRFs and SRFs reportedly increased by 45 percent.[39] And it is still on the rise. A June 2021 publication from IHS Markit states, "Coated fertilizers, particularly polymer-coated products, have been the fastest-growing segment of the CRF and SRF market, and will continue to grow at a faster rate than other CRF and SRF types. The advent of less-expensive polymer coating technology has led to increased consumption of CRFs in commodity (big-acreage) agriculture, especially in North America (the United States and Canada) and mainland China."[40] According to one market report, the global CRF market is projected to grow at a compound annual growth rate of over 6 percent to reach a value of $3.3 billion by 2026.[41] One major producer of CRFs, Nutrien, is reportedly looking to increase its output due to expected rising demand from farmers seeking what industry markets as more "sustainable" or efficient options.[42] Given their high potential to pollute, however, agrochemicals with added microplastics are anything but environmentally sound.

PART 3

Plastic-Coated Agrochemicals Directly Release Microplastics into the Environment

The large-scale, intentional usage of microplastics in the agriculture sector results in an enormous quantity of plastic particles entering soils each year. Agrochemicals that use capsules made from plastics have a direct-release environmental impact, meaning that all of the microplastic applied through the product to crops or soil has the potential to pollute.[43] ECHA describes the fertilizer and pesticide sectors as a source of "direct and unfiltered emissions of microplastics."[44] Of the estimated 51,500 tonnes of intentionally added microplastics used in fertilizers, pesticides, and seed coatings in the EEA each year, approximately 36,000 tonnes end up in the environment.[45] As noted above, the agricultural sector is the largest single user of microplastics, accounting for 46 percent of all intentionally added microplastics in the region.[46] More significantly, because all of these microplastics are released directly into the environment, agricultural microplastics account for *more than 65 percent of all environmental releases* of intentionally added microplastics in the EEA.[47]

Microplastics remain in the soil environment long after the encapsulation has fulfilled its intended purpose.[48] Synthetic polymer materials do not easily degrade — rather, the plastic particles accumulate at rates of up to 50 kilograms per hectare per year, polluting the soil,[49] from where they can be readily dispersed in the air, by water, or through other vectors.

PART 4

Old Technology, New Packaging: How Industry Sells Microplastics in Agrochemicals

Plastic-coated fertilizers and pesticides are not new. CRF technologies were commercialized starting in the mid-twentieth century. In 1965, Archer Daniels Midland (ADM) filed a patent application for slow-release fertilizer with "a plurality of urethane resin coatings."[50] ADM is said to have pioneered coated fertilizers, including Osmocote, in the 1960s.[51] The fertilizer industry acknowledged this application of plastic more than forty years ago. Documentation of the Fertilizer Industry Round Table annual meeting from 1970 states: "Several processes for producing coated granules of nitrogen (or compound) fertilizers have been announced. Controlled or delayed release is obtained by *coating granules of soluble fertilizer with a plastic film*, with sulfur plus additives, or with an asphalt-wax mixture" (emphasis added).[52]

Similarly, chemical manufacturers have been producing encapsulated pesticide formulations for over fifty years.[53] According to a summary of a 1993 seminar on controlled-release formulations of pesticides, such formulations originated about twenty-five years prior, around 1970.[54] A professional body called the Controlled Release Society started up in the 1970s and held its first symposium in 1974, where almost half of the papers related to agrochemicals.[55] (Other uses of controlled-release technology, like in pharmaceuticals, have since come to dominate the focus.[56]) Plastic materials like polyurethanes were used in early formulations of controlled-release pesticides, as these synthetic polymers met certain technical criteria and were readily available.[57]

What is new, however, is the industry's approach to pushing these products into the market. Today, the industry is presenting plastic-wrapped agrochemicals as a planet-safe option. This "repackaging" of the technology manifests in several ways. First, product descriptions may omit the mention of plastics altogether, using instead less well-known and non-specific terms like "polymer" when referring to the coating material.[58] Second, plastic encapsulation may be portrayed as a plus for the environment.[59] Agrochemical industry marketing and messaging around controlled-release products emphasizes the technology's purported efficiency as a key to more sustainable farming.[60] Some industry materials refer to controlled-release fertilizers as "enhanced-efficiency fertilizers."[61] Others, such as ICL's 2020 Corporate Responsibility Report, assert that CRFs' efficient use of fertilizer nutrients is important for what the company refers to as "sustainable agriculture."[62] And the fertilizer industry's promotion of a framework it calls the "4Rs,"[63] meaning right fertilizer, right rate, right time, and right place, encourages greater reliance on controlled-release fertilizers. As a fertilizer industry representative admitted in a 2011 article, this 4R framework is part of the industry's "response to the economic, environmental and public relations challenges" it is facing.[64]

Third, the use of controlled-release products may be presented as more adaptable to the reality of a changing climate.[65] Some industry actors pitch controlled-release or "enhanced-efficiency" agrochemicals as a solution to the pollution and other negative impacts of synthetic fertilizers and pesticides under the umbrella of "precision" or "climate-smart" agriculture.[66] Fertilizer producers claim microplastics allow nutrient release in a more targeted way that can purportedly reduce losses to air or water.[67] Other claimed advantages include labor- and time-saving effects.[68]

The evidence for such claims, however, is questionable. Data gaps regarding the effectiveness of controlled-release technologies at actually slowing or targeting the delivery of fertilizer[69] mean that efficiency gains may be overstated. The absence of

"standardized methods to determine the nutrient release rate from CRF in a reliable way" and discrepancies between laboratory tests and field data[70] cast doubt on industry assertions. The industry even acknowledges these gaps — as the IFA states in a 2020 publication: "Due to the intrinsic nature of these products, it is not always possible to test the release under controlled –laboratory- conditions in such a way that a release properties under the field conditions can be automatically determined or predicted."[71] The IFA further notes that no test yet exists for comparing CRF performance in the field for a certain crop.[72]

Emerging research likewise raises questions about asserted climate benefits of controlled-release agrochemicals. Studies indicate that "enhanced-efficiency" or coated fertilizers may not be effective in reducing nitrous oxide emissions,[73] which is a critical environmental impact of nitrogen fertilizer and a potent greenhouse gas that contributes to the climate crisis.

While the agrochemical industry touts the purported advantages of its products, it remains largely silent on their risks.[74] According to pesticide experts, synthetic polymer encapsulation, originally used as a protective barrier to reduce skin contact with highly toxic pesticides, is now used for delayed- or controlled-release function.[75] The industry asserts that microencapsulation minimizes the amount of pesticide used, as well as toxicity and environmental impacts.[76] Recent research challenges this claim. A 2019 study from researchers at Oregon State University found that a common insecticide with the active ingredient encapsulated in nanometer-sized plastic was *more* toxic than applying the same active ingredient either with a larger plastic capsule or without any encapsulation.[77] Professor Stacey Harper, environmental toxicologist and one of the co-authors of the study explains, "What we've found is that encapsulation makes a difference in toxicity and that it is size-dependent."[78] Encapsulation is thought to enhance toxicity and mobility, because it prevents the active chemical ingredient from breaking down in water, which would dilute the toxicity, and it allows the chemical to be transported further away from the point of application, enhancing potential exposure.

Plastic-coated fertilizers and pesticides are not only dangerous, but also unnecessary, because effective alternatives exist. There are a multitude of strategies for reducing the use of synthetic pesticides and fertilizers, including high-performing agroecological techniques that do not rely on fossil fuel-based agrochemical inputs at all.[79] But even in the case of the market for coated, controlled-release products, there are non-toxic alternatives, such as inorganics like sulfur and organic materials like biochar.[80] The industry has claimed that plastic provides more favorable technical properties for the controlled-release function than other materials.[81] However, research into biodegradable coatings has been underway since at least the 1990s,[82] and in recent years, has been accelerating the shift towards improving and utilizing natural and biodegradable materials for coatings.[83]

Contrary to the industry's narrative, the rising use of controlled-release agrochemicals, particularly those formulated with plastic encapsulation, is only accelerating the problem of microplastic pollution and increasing the risk of harm to ecosystems and human health.

TEXT BOX:

Producer Profiles: Agribusiness Giants and Specialty Firms Focus on Coated Fertilizers and Pesticides

Nutrien, Koch Agronomic Services, ICL Specialty Fertilizers, and Kingenta Ecological Engineering Group Co. are among the largest producers of controlled-release fertilizers (CRFs) and slow-release fertilizers (SRFs).[i] Other major producers of CRFs and their plastic coatings include plastics producers like Dow[ii] and chemicals producers like BASF, Haifa Chemicals, and Mitsubishi Chemical.[iii] Bayer, BASF, Syngenta, and FMC Corporation — four of the top five biggest pesticide companies — are among the key players in the microencapsulated pesticide market.[iv]

The producers named above are not the only companies making plastic-coated agrochemicals. The practice of coating fertilizers and pesticides is fairly widespread across the industry and geographic regions. The manufacturers involved in this practice have the greatest power and responsibility to alter their products to avoid this non-essential use of plastic material. The following listed companies are examples of firms that manufacture coated fertilizers and pesticides. With the exception of Syngenta and Koch Agronomic Services, these companies are publicly traded.

Nutrien:
Headquarters: Saskatoon, Saskatchewan, Canada

Nutrien is one of the world's largest fertilizer companies and the third-largest producer of nitrogen fertilizer, with a production capacity of over 11 million tonnes of nitrogen.[v] The company operates sixteen nitrogen production facilities in the United States, Canada, and Trinidad. Nutrien produces over 400,000 tonnes per year of a CRF made with a polymer coating, marketed as "Environmentally Smart Nitrogen" (ESN).[vi] This polymer-coated fertilizer is produced at two facilities in North America — one in Alberta, Canada, and one in Missouri, United States.[vii] Nutrien and its predecessor Agrium have produced this polymer-coated fertilizer since 2000.[viii] Nutrien reportedly has a production capacity of more than 450,000 tonnes (annually) for ESN,[ix] and the company plans to increase its ESN production.[x]

ICL Specialty Fertilizers:
Headquarters: Tel-Aviv, Israel

ICL Specialty Fertilizers is a subsidiary of parent company ICL Group, an Israeli multinational corporation that produces specialty minerals (including fertilizers) and chemicals.[xi] The company produces CRFs at facilities in the Netherlands, the US, and Brazil.[xii] The coated CRFs and other fertilizer products are intended for ornamental horticulture, turf, and agricultural applications. ICL Specialty Fertilizers' Osmocote product is a leading coated fertilizer used in ornamental horticulture,[xiii] and for agricultural crops, the company produces branded CRFs such as Agroblend and Agrocote.[xiv] ICL Group's annual production capacity for CRFs is approximately 200,000 tons.[xv]

Kingenta:
Headquarters: Linyi, Shandong, China

Kingenta Ecological Engineering Group Co. is a Chinese enterprise that produces various fertilizer products such as compound fertilizer, water-soluble fertilizers, SRFs, and CRFs. Its annual fertilizer production capacity is over 7 million tons,[xvi] and its production bases are located in eight provinces throughout China. Kingenta's production capacity for SRFs and CRFs (as of 2016) is around 1.7 million tonnes,[xvii] and Kingenta manufactures the lion's share of China's growing output of these coated fertilizers.[xviii] The company makes CRFs using polymer coatings — including plastic.[xix]

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TEXT BOX (CONTINUED):

Producer Profiles: Agribusiness Giants and Specialty Firms Focus on Coated Fertilizers and Pesticides

