

Plastic pellets, powders, and flakes – a key source of microplastics to the environment

Fate, effects, and mitigation strategies

Introduction

Plastics are material(s) made wholly or partly of synthetic or semisynthetic polymers¹, and microplastics are small pieces of plastic (longest dimension ≤ 5 mm). They are widely distributed in the environment, with evidence of harm at multiple levels of biological organisation.^{2,3} Microplastics originate from multiple sources; broadly subdivided as primary microplastics, which are manufactured to be < 5 mm including: preproduction pellets, and particles that are intentionally added to products such as paints⁴ and cosmetics⁵; and secondary microplastics which are generated by the wear of larger items including: tyres⁶, textiles⁷ and plastic debris. It is estimated that 10 to 40 million tonnes of microplastics enter the environment annually³ they are persistent and cannot effectively be removed. Hence, interventions to minimise releases are key.

This document focuses on pellet loss, as they are recognized as the third largest source of unintentionally released microplastics, and therefore a significant source of plastics pollution. Estimates of pellets release globally each year range from nearly 450,000 to 848,000 tonnes with losses occurring across supply chains, on land and at sea.⁸⁻¹¹

Plastic pellets have been estimate to account for 9% of microplastics emissions in the EU, increasing from 2016–2022.¹² In global estimates, pellets account for 22% and 39.1% of releases to oceans and land, respectively, and together with paint and tyre wear particles, account for 93% and 99% of microplastics emitted.¹¹

Definitions, functions, use, and quantities and pathways to the environment

Microplastics² are released to the environment at all stages of the plastics life cycle, including during the production of plastic product precursors, such as pellets (also known as nurdles) which are used as the raw material in the manufacturing of plastic products.

In addition to pellets (typically 3–5 mm in size), primary plastic polymers can also be produced in other forms such as films, flakes and powders

Primary microplastics

- Pellets, powders, and flakes are plastic materials that are produced as microplastics (< 5 mm).
- These are released to the environment across the supply chain: at production sites, during storage, shipping, transportation, and manufacturing.
- Primary microplastic releases are widespread, persistent, and harmful to ecosystems and wildlife, and incur significant socio-economic costs.
- Key solutions include preventing releases and leakage through stricter handling and transport controls, mandatory reporting and cleanup obligations, and stronger international regulations across the plastics supply chain.



Photo credit: Juan Baztan, taken in Galicia, Spain, taken after the Toconao pellet spill in December, 2023.

(< 1 mm in diameter). They are produced from monomers, the raw materials or building blocks of plastics, as well as additives, processing agents and non-intentionally added substances, including by-products, degradation products, and contaminants.¹³ Further, plastic pellets, flakes and powders may be produced from recycled plastics materials in waste stages. All plastics contain chemicals, including additives and non-intentionally added substances^{13,14} but recycled plastics pellets can contain more complex mixtures of toxicants due to the complex and highly unregulated nature of plastic waste flows, mixtures of products containing unreported chemicals, and sources of contamination.¹⁴

Pellets are commonly lost to the environment through spills at production sites, during conversion, storage, handling, and during land-transport and shipping. Releases can be chronic, or acute such as in the form of large spills. Pellets can accumulate in terrestrial soils or wash into streams and rivers via surface runoff and find their way to the ocean.¹⁵ Rivers are an important pathway of pellets to the ocean and a higher abundance of pellets is observed on beaches near river mouths.¹⁶

Coastal environments are significant sites of pellet accumulation, and the sources are generally port facilities, cities, and industrial areas,¹⁸ as well as spillage resulting from incidents at sea. Pellets can also be present in pristine coastal environments¹⁹ due to long-range environmental transport via ocean currents and wind, from nearby industrialised areas, leakage of pellets during maritime transportation, or following container negligence in handling, loss/shipping accidents and incidents, and environmental disasters.²⁰

The *X-Press Pearl* disaster in Sri Lanka (May 2021) was the largest plastic-based disaster from a single vessel in maritime history: a spill of 12,000 tonnes of plastic materials, including ~70 billion plastic pellets.²¹ These pellets accumulated on the beach, leading to social, economic and environmental repercussions, including environmental degradation and costs of cleanup or loss of ecosystems services. Another significant, large scale plastic pellet spill occurred in European waters in late 2023. The *Toconao*, a Liberia-registered vessel chartered by the shipping company Maersk, lost 1,000 sacks, each containing 25 kg of pellets manufactured by the Indian company *Coroplast*, 80 km offshore of Portugal, with pellets washing ashore across regions of Portugal, Spain and France.²¹⁻²³ Yet another container ship, the *MSC Elsa 3*, sank off the coast of India in 2025, polluting the area with pellets.²⁴

Pellets are produced and traded internationally highlighting the need for global mitigation strategies. The International Maritime Organisation (IMO), MARPOL under Annex III, has taken significant steps to classify pellets as hazardous, meaning they are now placed lower down on cargo ships to reduce the chance of loss. However, this recommended legislation only addresses maritime shipping and does not address all other sources of pellets.

