Operational Guide

PLASTIC PELLETS:
LOSS PREVENTION ON INDUSTRIAL SITES AND RESPONSE IN THE ENVIRONMENT

Cedre

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Purpose and structure of this guide

Demand for plastic products has been on the rise since the end of World War II. The manufacture of plastic items involves the production of plastic pellets, an intermediary between the raw material (e.g. oil, gas, other bio-based substances) and the finished plastic product. In 2023, more than 310 million tonnes of plastic pellets were produced worldwide. As a result of possible operational losses throughout the production and processing chain or accidental losses during transport (by sea, river, rail or road), plastic pellets are released into the environment and can reach aquatic environments where they are liable to cause ecological and socio-economic damage.

Against this backdrop, this guide presents the main aspects to be considered in order to (1) prevent plastic pellet losses throughout the production and processing chain, (2) respond to incidents resulting in the release of plastic pellets into the environment. It draws primarily on a literature review, the knowledge developed by Cedre and the experience acquired during response operations following plastic pellet spills.

This guide is divided into five sections presenting:
- The general characteristics of plastic pellets (definition, transport, identification and behaviour in the environment, composition, potential risks);
- The methods available to industry (e.g. manufacturers, processors, logistics companies) and freight carriers to prevent losses;
- The response resources and techniques that can be implemented following a release into the environment (e.g. response organisation, equipment to be considered, pollution assessment and monitoring, waste management);
- Case studies;
- Tech Sheets.

The words and expressions followed by a • in the text are defined in the glossary on page 84.

The guides published by Cedre that are mentioned in this document can be downloaded from Cedre's website.

Contents

I - GENERAL ASPECTS

1. Definition and composition

Plastic pellets•, also referred to as pre-production plastic pellets, plastic resin pellets, or more commonly as "nurdles", are an intermediary between the raw material (oil, gas, other bio-based substances, recycled plastics) and the finished plastic product. Plastic pellets are composed of thermoplastics, i.e. plastics which are malleable under the effect of heat, meaning that they can be moulded to form a predetermined plastic object (see Figure 1 for a simplified representation of the manufacture of plastic products).

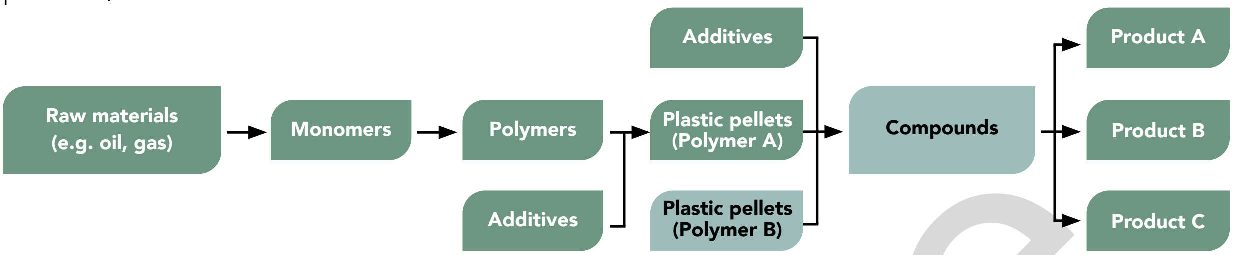


Figure 1. Simplified representation of the manufacture of plastic products. The pale green boxes represent optional stages.

A pellet is defined within ISO 472:2013 as a "*small mass of preformed moulding material, having relatively uniform dimensions in a given lot, often used as feedstock in moulding and extrusion operations*". Under French law, plastic pellets are defined as "*plastics marketed in various forms, whose outer dimensions are greater than 0.01 mm and less than 1 cm*" (French decree no. 2021-461 of 16 April 2021 on preventing the loss of plastic pellets into the environment). While plastic industrial raw materials come in various forms (pellets, flakes, powders), this guide will focus on pellets which are the most common form (> 80 % of production).