Koch Agronomic Services:
Headquarters: Wichita, Kansas, United States

Koch Agronomic Services, an affiliate of Koch Fertilizer — a major US synthetic fertilizer producer and part of Koch Industries — manufactures "enhanced-efficiency" fertilizers, including coated controlled-release products and fertilizer additives. Examples of its branded CRFs include Polyon and Duration CR, which are both used in turf and landscaping and specialty agriculture applications.[xx] Polyon uses a polyurethane coating, which, as the manufacturer notes, does not degrade, and the coating's microscopic fragments become incorporated into the soil profile.[xxi] In 2019, Koch sold Polyon off to a company called Harrell's. Under the agreement, Harrell's will custom manufacture the product for Koch, and Koch will hold exclusive rights to the brand in certain international markets.[xxii] Duration CR fertilizer also uses a polymer coating and is now marketed and distributed by an entity called Allied Nutrients.[xxiii]

BASF:
Headquarters: Ludwigshafen am Rhein, Germany

BASF is a German-headquartered multinational chemical firm and one of the world's largest producers of pesticides, which are manufactured under the company's "Agricultural Solutions" division. As one of the top five corporate pesticide producers, BASF does make pesticides with a microencapsulated formulation. Examples include an encapsulated insecticide called Fastac CS,[xxiv] the DuraGuard ME microencapsulated insecticide,[xxv] and a controlled-release insecticide product branded as Cy-Kick CS.[xxvi] BASF also manufactures a polymer coating for CRFs, specifically a patented polyurethane coating.[xxvii]

Dow:
Headquarters: Midland, Michigan, United States

Dow, a major chemical company and one of the world's largest plastic producers, is a supplier of the plastic encapsulation technology used by agrochemical companies. Dow manufactures a polyurethane coating for controlled-release fertilizers, and the company has a web page illustrating the purported benefits of its fertilizer encapsulation.[xxviii] Dow also makes encapsulation and capsule suspension technology for pesticides.[xxix] Dow has a long history of working in agribusiness markets and the agrochemical space; DowDupont was previously a leading pesticide producer, but in 2019 the entity spun off its agriculture business into a separate company called Corteva Agriscience.[xxx]

Syngenta:
Headquarters: Basel, Switzerland

Syngenta is a global agrochemical corporation (under the parent organization ChemChina) that manufactures seeds and pesticides. Created in 2000 through the merger of the respective agrochemical businesses of Novartis and AstraZeneca, Syngenta was acquired by the China National Chemical Corporation (ChemChina) in 2015 and subsequently merged with the agricultural business of SinoChem.[xxxi] It is among the top five largest pesticide producers in the world. The company, therefore, has a stake in the microencapsulated pesticide market. Syngenta makes, for example, an insecticide product called Demand CS for controlled-release application using a patented microencapsulation technology called iCAP.[xxxii]

PART 5

Compounding Risk: Agrochemicals Plus Microplastics Equals a Toxic Combination

Agrochemicals and their overuse already pose serious risks for human health and the environment at multiple scales — from impacts on farmworkers, local communities, and those exposed to pesticide-contaminated food products to regionally and globally significant impacts on pollinators, insect biomass, coastal and estuarine ecosystems, and the global climate.[84] Adding microplastics to the mix introduces new risks, compounding the potential for harm. Plastic generally contains toxic additives and can be a carrier of other pollutants.[85] The confluence of chemicals in the agricultural sector may cause adverse impacts on both soil health and human health, as microplastics accumulate in ever greater volumes in farmland and, ultimately, in our bodies.

The Intrinsic Risks of Synthetic Pesticides and Fertilizers

On their own, pesticides and fertilizers pose numerous risks: exposure to pesticides has been linked to adverse effects on humans, ranging from reproductive disorders to cancers,[86] while fertilizers are a primary driver of agricultural greenhouse gas emissions (GHG). [87] Some synthetic pesticides, called highly hazardous pesticides (HHP), have been associated with exceptionally high levels of acute or chronic harm and are recognized by the international community as an "issue of concern."[88] As early as 2006, the FAO recommended a progressive ban on HHPs,[89] although implementation has lagged. The use of HHPs is particularly concerning for agricultural workers and farmers, who face greater exposure at higher doses and for extended periods, which can result in poisoning (in some cases, death).[90] Research cited by the International Labor Organization has shown that "[p]esticide poisoning represents a major occupational health crisis with estimates indicating that up to 44 percent of farmers are poisoned every year."[91] But this is not inevitable: The aggressive promotion of pesticides to ensure "food security" has been denounced by UN independent experts as a misleading myth.[92] A dangerous disconnect exists between the recognized risks of these chemicals and the narratives that the industry has developed to promote them as safe and sustainable.

The negative impacts of pesticide exposure go beyond workers' health, and UN independent experts have called pesticides a "global human rights concern."[93] Several groups of people are particularly vulnerable to pesticide exposure and face higher risk from pesticide use, including those living near farmland, Indigenous Peoples, pregnant and breastfeeding people, and children. Less stringent regulations and compliance mechanisms have exacerbated the situation in some countries.[94]

Chemical fertilizers are one of the main drivers of agricultural GHG emissions and are especially harmful from a climate perspective.[95] Synthetic nitrogen fertilizer is made from fossil fuels, and the production process is incredibly emissions intensive. Additional GHG emissions occur once the fertilizer is applied to soils. Once treated with synthetic nitrogen fertilizer, agricultural soils emit both carbon dioxide and nitrous oxide — the latter is a more potent driver of climate change, nearly 300 times more heat-trapping than CO2, and has been rising at alarming rates, primarily driven by the overuse of nitrogen fertilizers.[96] According to the Intergovernmental Panel on Climate Change (IPCC), studies indicate that agricultural emissions of nitrous oxide have increased by more than 45 percent since the 1980s, due mainly to the widespread use of nitrogen fertilizer and manure.[97] Research published in 2021 found that the synthetic nitrogen supply chain was responsible for over 20 percent of all direct emissions from the agricultural sector in 2018, generating more greenhouse gases than the aviation sector did that same year.[98]

Furthermore, the use of pesticides and fertilizers can pollute soil and freshwater, which may aggravate water scarcity and broadly affect biodiversity.[99] The case of neonicotinoids is a staggering example: often used in seed coatings, these widely used systemic pesticides are chemically similar to nicotine. Neonicotinoids are particularly concerning because they can affect the plant on a systemic level, meaning they can pass from the roots to the leaves, flowers, pollen, and nectar. For this reason, they can become toxic or deadly not only to the target organisms but also to non-target species, such as pollinators.[100] These effects may not be limited to exposed organisms but can alter reproduction for generations.[101] Concern about such impacts prompted the EU to ban the use and sale of seeds treated with certain neonicotinoid pesticides due to their acute risks for bee populations.[102]

Microplastics Are a Carrier for Toxic Chemicals

Coating agrochemicals with plastic material is especially concerning, given the inherent health and environmental impacts and routes of exposure to toxic chemicals associated with plastic.

Microplastics, in particular, raise several health concerns because of their intrinsic: 1) physical hazards and potential to accumulate in the human body and move through biological barriers; 2) chemical components, such as residual molecules (monomers) and chemical additives; and 3) capacity to adsorb contaminants from the external environment and act as carriers of chemical mixtures. This last point led the United Nations Environment Programme (UNEP) to coin the phrase "the new toxic time bomb," referring to marine plastics, particularly microplastics, as a transport vector for toxic chemicals.[103]

Physical Hazards of Tiny, Mobile Plastic Particles

Due to the physical hazards of the particles, microplastics raise numerous health concerns of their own.[104]

Microplastics are ubiquitous in the environment, and growing evidence indicates they are entering the human body on a daily basis through ingestion and inhalation.[105] New research has detected microplastics in human lung tissue sampled from living patients, further supporting inhalation as a direct route of exposure.[106] Once in the human body, microplastic particles can a) deposit, accumulate, and cause inflammation, or b) translocate, for example, from the guts or the lungs to other parts of the body, such as other organs and tissues.[107] Microplastics have been detected in the human bloodstream,[108] meaning that blood can be the "transport pathway for oxygen, nutrients and potentially also plastic particles around the body to other tissues and organs."[109] The scientists who made this discovery concluded that "it is certainly reasonable to be concerned."[110] Microplastics also have been detected in human stool, both in adults and infants, in many parts of the world,[111] proving that ingested particles can pass through the gastrointestinal tract and that all food chains are likely contaminated.[112] Furthermore, new evidence shows that microplastics may even cross the human placenta.[113]

According to several studies, some of the potential health effects of microplastic exposure include neurotoxicity, metabolic disturbances, and increased cancer risk.[114] Microplastics in the human body may result in health impacts such as inflammation, oxidative stress, and cellular mutations or cell death, which are associated with diseases and conditions like heart disease, cancer, chronic inflammation, rheumatoid arthritis, diabetes, and more.[115]

While additional research is needed to assess the full extent of microplastics' persistence and effects in the human body, a growing body of scientific literature demonstrates that ingested and inhaled microplastics may cause harm due to their physical presence, their chemical burden, and/or the microbial communities they carry.[116] Effects could include immune and stress responses and reproductive and developmental toxicity.[117] Pregnancy, infancy, and childhood are sensitive windows for human development, and the current assessments of evidence around early life exposures to micro- and nanoplastics provide yet another cause for concern and justification for the use of the precautionary principle.[118] That foundational principle, discussed further below, requires that, in the absence of scientific certainty or consensus, governments should act with caution and diligence to avoid causing harm to health and the environment, including through the regulation of hazardous substances.[119]

Toxicity of Additives and Chemicals Used to Produce Plastics

The health risks posed by micro- and nanoplastics are not limited to the presence and accumulation of particles in the human body. Microplastics can also contain hazardous additives and other substances from the plastic manufacturing phase that present their own health risks.[120] Many toxic additives in plastic are endocrine-disrupting chemicals (EDCs) like bisphenol A and phthalates, with wide-ranging negative health impacts, even at extremely low doses.[121] These include neurological and behavioral effects, obesity, infertility, genital malformations, decreased sperm count, and hormone-sensitive cancers such as prostate and breast cancer.[122]

Because of how plastics are manufactured, these chemicals are not always bound to the plastic material. Plastics release chemicals over time, including as they fragment, presenting humans and wildlife with potential exposure to an assortment of toxins associated with health impacts like oxidative stress and endocrine disruption.[123] While complete information on the chemicals, monomers, additives, and processing aids used in plastics is still lacking, plastics can contain more than 10,000 substances[124] and potentially tens of thousands more.[125] According to one conservative study, over 2,400 substances used in plastic production were "identified as substances of potential concern as they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union."[126] Furthermore, "certain plastics have been shown to leach over 80% of their chemicals into water, highlighting the potential for human exposure."[127]

External Toxins Absorbed in Plastics

Microplastics may further adsorb and serve as a vector for other contaminants from the environment,[128] resulting in a "cocktail of contaminants"[129] for human health. A report published by the Canadian government on the state of the science regarding the potential health and environmental impacts of plastics pollution identified the risk posed by microplastics' transport of chemicals: "In addition to the physical hazards presented by plastic particles themselves, it is possible that effects could occur as a result of exposure to residual monomers, chemical additives, and sorbed environmental contaminants (e.g., persistent organic pollutants [POPs] and metals) that may leach from microplastic particles."[130]

As a result, "[m]icroplastics that accumulate in the body are a source of chemical contamination to tissues and fluids. A variety of chemical additives in plastic, plastic monomers, and plastic processing agents have known human health effects. For example, several plasticizers, such as bis(2-ethylhexyl) phthalate (DEHP) and BPA, can cause reproductive toxicity. Others, such as vinyl chloride and butadiene, are carcinogens. Benzene and phenol are mutagenic (i.e., they change the genetic material, usually DNA, of an organism, increasing the frequency of mutations). Some of the harmful additives include harmful chemicals known to leach from plastic polymers such as antioxidants, UV stabilizers, and nonylphenol."[131]

However, the lack of full transparency about the chemical composition of plastic material (e.g., what additives and non-intentionally added substances are present) makes it impossible to fully assess the risks and potential health impacts.