Due to their small size, pellets can be transported by wind and water (rivers, oceans) becoming dispersed over significant distances and geographic locations. Consequently, when spilled, there is no easy or effective way of cleaning up pellet pollution from the environment. Therefore, prevention is key.

Environmental and socio-economic impacts

As with other plastics, pellets are transboundary in nature, persistent, remaining in the environment for many years, fragmenting into smaller micro- and nanoplastics over time, and releasing molecular degradation products. This fragmentation is influenced by ultraviolet light, heat, humidity and microorganisms, as well as wind or wave energy. Newly produced plastics pellets will contain a number of potentially hazardous chemicals, such as UV-stabilizers,²¹ while recycled plastics pellets will contain hundreds of additional chemicals that have sorbed into the plastics during the use and waste phases, including pesticides, pharmaceuticals, and persistent organic pollutants (POPs) like polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).¹⁴ Further, pellets adsorb environmental contaminants, acting as vectors for agrochemicals, and accumulating hazardous chemicals from the surrounding water that within a matter of days can become orders of magnitude more concentrated than in the surrounding water.²⁵ A shipping incident may involve cargo consisting of both plastics pellets and other chemicals or be associated with a fire, e.g. the *X-pearl* accident, and this combination can result in increased bioavailability and dispersal of other substances via the plastics.

Pellets can easily be mistaken for food by birds and marine organisms. Ingestion of plastic pellets by wildlife has been recognised as potentially harmful for over 50 years, and substantial proportion of fish, turtles and sea bird populations have been contaminated in some locations.²⁶ Ingestion of pellets can cause physical and chemical impacts,²⁷ including structural damage to the digestive tract and disruptions in feeding behavior. Impacts on terrestrial biodiversity have also been reported.²⁸ The toxic substances associated with plastics can have hazardous properties including metabolic, carcinogenic, endocrine or immunological effects.¹³ Further, pellets can harbor microbial communities, including pathogens such as *Vibrio spp.* and *E. coli*, antibiotic resistance genes, and harmful algal bloom species.^{29,30}

Additionally, harm may be measured in the form of socio-economic damages, for example impacts on coastal fishing communities and tourist industries.^{31,32} An evaluation of the impacts of the pellet spill in Sri Lanka found major direct impacts on sensitive coastal environments, local communities and economies. An estimated 20,000 fishing families were impacted following the *X-Press Pearl* spill, due to fishing bans, with little compensation.³² Fishers and their families were also reported to suffer psychological stress due to the collapse of their industry and loss of income and a food source. Cleanup is difficult, time consuming and costly, and is still ongoing in Sri Lanka. Costs have been calculated to be very high, with Sri Lanka's Supreme Court following the polluter pays principle (PPP) to order payments equaling \$1 billion in compensation to cover costs of cleanup and damage, from the owners and local agents of the *MV X-Press Pearl*.^{33,34} Following another pellet spill that took place in Durban, South Africa in 2017, the plastic producer *Saudi Basic Industries Corporation (SABIC)*, was again subject to the PPP. The PPP was also applied in Hong Kong in 2012, after 150 tonnes of pellets were dumped into the ocean. The company that owned the pellets, *Sinopec Corp.*, was ordered to contribute the equivalent of \$1.28 million towards the cleanup effort.³⁵

Pellet spills pose a major risk to the resilience of marine and coastal ecological systems as well as socio-economic costs.

Potential interventions

Plastic pellet pollution is a chronic and an acute problem. While acute (e.g. *X-Press Pearl*) losses receive most media attention, are easier to measure, and constitute international maritime disaster incidents; chronic pellet leakage (i.e. small but steady), on the other hand, occur daily and are similarly consequential. Pellets are lost at all stages of the supply chain. Cleanup is costly and difficult and must be done in an environmentally sound manner. Consequently, coordinated international action to improve conditions and processes at all stages of the pellet supply chain are needed, including primary plastic polymer reduction targets, prevention of releases, leakages and spills from production, storage, handling and transportation.

Pellet loss can be addressed by ensuring the agreed treaty text results in obligations including

- following the waste hierarchy, and as a priority, reducing primary plastics production.
- establishing obligations on transparency and reporting concerning production of pellets all along the life cycle (including information on volumes of polymers and chemicals)
- require instalment of traps to prevent loss within industrial facilities handling pellets
- necessitating obligations on cleanups of spilled pellets via extended producer responsibility (EPR) and dedicated funds, optimally facilitated by producer or transporter
- establishing mandatory EPR schemes throughout the entire life cycle of plastics
- increasing awareness and requirements of workers handling and shipping pellets to avoid spills
- including of pellets on HSN (Harmonised System of Nomenclature) lists
- harmonizing the global plastics treaty existing legislation under e.g., Annex III and V of the International Convention for the Prevention of Pollution from Ships (MARPOL Convention),³¹ the London Convention and its Protocol,³⁶ regulation of spillage of pre-production pellets, powders and flakes during transportation by the IMO under the International Maritime Dangerous Goods (IMDG) Code,³⁷ as well as handling and management strategies and practices relevant to land and sea, outlined in PAS 510:2021.³⁸

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