Dangerous Interaction: Chemicals and Coatings

Notwithstanding the widespread and growing use of plastic-coated pesticides and fertilizers, there has been little research on whether the toxic residues from pesticides and fertilizers can be entrained in the microplastics themselves and thus moved deeper into the food system through the plastic coatings. However, it is known that microplastics can adsorb and concentrate toxics, including in the case of plastics used in agriculture.[132] Studies also make clear that plastic and agrochemicals can interact generally. For example, a review article discussing plastic in agricultural soil as a risk for drinking water indicates that plastic may facilitate pesticide transport through soil, eventually leading to groundwater contamination.[133] The article notes that while plastic and pesticide interactions in soil systems are "likely to occur," they remain "poorly explored."[134] Furthermore, microplastics may multiply the effects of toxic chemicals, such as heavy metals, already present in the soil, creating the potential for "combined effects on soil microbial community,"[135] as further discussed below.

Microplastics Disturb Soil Ecosystems

The adverse impacts of microplastics extend beyond human health to ecosystem health, particularly to agricultural soils, which form the foundation of food production. The presence of micro- and nanoplastics in the food chain may contribute to plant stress and raise numerous food safety concerns.[136]

Studies suggest that microplastic presence in soils could already be affecting soil health,[137] and recent research has documented "adverse effects of [microplastics] on growth, reproduction, feeding, survival, and immunity level of the soil biota."[138] According to one study, research shows that microplastics in agricultural soils, together with pollutants they may have adsorbed, can affect soil health and function in both the aboveground and underground parts of the soil ecosystem, and can be taken up by plants and transferred along the food chain.[139] Microplastics may, for example, impact and disturb the biophysical properties of soil, like bulk density and microbial activity.[140] The potential effects on the soil microbiome are important because the microbiome underlies the role of soil in regulating biogeochemical cycling, which is key for healthy ecosystems and related services like increased food security. Microplastic accumulation in soil may therefore interfere with nutrient cycling (by altering the soil's bacterial composition, for example), and it can affect the rooting ability of plants and may exacerbate plant damage in combination with other pollutants.[141]

Research also shows the wide-ranging effects of microplastics on organisms that play a vital role in maintaining healthy soil. For example, emerging evidence indicates that microplastics in soil negatively affect earthworms' growth rate and overall health.[142] Reducing the size and vigor of earthworm populations could impair soil quality and functioning. On the other hand, soil organisms like earthworms may facilitate the integration of microplastics deeper into soils, which could increase the risk of groundwater contamination and result in microplastics disintegrating into nanoplastics that are even more easily transferable (e.g., uptake by plants).[143] Emerging evidence also suggests that chemical additives in plastic can leach into soils, harm earthworms and other soil fauna, and disturb soil function.[144]

Furthermore, by negatively impacting soil health and bacterial composition, microplastic pollution may also reduce the soil's ability to absorb and store carbon dioxide, potentially impairing the role of agricultural soils as a carbon sink. However, more research is needed to better understand how microplastics interact with these processes.[145]

The data are clear: The intentional use of microplastics in agrochemicals contributes to the growing accumulation of microplastics in soils. Given the science suggesting adverse ecological and human health impacts from this increasing exposure, governments must act to halt the deliberate use of microplastics in agrochemicals and other products.

The Need for a Precautionary Approach

The growing scientific evidence on the hazards of microplastic — with its characteristics of toxicity and persistence and the potential to serve as a vector for other toxins — reveals significant grounds for concern and justifies measures to prevent the production, use, and release of microplastics. The use of microplastics *in combination* with hazardous pesticides or fertilizers further compounds these health and environmental risks — risks that are only more acute because the substances are applied directly to crops that form a critical part of the human food supply.

The significant potential for adverse impacts from microplastic pollution, and the compounded risks resulting from its intentional use in agriculture, warrant regulatory action consistent with the precautionary principle.[146] As the Group of Chief Scientific Advisors of the European Union recognized in its 2019 Scientific Opinion on the environmental and health risks of microplastic pollution, the precautionary principle, together with the principles of prevention and of preventing pollution at the source, may properly be invoked to stop the distribution of products such as these "when there is scientific uncertainty about a suspected risk to human health or to the environment" arising from its use.[147] As discussed above, a growing body of research points to the significant adverse impacts of microplastic pollution. There is reason to believe that intentionally adding microplastics to agrochemicals could increase toxicity and multiply exposure pathways. Residual uncertainties around the severity and extent of risks to human health and ecosystems from microplastic pollution and the use of microplastics in agriculture[148] cannot justify continued inaction or the lack of protective measures.

PART 6

Preventable Pollution: Curbing the Use of Intentionally Added Microplastics

The threat is clear: As UNEP has stated, "continuous use and releases of microplastics will lead to increasing accumulation of microplastics in the environment and thus increasing exposure and risks."[149] And the source is known or knowable: The addition of microplastics to a variety of products, including agrochemicals, is an intentional act by the companies involved. And yet, while primary microplastic pollution is preventable, as UNEP notes, regulation is lagging: "[T]he current level of action is not yet adequate for addressing sound management of intentionally added microplastics."[150]

To date, regulatory action concerning the intentional use of microplastics has been mostly limited to addressing microplastics in personal care products. According to ECHA, "very few countries outside of the EU have already introduced bans on intentional use of microplastics," and those that have targeted personal care products like wash-off cosmetics and cleaning products, not agricultural chemicals.[151] In the United States, for example, a federal law, the Microbead-Free Waters Act of 2015, bans plastic microbeads in rinse-off cosmetics.[152] The US has yet to take comprehensive action to address microplastic pollution, however, including microplastic accumulation in soils. State-level action on microplastics is also limited, although California is taking steps to address microplastics in drinking water[153] and in the state's coastal and marine environments.[154] California's "Statewide Microplastics Strategy," released in 2022, notably references plastic use in agriculture and indicates future research and investigation could involve monitoring microplastics in agricultural soils and targeting the agricultural sector to reduce microplastic pollution.[155] A bill is also pending in the California state legislature that would ban intentionally added microplastics from certain products, including cosmetics, detergents, waxes, and polishes.[156] Several other countries such as Canada, South Korea, and New Zealand have banned plastic microbeads in cosmetics and personal care products.[157] There remain considerable regulatory gaps worldwide addressing intentionally added microplastics in products, especially beyond the cosmetics sector.

The EU, however, is currently considering restricting intentionally added microplastics used in a wide range of industries and products, including in the agriculture sector. In 2019, ECHA issued a report[158] detailing the proposed restriction, which is based on a scientific assessment undertaken at the request of the European Commission. The proposal is expected to prevent the release of up to 500,000 tonnes of microplastics over twenty years.[159] The restriction would significantly impact CRFs and fertilizer additives, with more than half of the expected prevention of microplastics release (or approximately 262,500 tonnes) coming from the fertilizer sector alone.[160] For pesticides and coated seeds, the estimated release prevention is 15,000 tonnes.[161]

The rising regulatory risks have not gone unnoticed by the industry. For example, Bayer — one of the biggest pesticide producers and a key player in the microencapsulated pesticide market[162] —acknowledged in its 2021 Annual Report that residues of its chemical products and microplastics in the environment could face more stringent regulation.[163]

The EU's drafting of a proposed restriction is an important first step to addressing the pervasive presence of microplastics in certain products like agrochemicals. The transition periods for agrochemicals included in the proposal, however — eight years for pesticides and five years for fertilizer and seed treatments — would result in the substantial additional release of microplastics to the environment.[164] Non-plastic alternatives[165] already exist for most of the agricultural uses of microplastics.[166] Accordingly, there is no justification for allowing the continued use of microplastics in fertilizers and pesticides.

Biodegradable materials for CRFs are available and will be required in the coming years, per a new EU regulation. The European Commission's 2019 Fertilising Products Regulation restricts polymer-coated fertilizers to formulations that comply with biodegradability criteria.[167] The restriction will take effect in 2026 for all EU Member States. Substituting plastic with biodegradable or natural materials, however, does not address the larger problem of the dangerous and unsustainable overuse of agricultural chemicals.

Other jurisdictions outside the EU should follow suit and take action to address the intentional use of microplastics in products, particularly coated fertilizers and pesticides. So, too, should relevant international institutions, such as the World Health Organization, follow the lead of bodies like the FAO, whose 2021 report on agricultural plastics recommends restrictions on plastic-coated fertilizers and pesticides.[168] Key places for regulatory action include the US and Canada, where consumption of polymer-coated fertilizers has grown in recent years.[169] Canada has established a new rule requiring the registration of fertilizer products that contain polymers,[170] indicating heightened concern about these products. But this regulation falls short of restricting or prohibiting the use of synthetic polymers in fertilizers. Asia is another significant market for these products: China is a major producer and user of CRFs. In Japan, evidence shows that microplastics, specifically from coated fertilizers, accumulate in agricultural soil, including paddy fields.[171] Absent restrictions on plastic usage in agrochemicals, plastic-coated fertilizers and pesticides will continue to be a source of microplastic pollution in the world's soils and contribute to accumulation in the environment and in human bodies.

Conclusion and Recommendations: Tackling the Toxic Triad

Halting the accumulation of microplastics in the environment is critical for human health, biodiversity, and the climate. One of the most controllable sources is the intentional addition of microplastics to agrochemical products. In order to confront the problem, policymakers should prioritize measures to 1) end the use of intentionally added microplastics in the agricultural sector and across all manufactured products, 2) deepen research on the harms of microplastics and impose strict industry disclosure requirements, 3) curb dependency on industrial agriculture and chemical fertilizers and pesticides, and 4) adopt a comprehensive global approach to plastics regulation.

1) End the use of intentionally added microplastics in the agricultural sector and across all manufactured products

The release of microplastics into the environment through their intentional addition to products like fertilizers and pesticides can and should be prohibited. Knowledge gaps and uncertainty should not preclude or delay regulatory action; the precautionary principle warrants **carefully crafted and comprehensive restrictions on the intentional uses of microplastics.** Such restrictions must be geographically and sectorally comprehensive, expanding **beyond the EU and addressing all intentional uses, including in agriculture**. Rather than capitulating to corporate demands, regulators should act in the public interest by swiftly regulating and ultimately banning the intentional use of microplastic in products. The FAO's 2021 report on agricultural plastics, for example, recommends banning non-biodegradable polymer-coated fertilizer, seeds, and pesticides.[172] The use of synthetic polymers and intentionally added microplastics in agriculture and horticulture should be phased out rapidly, systematically, and completely. States should set short-term monitoring measures and reduction targets for microplastic release with the aim of achieving zero intentional releases of microplastics in the long run.

2) Deepen research on the harms of microplastics and impose strict industry disclosure requirements

There is a pressing need for **more research** and **far greater industry disclosure** on the extent of microplastic usage in agrochemicals, the full chemical composition of products, and their potential environmental and health impacts. The FAO report on agricultural plastics recommends further research to fill data gaps and calls on governments to start collecting data on agricultural plastics use and their fate.[173]

Until a ban on the intentional use of microplastics comes into effect, enacting and enforcing stronger disclosure requirements is especially important for agrochemicals formulated with a microplastic coating. Such requirements should compel plastic and agrochemical companies to adequately test and fully disclose all chemicals intentionally added to their products in addition to known or likely chemical contaminants that may be added or created during manufacturing processes.

3) Curb dependency on industrial agriculture and chemical fertilizers and pesticides

The intentional use of microplastics in agrochemicals provides yet another reason to **dramatically reduce dependence on**

synthetic fertilizers and pesticides. Such action is necessary as part of the shift away from the fossil economy and a move toward more sustainable methods for food production like organic agriculture, permaculture, and agroecology. Contrary to agrochemical industry claims, synthetic pesticides[174] and fertilizers[175] are unnecessary to feed the world, and their increasing usage harms both human and ecosystem health. Setting targets to reduce the use of chemical pesticides and fertilizers — and then following through on those targets — are essential first steps.[176] Ultimately, protecting health, the environment, and the climate requires a systemic shift away from chemical-dependent industrial agriculture to safer and more sustainable farming systems.

4) Adopt a comprehensive global approach to plastics regulation

At the resumed fifth session of the United Nations Environment Assembly (UNEA-5.2) in 2022, Member States agreed to develop an international legally binding instrument on plastic pollution, addressing the full life cycle of plastic and plastic pollution in all environments, including microplastics.[177] **Legally binding restrictions on plastic production** and its toxic components are necessary to address the plastic pollution problem broadly, including **microplastic accumulation** and exposure to hazardous substances. Consistent with the mandate and what is required to address the plastics crisis effectively, the treaty should cover measures along the entire life cycle of plastics, including extraction of fossil fuel feedstocks, product design, production, transport, use, disposal, and remediation. The treaty must take a human rights-based approach to plastics management and ensure the meaningful participation of multiple stakeholders in its negotiations, including farmers, civil society, Indigenous Peoples, workers and trade unions, women, and children and youth. Fulfilling the right to information, which is a critical component of a rights-based approach, requires ensuring access to information on plastics production, polymer components, and chemical additives, which is essential to regulating product safety, improving product design, and advancing a circular economy. With the right provisions, the treaty can also be a critical tool to support the above recommendations, including a target for the global phaseout of microplastic use in agriculture and bans on other non-essential plastics.[178]

Synthetic fertilizers and pesticides have well-documented harmful impacts on human and ecological health. Deliberately adding tiny plastic particles to these agrochemicals — and applying those microplastics directly to food crops at a massive scale — only compounds these already significant risks and adds to the growing plastic pollution crisis. Because such pollution is intentional, not incidental, it can and should be stopped.

While such measures are both necessary and feasible, they are by no means sufficient to confront the widespread, severe, and rising impacts to human, ecosystem, and planetary health arising from the world's dangerous reliance on pesticides and fertilizers. Yet the underrecognized threat from agricultural microplastics reflects the deep and fundamental interlinkages between these issues. Petroleum-based agrochemicals, plastics, and the oil and gas that feed their production and fuel their use are interwoven and interdependent facets of the same fossil economy. For decades, the exploration, extraction, and processing of fossil fuels for energy and transport and the industries' need to dispose of and, where possible, profit from the waste streams and byproducts of fossil fuels, have subsidized and incentivized the production of petroleum-based plastics, pesticides, and fertilizers in ever greater amounts. The accumulating pollution, toxicity, and warming from these converging threats are pushing the Earth not only beyond critical climate limits, but beyond planetary boundaries for chemical pollution, nitrogen deposition, and biodiversity loss, among others. The passing of those planetary boundaries has been coupled with growing impacts on human health, human lives, and human rights that threaten people on every continent and of every generation, including generations yet to come.

Ultimately, the solutions to these intersecting crises will be as interlinked as the fossil fuels and fossil products that drive them. Even as ending humanity's production and use of fossil fuels is critical to confronting the climate crisis, it will fundamentally transform the economic incentives that drive the overproduction and overuse of plastics and agrochemicals. Momentum is growing toward both a global plastics treaty and national actions worldwide to stem the tide of plastic pollution and confront plastic's own significant climate impacts. In turn, the industry's hopes for plastics and petrochemicals as a future driver of fossil fuel demand are rapidly fading, compounding the economic and regulatory uncertainties confronting the fossil economy. Despite decades of warnings and calls for action on agrochemicals from scientists, health experts, and affected communities, progress in confronting this third leg of the fossil economy's toxic triad remains limited. But the scientific evidence is clear, public concern is growing, and just as in the contexts of climate change and plastics, the world is rapidly recognizing that alternative pathways are not only viable, they are attainable.

Endnotes

1. Carolyn Wilke, “Plastics are showing up in world’s most remote places, including Mount Everest,” *ScienceNews*, November 20, 2020, https://www.sciencenews.org/article/plastics-remote-places-microplastics-earth-mount-everest.
2. Anderson Abel de Souza Machado et al., “Microplastics as an emerging threat to terrestrial ecosystems,” *Global Change Biology* 24, no. 4 (April 2018): 1405–16, https://doi.org/10.1111/gcb.14020; Elizabeth Claire Alberts, “‘Our life is plasticized’: New research shows microplastics in our food, water, air,” *Mongabay*, July 15, 2020, https://news.mongabay.com/2020/07/our-life-is-plasticized-new-research-shows-microplastics-in-our-food-water-air/.
3. Center for International Environmental Law et al., *Plastic & Health: The Hidden Costs of a Plastic Planet* (CIEL, February 2019), 37, https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf.
4. See generally Manish Kumar et al., “Microplastics as pollutants in agricultural soils,” *Environmental Pollution* 265, Part A (October 2020), https://doi.org/10.1016/j.envpol.2020.114980; Kate S. Petersen, “Microplastics in farm soils: A growing concern,” *Environmental Health News*, August 31, 2020, https://www.ehn.org/plastic-in-farm-soil-and-food-2647384684.html.
5. Kumar et al., “Microplastics as pollutants,” 3 (in pdf version).
6. Kumar et al., “Microplastics as pollutants,” 4 (in pdf version); Alice A. Horton et al., “Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities,” *Science of the Total Environment* 586 (May 2017): 127–41, https://doi.org/10.1016/j.scitotenv.2017.01.190.
7. Kumar et al., “Microplastics as pollutants,” 2, 7–8 (in pdf version).
8. United Nations Environment Programme, *Environmental and health impacts of pesticides and fertilizers and ways of minimizing them: Summary for Policymakers* (UNEP, January 2021), 16–19, https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/34463/JSUNEPPF.pdf?sequence=13.
9. CHEM Trust, *PFAS — the ‘Forever Chemicals,’ invisible threats from persistent chemicals* (CHEM Trust, September 2019), 6, https://chemtrust.org/wp-content/uploads/PFAS_Brief_CHEMTrust_2019.pdf.
10. See Center for International Environmental Law et al., *Fueling Plastics* (CIEL, 2017), https://www.ciel.org/reports/fuelingplastics/; “Gas as fertilizer feedstock,” PetroWiki, last updated July 16, 2015, https://petrowiki.spe.org/Gas_as_fertilizer_feedstock. As one article describing the link between pesticides, plastics, and fossil fuels explains, “many pesticides such as neonicotinoids, pyrethroids, and glyphosate formulants are produced from gas and oil.” Barbara A. Demeneix, “How fossil fuel-derived pesticides and plastics harm health, biodiversity, and the climate,” *The Lancet Diabetes & Endocrinology* 8, no. 6, (June 2020): 463, https://doi.org/10.1016/S2213-8587(20)30116-9.
11. See Center for International Environmental Law, *Plastic & Climate: The Hidden Costs of a Plastic Planet* (CIEL, May 2019), 7, https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf; “Regulatory Definition of Microplastics and Oxo-degradable Plastics,” ChemSafetyPRO, accessed April 13, 2022, https://www.chemsafetypro.com/Topics/Restriction/Definition_of_Microplastics.html; and Karen Duis and Anja Coors, “Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects,” *Environmental Sciences Europe* 28, no. 1 (2016): 1, 20, https://enveurope.springeropen.com/track/pdf/10.1186/s12302-015-0069-y.pdf.
12. European Chemicals Agency, *Annex XV Restriction Report – Microplastics* (Helsinki: ECHA, August 2019), 8, https://echa.europa.eu/documents/10162/05bd96e3-b969-0a7c-c6d0-441182893720.
13. United Nations, General Assembly, *Implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes*, A/76/332 (22 July 2021), 8, https://undocs.org/A/76/207.
14. CIEL et al., *Plastic & Health*, 35.
15. As the European Chemicals Agency explains on its website: “Microplastics are intentionally added to a range of products including fertilisers, plant protection products, cosmetics, household and industrial detergents, cleaning products, paints and products used in the oil and gas industry.” “Microplastics,” European Chemicals Agency, accessed April 13, 2022, https://echa.europa.eu/hot-topics/microplastics.
16. United Nations Environment Programme, *An Assessment Report on Issues of Concern: Chemicals and Waste Issues Posing Risks to Human Health and the Environment* (UNEP, September 2020), 93, https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y; and CIEL et al., *Plastic & Health*, 37, 39–40, 51–59.
17. Sarah-Jeanne Royer et al., “Production of methane and ethylene from plastic in the environment,” *PLoS ONE* 13, no. 8 (August 2018): 1, 4–5, 9–10 (in pdf version), https://doi.org/10.1371/journal.pone.0200574.
18. Food and Agriculture Organization and United Nations Environment Programme, *Global assessment of soil pollution: Summary for policy makers* (Rome: FAO, 2021), 9, https://doi.org/10.4060/cb4827en.
19. 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 2020): 4 (in pdf version), https://doi.org/10.1016/j.envres.2020.109677.
20. 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 2020): 1212 (15 in pdf version), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7068600/.
21. Campanale et al., “Potential Effects of Microplastics,” 15 (in pdf version); Kieran D. Cox et al., “Human Consumption of Microplastics,” *Environmental Science & Technology* 53, no. 12 (June 2019): 7068–74, https://doi.org/10.1021/acs.est.9b01517.
22. See, e.g., “Beat the Microbead,” A campaign by Plastic Soup Foundation, accessed April 13, 2022, https://www.beatthemicrobead.org/.
23. See, e.g., “Micro plastics,” Fertilizers Europe, accessed April 14, 2022, https://www.fertilizerseurope.com/circular-economy/micro-plastics/; Dow, *Formulations Guide CS Capsule Suspension*, 2, https://www.dow.com/content/dam/dcc/documents/en-us/formulation/119/119-02444-01-capsule-suspension-cs-formulations-guide.pdf?iframe=true.
24. Dora Lawrencia et al., “Controlled Release Fertilizers: A Review on Coating Materials and Mechanism of Release,” *Plants* 10, no. 2 (2021): 238 (2 in pdf version), https://doi.org/10.3390/plants10020238.
25. Leondina Della Pietra, “Microplastics in fertilizers,” (PowerPoint presentation, Fertilizers Europe, ECHA stakeholder workshop on intentional uses of microplastic particles, May 31, 2018), 3–4, https://echa.europa.eu/documents/10162/23964241/07_fertilizers_europe_della_pietra_en.pdf/9e469ca1-e387-d260-6a8f-bad31369ed40. Although slow-release fertilizer and controlled-release fertilizer are often used interchangeably, CRFs are a sub-set of SRFs, the category of fertilizers containing a physical barrier. While some SRFs are made with a physical barrier, others use different low solubility chemical structures to slow nutrient release. Lawrencia et al., “Controlled Release Fertilizers,” 3 (in pdf version).
26. Roberto M. Pereria and Philip G. Koehler, “Formulations to make insecticide treatments last longer,” *Pest Pro*, March 2014, 16, 18, https://pested.ifas.ufl.edu/pdfs/Insecticide_Treatments.pdf.
27. Sebastien Bonifay, “ECHA workshop on microplastic particles: A perspective from the Seed and Plant Protection industry,” (PowerPoint presentation, Corteva Agriscience, May 30, 2018), 4, https://echa.europa.eu/documents/10162/23964241/06_dow_dupont_bonifay_en.pdf/456e61cd-3566-b7af-a009-c8ab11219278.
28. ECHA, *Annex XV Restriction Report – Microplastics*, 31 (Table 6).
29. UNEP, *An Assessment Report on Issues of Concern*, 94–95.
30. UNEP, *An Assessment Report on Issues of Concern*, 95.

31. ECHA, *Annex XV Restriction Report – Microplastics*, 74 (Table 15). [The European Economic Area includes the Member States of the EU as well as Norway, Iceland, and Liechtenstein.]
32. ECHA, *Annex XV Restriction Report – Microplastics*, 74 (Table 15).
33. Food and Agriculture Organization, *Assessment of Agricultural Plastics and Their Sustainability: A Call for Action* (Rome: FAO, 2021), 22 (Figure 10), https://doi.org/10.4060/cb7856en. Data on coated pesticides were not available in the report.
34. FAO, *Assessment of Agricultural Plastics*, 26.
35. "ESN: How it's made," Nutrien, accessed April 14, 2022, https://smartnitrogen.com/esn-how-its-made/; Nutrien, *Nutrien Annual Report 2020* (Saskatoon, SK: Nutrien, 2021), 17, https://nutrien-prod-asset.s3.us-east-2.amazonaws.com/s3fs-public/uploads/2021-03/Nutrien-2020-Annual-Report-Enhanced.pdf.
36. ICL Group Limited, *Annual Report For the Period Ended December 31, 2021* (Tel Aviv: ICL Group Limited, 2022), 82, https://www.sec.gov/Archives/edgar/data/941221/000117891322000767/zk2227317.htm.
37. Jidong Zhai, "Improving Nitrogen Use Efficiency through Slow & Controlled Release Fertilizers," (PowerPoint presentation, Kingenta, New Delhi, India, March 2015), 15, https://www.fertilizer.org/images/Library_Downloads/2015_ifa_fai_newdelhi_jidong.pdf; "CCM: Kingenta to benefit from Chinese government's promotion of controlled release fertilizers," *CCM Data & Business Intelligence*, March 31, 2016, http://www.cnchemicals.com/Press/84064-CCM:%20Kingenta%20to%20benefit%20from%20Chinese%20governments%20promotion%20of%20controlled%20release%20fertilizers.html.
38. Fior Markets, "Global Microencapsulated Pesticides Market is Expected to Reach USD 817.45 Million by 2025: Fior Markets," GlobeNewswire, news release, July 31, 2019, https://www.globenewswire.com/en/news-release/2019/07/31/1894943/0/en/Global-Microencapsulated-Pesticides-Market-is-Expected-to-Reach-USD-817-45-Million-by-2025-Fior-Markets.html.
39. M.E. Trenkel, *Slow- and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture* (Paris: International Fertilizer Industry Association, 2010), 101, https://www.fertilizer.org/images/Library_Downloads/2010_Trenkel_slow%20release%20book.pdf.
40. IHS Markit, *Chemical Economics Handbook: Controlled- and Slow-Release Fertilizers* (IHS Markit, June 2021), https://ihsmarkit.com/products/controlled-and-slow-release-chemical-economics-handbook.html.
41. "Controlled Release Fertilizer Market," Markets and Markets, accessed April 14, 2022, https://www.marketsandmarkets.com/Market-Reports/controlled-release-fertilizers-market-136099624.html. Another industry report by Fortune Business Insights reportedly predicted the CRF market to increase to nearly $3.9 billion USD by 2026. Fortune Business Insights, "Controlled Release Fertilizers Market to Worth $3,862.2 Million by 2026," GlobeNewswire, news release, September 14, 2021, https://www.globenewswire.com/news-release/2021/09/14/2296325/0/en/Controlled-Release-Fertilizers-Market-to-Worth-3-862-2-Millon-By-2026-Fortune-Business-Insights.html.
42. Marcy Nicholson, "Nutrien Eyes Boosting Output of Time-Release 'Smart' Fertilizer," *Bloomberg*, April 1, 2021, https://www.bloomberg.com/news/articles/2021-04-01/nutrien-eyes-boosting-output-of-time-release-smart-fertilizer.
43. ECHA, *Annex XV Restriction Report – Microplastics*, 74 (Table 15) (showing that 100 percent of intentionally added microplastics used in the agriculture and horticulture sector are released to the environment).
44. ECHA, *Annex XV Restriction Report – Microplastics*, 104 (Table 23).
45. ECHA, *Annex XV Restriction Report – Microplastics*, 74–75 (Table 15).
46. ECHA, *Annex XV Restriction Report – Microplastics*, 74 (Table 15).
47. ECHA, *Annex XV Restriction Report – Microplastics*, 74 (Table 15).
48. Committee for Risk Assessment and Committee for Socio-economic Analysis, *Opinion on an Annex XV dossier proposing restrictions on intentionally-added microplastics* (European Chemicals Agency, 2020), 62, https://echa.europa.eu/documents/10162/a513b793-dd84-d83a-9c06-e7a11580f366.
49. Lawrencia et al., "Controlled Release Fertilizers," 7 (in pdf version).
50. Louis I. Hansen. Slow release fertilizer granule having a plurality of urethane resin coatings. US Patent 3,264,089, filed December 10, 1965, and issued August 2, 1966, https://patents.google.com/patent/US3264089A/en?q=~patent%2fWO2002000573A2.
51. "50 years Osmocote," ICL Specialty Fertilizers, accessed April 14, 2022, https://icl-sf.com/global-en/osmocote50/.
52. Travis P. Hignett, "Trends in Fertilizer Materials, 1970-1980," in *Proceedings of the 20th Annual Meeting Fertilizer Industry Round Table 1970* (Parsippany, NJ: Wayne E. Dorland Company, 1971), 11, http://www.firt.org/sites/default/files/pdf/FIRT1970.pdf.
53. Oregon State University, "Packaging insecticides in tiny capsules may make them more toxic," news release, February 26, 2019, https://today.oregonstate.edu/news/packaging-insecticides-tiny-capsules-may-make-them-more-toxic.
54. International Atomic Energy Agency, "Summary of the Seminar," in *Research and development of controlled release formulations of pesticides, Volume I, Development and evaluation of controlled release formulations of pesticides* (Vienna: International Atomic Energy Agency, 1994), 8, https://inis.iaea.org/collection/NCLCollectionStore/_Public/26/036/26036976.pdf.
55. International Atomic Energy Agency, "Summary of the Seminar," 8.
56. G.G. Allan and J.P. Carroll, "Controlled Release Delivery of Agrochemicals: Looking Back and Looking Forward," in *Research and development of controlled release formulations of pesticides, Volume I, Development and evaluation of controlled release formulations of pesticides* (Vienna: International Atomic Energy Agency, 1994), 13, https://inis.iaea.org/collection/NCLCollectionStore/_Public/26/036/26036976.pdf.
57. Allan and Carroll, "Controlled Release Delivery of Agrochemicals," 15.
58. See, e.g., this fact sheet from Syngenta describing an insecticide product where the active chemical ingredient is "enclosed within polymer spheres." Syngenta, *Competitive Comparison* (Syngenta, 2008), 2, https://www.syngenta-us.com/images/resource_pages/pmp/demand_ez_ss_compare.pdf. See also "How ESN Works," Nutrien, accessed March 8, 2022, https://smartnitrogen.com/how-esn-works/.
59. See, e.g., ICL, "Controlled Release Fertilizers," *2020 Corporate Responsibility Report* (ICL, 2020), https://icl-group-sustainability.com/reports/controlled-release-fertilizers/ (claiming that CRFs allow growers to "reduce their fertilizer usage" and "significantly reduce their environmental impact").
60. See, e.g., "4RFarming.org," The Fertilizer Institute, 2019, accessed April 14, 2022, https://www.4rfarming.org/; "Nutrient Management," 4R Plus, accessed April 14, 2022, https://www.4rplus.org/nutrient-management/.
61. See, e.g., a recent news release from The Fertilizer Institute, which claims: "EEFs [enhanced-efficiency fertilizers] and other new product technologies and formulations control fertilizer release…to increase nutrient uptake by the plant and reduce nutrient losses to the environment." The Fertilizer Institute, "The Fertilizer Institute Announces Its Next Gen Challenge Winners," AgriMarketing, news release, October 21, 2021, https://www.agrimarketing.com/s/138364.
62. See this section on CRFs from ICL's 2020 Corporate Responsibility Report, touting the benefits of CRFs and stating: "Modern sustainable agriculture demands an increase in Nitrogen Use Efficiency (NUE)… Controlled release (coated) fertilizers offer a predictable and consistent release of nutrients in a specific time period. Since the amount of nitrogen released daily is small and in line with plant uptake requirements, this type of fertilizers can be an ideal tool to reduce nutrient losses and optimize NUE." ICL, "Controlled Release Fertilizers."
63. The "4Rs" refers to Right (fertilizer) source, Right rate, Right time, and Right place. The Fertilizer Institute, "What are the 4Rs," Nutrient Stewardship, accessed April 14, 2022, https://nutrientstewardship.org/4rs/.
64. Lara Moody, "Embracing the 4Rs," *CropLife*, September 1, 2011, https://www.croplife.com/crop-inputs/fertilizer/embracing-the-4rs/.
65. In its 2020 Corporate Responsibility Report, for example, ICL quotes goal 2 of the Sustainable Development Goals, about implementing agricultural practices that "strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters," alongside its description of the benefits of CRF. ICL also claims that its controlled-release fertilizer, Agrocote, has "better environmental performance (vs conventional fertilizers) in terms of climate change (~10% reduction), acidification (max. of 20% reduction) and eutrophication (max. of 40% reduction)." ICL, "Controlled Release Fertilizers."
66. GRAIN, *The Exxons of agriculture* (GRAIN, September 2015), 4–5, 8–9 (in pdf version), https://grain.org/article/entries/5270-the-exxons-ofagriculture; Vasilis Tsampardoukas, "Controlled Release Fertilizer Technology (CRFT) – the way towards the precised arable crops nutrition and precision Agriculture," *Haifa* (blog), January 18, 2022, https://www.haifa-group.com/haifa-blog/controlled-release-fertilizer-technology-crft-way-towards-precised-arable-crops-nutrition.

67. "Micro plastics," Fertilizers Europe.
68. Lawrencia et al., "Controlled Release Fertilizers," 4 (in pdf version); "Controlled Release Fertilizer solution for different segments webinar," Haifa Group, video, 4:05, https://www.youtube.com/watch?v=-OWaO-Q38EFA.
69. See, e.g., Lawrencia et al., "Controlled Release Fertilizers," 4 (in pdf version).
70. See, e.g., Lawrencia et al., "Controlled Release Fertilizers," 4 (in pdf version); Trenkel, *Slow- and Controlled-Release and Stabilized Fertilizers*, 67.
71. International Fertilizer Industry Association, *Review of Analytical Methods for Slow- and Controlled-Release Fertilizers* (Paris: IFA, 2020), 14, https://www.fertilizer.org/member/Download.aspx?PUBKEY=18f0e000-a48b-4dc7-9654-7abc0652a3c8.
72. International Fertilizer Industry Association, *Review of Analytical Methods*, 3.
73. Yanyan Li et al., "Enhanced efficiency nitrogen fertilizers were not effective in reducing N2O emissions from a drip-irrigated cotton field in arid region of Northwestern China," *Science of the Total Environment* 748 (December 2020): 8–9, https://doi.org/10.1016/j.scitotenv.2020.141543; Timothy B. Parkin and Jerry L. Hatfield, "Enhanced Efficiency Fertilizers: Effect on Nitrous Oxide Emissions in Iowa," *Agronomy Journal* 106, no. 2 (March 2014): 694–702, https://doi.org/10.2134/agronj2013.0219.
74. See, e.g., Sebastien Bonifay, "ECHA workshop on microplastic particles," 4; "ESN Reduces N Loss," Environmentally Smart Nitrogen, Nutrien, accessed April 14, 2022, https://smartnitrogen.com/esn-reduces-n-loss/.
75. Pereira and Koehler, "Formulations to make insecticide treatments last longer," 16.
76. Sebastien Bonifay, "ECHA workshop on microplastic particles," 4.
77. Matthew Slattery, Bryan Harper, and Stacey Harper, "Pesticide Encapsulation at the Nanoscale Drives Changes to the Hydrophobic Partitioning and Toxicity of an Active Ingredient," *Nanomaterials* 9, no. 1 (January 2019): 81, https://doi.org/10.3390/nano9010081; Oregon State University, "Packaging insecticides in tiny capsules."
78. Oregon State University, "Packaging insecticides in tiny capsules."
79. See generally High Level Panel of Experts on Food Security and Nutrition, *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition* (Rome: HLPE, July 2019), 84–86, https://www.fao.org/3/ca5602en/ca5602en.pdf (discussing the elimination or reduction of synthetic inputs); International Panel of Experts on Sustainable Food Systems, *From Uniformity to Diversity: A paradigm shift from industrial agriculture to diversified agroecological systems* (IPES-Food, 2016), 31–44, https://www.ipes-food.org/_img/upload/files/UniformityToDiversity_FULL.pdf; Catherine Badgley et al., Organic agriculture and the global food supply, *Renewable Agriculture and Food Systems* 22, no. 2, (June 2007): 86–108, https://doi.org/10.1017/S1742170507001640; Tim G. Benton et al., *Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature* (Chatham House, February 2021), 25–26, 62–65 (discussing biodiversity-supporting shifts in approaches to farming); and Astrud Lea Beringer, "Agroecology can be our new food system," *Ecologist,* January 13, 2022, https://theecologist.org/2022/jan/13/agroecology-can-be-our-new-food-system.
80. Lawrencia et al., "Controlled Release Fertilizers," 4 (in pdf version).
81. See, e.g., Fertilizers Europe presentation at the 2018 ECHA stakeholder workshop on intentional uses of microplastic particles, claiming biodegradable polymers for CRF "lack the right barrier properties for water." Leondina Della Pietra, "Microplastics in fertilizers," 8. See also Lawrencia et al., "Controlled Release Fertilizers," 7–8 (in pdf version).
82. See, e.g., this paper that references research into biodegradable coatings citing research from the 1990s: "Several R&D groups devoted efforts recently to develop biodegradable polymeric coatings (Posey and Hester, 1994; et al., 1995; Tada, 1999)." Avi Shaviv, "Advances in Controlled-Release Fertilizers," *Advances in Agronomy* 71 (2001): 49–50 (in pdf version), https://doi.org/10.1016/S0065-2113(01)71011-5.
83. Lawrencia et al., "Controlled Release Fertilizers," 20–21 (in pdf version).
84. See, e.g., Megha Sud, "Managing the Biodiversity Impacts of Fertiliser and Pesticide Use: Overview and insights from trends and policies across selected OECD countries," *OECD Environment Working Papers, no. 155*, (March 2020): 8–11, https://doi.org/10.1787/63942249-en; UNEP, *Environmental and health impacts of pesticides and fertilizers*, 17.
85. CIEL et al., *Plastic & Health*, 2, 7, 27–37.
86. United Nations Environment Programme, *Global Chemicals Outlook II* (UNEP, 2019), 72, https://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions.
87. GRAIN, Greenpeace International, and Institute for Agriculture and Trade Policy, *New research shows 50 year binge on chemical fertilisers must end to address the climate crisis* (GRAIN, GPI, and IATP, November 2021), https://grain.org/e/6761.
88. United Nations, International Conference on Chemicals Management, *Report of the International Conference on Chemicals Management on the work of its fourth session,* SAICM/ICCM.4/15 (28 October 2015), 19, https://undocs.org/SAICM/ICCM.4/15; "Highly Hazardous Pesticides," SAICM Knowledge, accessed April 19, 2022, https://saicm-knowledge.org/program/highly-hazardous-pesticides.
89. Food and Agriculture Organization and World Health Organization, *International Code of Conduct on Pesticide Management: Guidelines on Highly Hazardous Pesticides* (Rome: FAO & UNEP, 2016), 1, http://apps.who.int/iris/bitstream/handle/10665/205561/9789241510417_eng.pdf;jsessionid=9BD4A3382FD5E8E2C23315DE2E73B8D3?sequence=1 (citing "Report of the Council of FAO, Hundred and Thirty-first Session, Rome, 20–25 November 2006").
90. Wolfgang Boedeker et al., "The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review," *BMC Public Health* 20, no. 1875 (December 2020): 14 (in pdf version) (concluding that acute unintentional pesticide poisoning results in around 11,000 fatalities annually), https://doi.org/10.1186/s12889-020-09939-0.
91. International Labour Organization, *Exposure to hazardous chemicals at work and resulting health impacts: A global review* (Geneva: ILO, 2021), 56, https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---lab_admin/documents/publication/wcms_811455.pdf (citing Boedeker et al., "The global distribution of acute unintentional pesticide poisoning").
92. United Nations, Human Rights Council, *Report of the Special Rapporteur on the right to food,* A/HRC/34/48 (24 January 2017), 19, https://undocs.org/A/HRC/24/48.
93. UN Office of the High Commissioner on Human Rights, "Pesticides are 'global human rights concern,' say UN experts urging new treaty," news release, March 7, 2017, https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=21306.
94. United Nations, Human Rights Council, *Report of the Special Rapporteur on the right to food,* A/HRC/34/48 (24 January 2017), 19, https://undocs.org/A/HRC/24/48.
95. GRAIN et al., *50 year binge on chemical fertilisers must end.*
96. Phil McKenna, "Emissions of Nitrous Oxide, a Climate Super-Pollutant, Are Rising Fast on a Worst-Case Trajectory," *Inside Climate News*, October 7, 2020, https://insideclimatenews.org/news/07102020/nitrous-oxide-fertilizer-emissions-nature-study/.
97. Josep G. Canadell et al., "Chapter 5: Global Carbon and other Biogeochemical Cycles and Feedbacks," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. V. Masson-Delmotte et al. (Cambridge and New York: Cambridge University Press, August 2021), 43, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_05.pdf; Gert-Jan Nabuurs, et al., "Chapter 7: Agriculture, Forestry and Other Land Uses (AFOLU)," in *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. P.R. Shukla et al. (Cambridge and New York: Cambridge University Press, April 2022), 7–35, https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_Chapter07.pdf (noting that "considerable increases in global use of synthetic nitrogen fertilizers since the 1970s" is a "major driver of increasing N2O emissions").
98. GRAIN et al., *50 year binge on chemical fertilisers must end,* 1 (in pdf version).
99. UNEP, *Global Chemicals Outlook II*, 66.
100. Michelle L. Hladik, Anson R. Main, and Dave Goulson, "Environmental Risks and Challenges Associated with Neonicotinoid Insecticides," *Environmental Science & Technology* 52, no. 6 (February 2018): 3331, https://doi.org/10.1021/acs.est.7b06388.

101. Clara Stuligross and Neal M. Williams, "Past insecticide exposure reduces bee reproduction and population growth rate," *Proceedings of the National Academy of Sciences* 118, no. 48 (November 2021): 1–3 (in pdf version), https://doi.org/10.1073/pnas.2109909118.
102. European Union, "Commission Implementing Regulation (EU) No 485/2013 of 24 May 2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing those active substances," OJ L 139 (2013), 12–26, https://eur-lex.europa.eu/eli/reg_impl/2013/485/oj; Michael DiBartolomeis et al., "An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States," *PLoS ONE* 14, no. 8 (August 2019), https://doi.org/10.1371/journal.pone.0220029 (studying the persistence and toxicity of neonicotinoids and finding that US agriculture has become more toxic to insects since neonicotinoids were introduced over 25 years ago).
103. United Nations Environment Programme, "Wider Impacts of Fertilizer and Plastic Pollution on Oceans Top This Year's Priority Issues in UNEP Year Book: UNEP Year Book 2011 Spotlights Urgent Need for Fundamental Green Economy Shift," news release, February 17, 2011, 4, https://www.oceanrecov.org/assets/files/news/UNEP-2011-Yearbook-Press-Release-Final.pdf.
104. Stephanie L. Wright and Frank J. Kelly, "Plastic and Human Health: A Micro Issue?," *Environmental Science & Technology* 51, no. 12 (May 2017): 6634–47, https://doi.org/10.1021/acs.est.7b00423.
105. See, e.g., Environment and Climate Change Canada and Health Canada, *Science Assessment of Plastic Pollution* (Government of Canada, October 2020), 64 https://www.canada.ca/content/dam/eccc/documents/pdf/pded/plastic-pollution/Science-assessment-plastic-pollution.pdf; and CIEL et al., *Plastic & Health*, 52–58.
106. Lauren C. Jenner et al., "Detection of microplastics in human lung tissue using μFTIR spectroscopy," *Science of the Total Environment* 831 (July 2022), https://doi.org/10.1016/j.scitotenv.2022.154907 (forthcoming).
107. Environment and Climate Change Canada and Health Canada, *Science Assessment of Plastic Pollution*, 64–68.
108. Heather A. Leslie et al., "Discovery and quantification of plastic particle pollution in human blood," *Environment International* 163 (May 2022): 1, 7 (in pdf version), https://doi.org/10.1016/j.envint.2022.107199.
109. Leslie et al., "Discovery and quantification of plastic particle pollution," 2 (in pdf version).
110. Damian Carrington, "Microplastics found in human blood for first time," *The Guardian*, March 24, 2022, https://www.theguardian.com/environment/2022/mar/24/microplastics-found-in-human-blood-for-first-time.
111. Junjie Zhang et al., "Occurrence of Polyethylene Terephthalate and Polycarbonate Microplastics in Infant and Adult Feces," *Environmental Science & Technology Letters* 8, no. 11 (September 2021): 989–94, https://doi.org/10.1021/acs.estlett.1c00559.
112. Philipp Schwabl et al., "Detection of Various Microplastics in Human Stool: A Prospective Case Series," *Annals of Internal Medicine* 171, no. 7 (October 2019): 453–57, https://pubmed.ncbi.nlm.nih.gov/31476765/; Klára Cverenkárová et al. "Microplastics in the Food Chain," *Life* 11, no. 12 (2021): 1349 (8–13 in pdf version), https://doi.org/10.3390/life11121349.
113. Antonio Ragusa et al., "Plasticenta: First evidence of microplastics in human placenta," *Environment International* 146, (January 2021), https://doi.org/10.1016/j.envint.2020.106274.
114. Arifur Rahman et al., "Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review," *Science of the Total Environment* 757 (February 2021): 5, 7–8 (in pdf version), https://doi.org/10.1016/j.scitotenv.2020.143872.
115. CIEL et al., *Plastic & Health*, 2, 39–40.
116. Kirsty Blackburn and Dannielle Green, "The potential effects of microplastics on human health: What is known and what is unknown," *Ambio* 51 (March 2022): 518, 525, https://doi.org/10.1007/s13280-021-01589-9.
117. Blackburn and and Green, "The potential effects of microplastics," 518, 525.
118. Kam Sripada et al., "A Children's Health Perspective on Nano- and Microplastics," *Environmental Health Perspectives* 130, no. 1 (January 2022): 9 (in pdf version), https://doi.org/10.1289/EHP9086.
119. United Nations, Human Rights Council, *Right to science in the context of toxic substances: Report of the Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes, Marcos Orellana*, A/HRC/48/61 (July 26, 2021), paras. 61–66, https://undocs.org/A/HRC/48/61 (citing "the landmark Rio Declaration on Environment and Development (1992) (principle 15), the United Nations Framework Convention on Climate Change (1992) (article 3 (3)), and the Stockholm Convention on Persistent Organic Pollutants (2001).").
120. CIEL et al., *Plastic & Health*, 29.
121. United Nations, General Assembly, *Implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes*, A/76/332 (22 July 2021), 8, https://undocs.org/A/76/207; Michele A. La Merrill et al., "Consensus on the key characteristics of endocrine-disrupting chemicals as a basis for hazard identification," *Nature Reviews Endocrinology* 16, (January 2020): 45–57, https://doi.org/10.1038/s41574-019-0273-8.
122. Andrea C. Gore et al., *Introduction to Endocrine Disrupting Chemicals (EDCs): A Guide for Public Interest Organizations and Policy-Makers* (Endocrine Society and IPEN, 2014), 14–22, https://ipen.org/sites/default/files/documents/ipen-intro-edc-v1_9a-en-web.pdf.
123. Lisa Zimmermann et al., "Plastic Products Leach Chemicals That Induce In Vitro Toxicity under Realistic Use Conditions," *Environmental Science & Technology* 55, no. 17 (September 2021): 11814, 11818, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8427741/.
124. Helene Wiesinger, Zhanyun Wang, and Stefanie Hellweg, "Deep Dive into Plastic Monomers, Additives, and Processing Aids," *Environmental Science & Technology* 55, no. 13 (June 2021): 9339–51, https://doi.org/10.1021/acs.est.1c00976.
125. Lisa Zimmermann et al., "Are bioplastics and plant-based materials safer than conventional plastics? *In vitro* toxicity and chemical composition," *Environment International* 145 (December 2020): 6 (in pdf version), https://doi.org/10.1016/j.envint.2020.106066.
126. Wiesinger, Wang, and Hellweg, "Deep Dive into Plastic Monomers," 9339.
127. Sripada et al., "A Children's Health Perspective," 1 (in pdf version).
128. FAO and UNEP, *Global assessment of soil pollution*, 9.
129. Campanale et al. "Potential Effects of Microplastics," 4 (in pdf version).
130. Environment and Climate Change Canada and Health Canada, *Science Assessment of Plastic Pollution,* 72.
131. CIEL et al., *Plastic & Health*, 29.
132. FAO, *Assessment of Agricultural Plastics*, 38.
133. Philipp Wanner, "Plastic in agricultural soils – A global risk for groundwater systems and drinking water supplies? – A review," *Chemosphere* 264 (February 2021): 1, 4–6 (in pdf version), https://doi.org/10.1016/j.chemosphere.2020.128453.
134. Wanner, "Plastic in agricultural soils," 3 (in pdf version).
135. Andrew Wirnkor-Verla et al., "Microplastic–toxic chemical interaction: a review study on quantified levels, mechanism and implication," *SN Applied Sciences* 1 (October 2019): 21 (in pdf version), https://doi.org/10.1007/s42452-019-1352-0.
136. Gilda Carrasco Silva et al., "Microplastics and Their Effect in Horticultural Crops: Food Safety and Plant Stress," *Agronomy* 11, no. 8 (July 2021): 1528, https://doi.org/10.3390/agronomy11081528.
137. See, e.g., Dunmei Lin et al., "Microplastics negatively affect soil fauna but stimulate microbial activity: insights from a field-based microplastic addition experiment," *Proceedings of the Royal Society B – Biological Sciences* 287, no. 1943 (September 2020): 5, 7 (in pdf version), https://doi.org/10.1098/rspb.2020.1268 (finding that "microplastic additions generally decreased the abundance of soil fauna" with "important ecological consequences on the structure and functioning of soil communities at different trophic levels").
138. Kumar et al., "Microplastics as pollutants," 5 (in pdf version).
139. Lin Yang et al., "Microplastics in soil: A review on methods, occurrence, sources, and potential risk," *Science of the Total Environment* 780 (August 2021): 2–3, 14–15 (in pdf version), https://doi.org/10.1016/j.scitotenv.2021.146546.
140. Anderson Abel de Souza Machado et al., "Impacts of Microplastics on the Soil Biophysical Environment," *Environmental Science & Technology* 52, no. 17 (July 2018): 9656–65, https://doi.org/10.1021/acs.est.8b02212.

141. Danlian Huang et al., "Research progress of microplastics in soil-plant system: Ecological effects and potential risks," *Science of the Total Environment* (November 2021), https://doi.org/10.1016/j.scitotenv.2021.151487.
142. Esperanza Huerta Lwanga et al., "Microplastics in the Terrestrial Ecosystem: Implications for *Lumbricus terrestris* (Oligochaeta, Lumbricidae)," *Environmental Science & Technology* 50, no. 5 (February 2016): 2685–91, https://doi.org/10.1021/acs.est.5b05478; Bas Boots, Connor William Russell, and Dannielle Senga Green, "Effects of Microplastics in Soil Ecosystems: Above and Below Ground," *Environmental Science & Technology* 53, no. 19 (September 2019): 11496, 11499, 11503, https://doi.org/10.1021/acs.est.9b03304.
143. Kumar et al., "Microplastics as pollutants," 9–10 (in pdf version).
144. Kumar et al., "Microplastics as pollutants," 10 (in pdf version).
145. Matthias C. Rillig, Eva Leifheit, and Johannes Lehmann, "Microplastic effects on carbon cycling processes in soils," *PLOS Biology* (March 2021): 1, 3, 4–6 (in pdf version), https://doi.org/10.1371/journal.pbio.3001130.
146. See, e.g., CIEL et al., *Plastic & Health*, 59 ("reports of plastic additives and toxic contaminants in vegetables and fruit serve as an early warning that should trigger the urgent implementation of the precautionary principle in order to reduce exposure."); Didier Bourguignon, *The precautionary principle: Definitions, applications and governance* (European Parliamentary Research Service, December 2015), https://doi.org/10.2861/821468; and Milieu et al., *Considerations on the application of the Precautionary Principle in the chemicals sector* (Brussels: European Commission, 2011), https://ec.europa.eu/environment/chemicals/reach/pdf/publications/final_report_pp.pdf.
147. Group of Chief Scientific Advisors, *Environmental and Health Risks of Microplastic Pollution* (Brussels: European Commission, April 2019), 14, https://ec.europa.eu/info/sites/default/files/research_and_innovation/groups/sam/ec_rtd_sam-mnp-opinion_042019.pdf.
148. A 2021 scoping review of published studies on potential human health impacts from microplastics finds a significant knowledge gap and recommends further research. Rahman et al., "Potential human health risks," 9–10 (in pdf version).
149. UNEP, *An Assessment Report on Issues of Concern*, 96.
150. UNEP, *An Assessment Report on Issues of Concern*, 96.
151. ECHA, *Annex XV Restriction Report – Microplastics*, 24–25.
152. "The Microbead-Free Waters Act: FAQs," U.S. Food & Drug Administration, content current as of February 25, 2022, accessed April 19, 2022, https://www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs.
153. California Water Boards, "State Water Board addresses microplastics in drinking water to encourage public water system awareness," news release, June 16, 2020, https://www.waterboards.ca.gov/press_room/press_releases/2020/pr06162020_microplastics.pdf.
154. California Ocean Protection Council, "California Takes Decisive Action to Reduce Microplastic Pollution: State Adopts a First-in-Nation Approach to Protecting Ocean and Human Health," news release, February 24, 2022, https://www.opc.ca.gov/2022/02/california-takes-decisive-action-to-reduce-microplastics-pollution-state-adopts-a-first-in-nation-approach-to-protecting-ocean-and-human-health/.
155. California Ocean Protection Council, *Statewide Microplastics Strategy* (February 2022), 13–14, 25, https://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20220223/Item_6_Exhibit_A_Statewide_Microplastics_Strategy.pdf.
156. Microplastics in Products, AB No. 2787, California Legislature 2021-2022 Regular Session (2022), https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB2787.
157. ECHA, *Annex XV Restriction Report – Microplastics*, 24–25.
158. ECHA, *Annex XV Restriction Report – Microplastics*.
159. "Microplastics," European Chemicals Agency, accessed April 15, 2022, https://echa.europa.eu/hot-topics/microplastics.
160. ECHA, *Annex XV Restriction Report – Microplastics*, 12 (Table 1).
161. ECHA, *Annex XV Restriction Report – Microplastics*, 12 (Table 1).
162. Fior Markets, "Global Microencapsulated Pesticides"; "Microencapsulated Pesticides Market," Markets and Markets, accessed April 14, 2022, https://www.marketsandmarkets.com/Market-Reports/microencapsulated-pesticide-market-108137381.html.
163. Bayer, *Bayer Annual Report 2021* (Leverkusen, Ger.: Bayer AG, 2022), 105, https://www.bayer.com/sites/default/files/2022-03/Bayer-Annual-Report-2021.pdf.
164. Alice Bernard et al., *Phasing out the use of microplastics: The road to an effective EU restriction of intentionally-added microplastics* (March 2021), 37, https://rethinkplasticalliance.eu/wp-content/uploads/2021/03/the_road_to_an_effective_EU_restriction_of_intentionally-added_microplastics.pdf.
165. See, e.g., a microplastic-free encapsulation technology called Sustaine derived from yeast extract. "Our technology - Sustaine," Eden Research, accessed April 21, 2022, https://www.edenresearch.com/technology/sustaine.aspx.
166. Bernard et al., *Phasing out the use of microplastics*, 38.
167. European Union, "REGULATION (EU) 2019/1009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003," OJ L 170 (2019), 1–114 at Annex II, CMC 9, https://eur-lex.europa.eu/eli/reg/2019/1009/oj.
168. FAO, *Assessment of Agricultural Plastics*, 105.
169. "The advent of less-expensive polymer coating technology has led to increased consumption of CRFs in commodity (big-acreage) agriculture, especially in North America (the United States and Canada) and mainland China." IHS Markit, *Chemical Economics Handbook*.
170. "Updated requirements for fertilizer and supplement products that are, or contain, polymers," Government of Canada, last modified March 30, 2021, https://inspection.canada.ca/plant-health/fertilizers/notices-to-industry/2021-04-01/updated-requirements-for-fertilizer/eng/1617038722060/1617041399920.
171. Naoya Katsumia et al., "Accumulation of microcapsules derived from coated fertilizer in paddy fields," *Chemosphere* 267 (March 2021): 1, 9 (in pdf version) https://doi.org/10.1016/j.chemosphere.2020.129185.
172. FAO, *Assessment of Agricultural Plastics*, 105.
173. FAO, *Assessment of Agricultural Plastics*, 107.
174. Damian Carrington, "UN experts denounce 'myth' pesticides are necessary to feed the world," *The Guardian*, March 7, 2017, https://www.theguardian.com/environment/2017/mar/07/un-experts-denounce-myth-pesticides-are-necessary-to-feed-the-world.
175. Richard Shiffman, "Why It's Time to Stop Punishing Our Soils with Fertilizers," *Yale Environment 360,* May 3, 2017, https://e360.yale.edu/features/why-its-time-to-stop-punishing-our-soils-with-fertilizers-and-chemicals.
176. The European Commission, for example, has included two pesticide reduction targets in its Farm to Fork Strategy: a 50 percent reduction in the use and risk of chemical pesticides by 2030, and a 50 percent reduction in the use of more hazardous pesticides by 2030. "Farm to Fork targets - Progress," European Commission, accessed April 21, 2022, https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides/farm-fork-targets-progress_en.
177. United Nations, Environment Assembly Resolution 5/14, *End plastic pollution: towards an international legally binding instrument,* UNEP/EA.5/RES.14 (7 March 2022), https://undocs.org/UNEP/EA.5/RES.14.
178. United Nations, General Assembly, *Implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes*, A/76/332 (22 July 2021), 23, https://undocs.org/A/76/207.

Text Box Endnotes

i. IHS Markit, *Chemical Economics Handbook: Controlled- and Slow-Release Fertilizers* (IHS Markit, June 2021), https://ihsmarkit.com/products/controlled-and-slow-release-chemical-economics-handbook.html; "Overview," Kingenta, accessed March 7, 2022, http://en.kingenta.com/Content/index/id/2.html.

ii. "Fertilizer Encapsulation," Dow, accessed April 15, 2022, https://www.dow.com/en-us/market/mkt-agro-feed-animal-care/sub-agro-crop-solutions/fertilizer-encapsulation.html.

iii. M.E. Trenkel, *Slow- and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture* (Paris: International Fertilizer Industry Association, 2010), 125–127, https://www.fertilizer.org/images/Library_Downloads/2010_Trenkel_slow%20release%20book.pdf.

iv. Fior Markets, "Global Microencapsulated Pesticides Market is Expected to Reach USD 817.45 Million by 2025: Fior Markets," GlobeNewswire, news release, July 31, 2019, https://www.globenewswire.com/en/news-release/2019/07/31/1894943/0/en/Global-Microencapsulated-Pesticides-Market-is-Expected-to-Reach-USD-817-45-Million-by-2025-Fior-Markets.html.

v. "Nitrogen," Nutrien, accessed April 15, 2022, https://www.nutrien.com/what-we-do/our-business/nitrogen.

vi. Nutrien, *Nutrien Annual Report 2020* (Saskatoon, SK: Nutrien, 2021), 17, https://nutrien-prod-asset.s3.us-east-2.amazonaws.com/s3fs-public/uploads/2021-03/Nutrien-2020-Annual-Report-Enhanced.pdf.

vii. "ESN: How it's made," Nutrien, accessed April 15, 2022, https://smartnitrogen.com/esn-how-its-made/.

viii. Trenkel, *Slow- and Controlled-Release and Stabilized Fertilizers*, 26.

ix. Nutrien, *Nutrien Annual Report 2021* (Saskatoon, SK: Nutrien, 2022), 30, https://nutrien-prod-asset.s3.us-east-2.amazonaws.com/s3fs-public/uploads/2022-02/2021%20Nutrien%20Annual%20Report.pdf.

x. Nutrien, *Nutrien Annual Report 2021*, 17, 31.

xi. ICL Group, accessed April 18, 2022, https://www.icl-group.com/.

xii. ICL Group Limited, *Annual Report For the Period Ended December 31, 2021* (Tel Aviv: ICL Group Limited, 2022), 81, https://www.sec.gov/Archives/edgar/data/941221/000117891322000767/zk2227317.htm.

xiii. "Osmocote®, a unique invention," ICL Specialty Fertilizers, accessed March 3, 2022, https://icl-sf.com/global-en/explore/nursery-stock-perennials-pot-bedding-plants/coated-fertilizers-oh/.

xiv. "Controlled Release Fertilizers," ICL Specialty Fertilizers, accessed March 3, 2022, https://icl-sf.com/global-en/explore/fruit-vegetables-arable-crops/controlled-release-fertilizers/.

xv. ICL Group Limited, *Annual Report For the Period Ended December 31, 2021*, 82.

xvi. "About Us," Kingenta, accessed March 8, 2022, https://www.kingenta.com/about.aspx?tags=0.

xvii. Jidong Zhai, "Improving Nitrogen Use Efficiency through Slow & Controlled Release Fertilizers," (PowerPoint presentation, Kingenta, New Delhi, India, March 2015), 15, https://www.fertilizer.org/images/Library_Downloads/2015_ifa_fai_newdelhi_jidong.pdf; "CCM: Kingenta to benefit from Chinese government's promotion of controlled release fertilizers," *CCM Data & Business Intelligence*, March 31, 2016, http://www.cnchemicals.com/Press/84064-CCM:%20Kingenta%20to%20benefit%20from%20Chinese%20governments%20promotion%20of%20controlled%20release%20fertilizers.html.

xviii. Zhai, "Improving Nitrogen Use Efficiency," 15.

xix. See, e.g., this 2008 patent filed for a thermoplastic membrane wrapping for CRF: 万连步, 张晓义, 徐恒军. Thermoplastic resin membrane wrapping control-releasing fertilizer and production method thereof. Chinese Patent CN101362663B, filed September 3, 1008, and issued May 30, 2012, https://patents.google.com/patent/CN101362663B/en?q=thermoplastic+coating+fertilizers&oq=thermoplastic+coating+fertilizers.

xx. "Koch Agronomic Services, LLC," Nutrient Stewardship, accessed April 15, 2022, https://nutrientstewardship.org/partners/koch-agronomic-services-llc/.

xxi. Harrell's, "POLYON® Polymer Coating Environmental Impact Report," *Harrell's* (blog), January 28, 2020, https://harrells.com/blog/post/polyon-environmental-impact#:~:text=In%20the%20production%20of%20POLYON,Degradation%20Mechanism.

xxii. Landscape Management Staff, "Harrell's acquires Polyon from Koch Agronomic Services," *Landscape Management* (blog), November 15, 2019, https://www.landscapemanagement.net/harrells-acquires-polyon-from-koch-agronomic-services/.

xxiii. "Duration CR," Allied Nutrients, accessed April 15, 2022, https://www.alliednutrients.com/Products/ControlledRelease/DURATIONCR/; "Koch Turf & Ornamental Licenses Technologies to TurfCare Supply Corporation," Koch Turf & Ornamental, accessed April 15, 2022, https://kochturf.com/.

xxiv. "Fastac® CS Insecticide," BASF, accessed March 3, 2022, https://agriculture.basf.us/crop-protection/products/insecticides/fastac-cs.html.

xxv. "DuraGuard® ME Microencapsulated Insecticide," BASF, accessed March 3, 2022, https://betterplants.basf.us/products/duraguard-me.html.

xxvi. "Cy-Kick® CS Controlled Release Insecticide," BASF, accessed March 3, 2022, https://pestcontrol.basf.us/products/cy-kick--cs-controlled-release-insecticide.html.

xxvii. "Controlled Release Fertilizers (CRF)," BASF Polyurethanes, accessed April 15, 2022, https://polyurethanes.basf.us/markets/controlled-release-fertilizers-crf.

xxviii. "Fertilizer Encapsulation," Dow, accessed April 15, 2022, https://www.dow.com/en-us/market/mkt-agro-feed-animal-care/sub-agro-crop-solutions/fertilizer-encapsulation.html.

xxix. See, e.g., Dr. Zhong Ling and Zhang Shi Ling, "Dow: Using Encapsulation Technology to Address the Agrochemical Formulation Trend," *AgNews*, October 31, 2018, https://news.agropages.com/News/NewsDetail---28137-e.htm; Dow, *Formulations Guide CS Capsule Suspension*, https://www.dow.com/content/dam/dcc/documents/en-us/formulation/119/119-02444-01-capsule-suspension-cs-formulations-guide.pdf?iframe=true.

xxx. Christopher Walljasper, "DowDupont split off its agriculture business; here's what to know about Corteva Agriscience," *Investigate Midwest*, June 12, 2019, https://investigatemidwest.org/2019/06/12/dowdupont-split-off-its-agriculture-business-heres-what-to-know-about-corteva-agriscience/.

xxxi. Reuters Staff, "ChemChina, Sinochem merge agricultural assets: Syngenta," *Reuters*, January 5, 2020, https://www.reuters.com/article/us-chemchina-sinochem-syngenta/chemchina-sinochem-merge-agricultural-assets-syngenta-idUSKBN1Z40FZ.

xxxii. "Demand CS Insecticide," Syngenta, accessed April 15, 2022, https://www.syngentapmp.com/product/demand-cs-insecticide.

SOWING A PLASTIC PLANET

How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future

We are increasingly living on a plastic planet. Due to the explosion in plastic production and use, plastic pollution has grown exponentially in recent years. Tiny particles of plastic — or microplastic — are accumulating across the planet in even the most remote areas, in the air, in water, in soil, in plants, and in animals, including in our bodies. Humans are ingesting and breathing plastics and the toxins they contain through this continued environmental exposure.

One of the least known and most concerning sources of microplastic pollution is their deliberate addition to synthetic fertilizers and pesticides used in industrial agriculture. The application of plastic-coated agrochemicals to soils and crops directly introduces microplastic into the environment and potentially into the food supply. It also compounds the health and environmental hazards posed by agrochemicals themselves.

Synthetic fertilizers and pesticides, derived primarily from oil- and gas-based feedstocks, are already some of the most toxic substances in use today. Encapsulating them in microplastic, itself fossil fuel in another form, only heightens the risks. Because of its deliberate and controlled nature, microplastic pollution from plastic-coated agrochemicals is especially egregious, but it is also readily preventable. The only barriers are public awareness of the problem and political will to tackle it at its source by regulating the plastics industry.

Sowing a Plastic Planet: How Microplastics in Agrochemicals Are Affecting Our Soils, Our Food, and Our Future exposes the growing use of microplastics in agrochemical products, the industry's promotion of this practice, and its threats to human health and the environment. It concludes that, in the face of known risks and the significant probability that plastic-coated fertilizers and pesticides only add to existing harm from toxic chemicals and microplastic, their production and use should be banned.

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