Pellets are produced after the polymerisation stage using industrial pelletizing machines. These machines melt the plastic, which is then made into strands by an extrusion line with extrusion dies. The strands are then cut by knives to form pellets. A detailed presentation of industrial pellet production processes is provided in the *Additional information* section on page 85.

In terms of their morphology, pellets are generally between 2 and 5 mm in size, weigh 0.02 to 0.025 g per pellet and come in various shapes (disc, cylindrical) and colours depending on the industrial production processes and their application (Figure 2). Because of their size, plastic pellets are classified as primary microplastics (manufactured plastics smaller than 5 mm).

Figure 2. Examples of the different shapes of plastic pellets.

In terms of their composition, plastic pellets are composed of two elements:

- **A polymer structure** makes up on average 93% of the mass of plastics. Although several dozen different polymers are used in the production of plastics on the market, the majority of global plastic pellet production (79%) is dedicated to the production of polyethylene (high and low density), polyethylene terephthalate, polypropylene, polystyrene (expanded or not) and polyvinyl chloride (PVC) *(details of production volumes are available in the Additional information section on page 85).*

- **Chemical additives** represent on average 7% of the mass of plastics. However, in certain specific cases, the percentage of additives can be much higher, as in the case of PVC or masterbatches• containing specific additives. When the *Toconao* lost containers overboard off the coast of Portugal in December 2023, one lost container was loaded with bags of pellets of a masterbatch, a blend of polyethylene with UV-622, a UV stabiliser, representing 10% of the mass of the pellets. Additives are incorporated into pellets and plastic products to give the finished product specific characteristics (e.g. colour, plasticity, UV resistance, heat resistance, impact resistance). The range of additives used is complex, with over 13,000 used in the plastics industry, in addition to which unintentionally added substances (reagent residues, transformation products•, by-products) can be found.

2. General physico-chemical characteristics and properties

Plastic pellets can be distinguished by their physico-chemical properties which differentiate them from oil and chemicals when released into the environment, although they do share some similarities.

Plastic pellets are:
- Solid;
- Persistent and resistant to biodegradation according to polymers and external conditions;
- Insoluble in water;
- Non-emulsifiable;
- Non-evaporating;
- Non-adhesive.

These characteristics are of major significance as they indicate that recovery is the only possible active method of responding to losses in the environment, contrary to oil and chemical spills for which various response techniques can be implemented (dispersion, burning) depending on the situation.

The physico-chemical properties of the five main polymers (~79% of world production in 2023) are shown in Table 1.

Polymers	Density (g/cm^3)	Melting point (°C)	Glass transition temperature (°C)	Resistance to tensile stress (MPa)	Crystallinity (%)
Polyethylene	0.89 - 0.98	90-130	-25	8-32	45-95
Polypropylene	0.83 - 0.92	130-175	(-10)-(-20)	31-41	50-80
Polyethylene terephthalate	0.96 - 1.45	245	70-73	48	0-50
Polystyrene + Expanded polystyrene	PS: 1.04 - 1.1; EPS: 0.01 - 0.04	N/A	87-105	36-52	0
Polyvinyl chloride	1.16 - 1.58	115-245	75-105	41-52	0-15

Table 1. Physico-chemical properties of the main polymers.

3. Modes of transport

To meet global demand, plastic pellets are transported in large quantities by land and sea. There are five main types of packaging used to transport plastic pellets (Figure 3) between where they are manufactured and where they are to be used: (i) 25 kg bags (~1 million pellets) on pallets (55 bags per pallet; 1,375 kg; ~60 million pellets); ii) 500-1,300 kg octabins (~20-52 million pellets); (iii) 500-1,000 kg big bags (~20-40 million pellets); (iv) in bulk in tanker trucks (up to 35 tonnes, i.e. ~1.4 billion pellets); (v) in containers with a dry bulk container liner (~25 tonnes, 1 billion pellets). The most common modes of transport (> 90% of volumes transported) are currently transport in 25 kg bags and in bulk.

Figure 3. Main packaging types for transporting plastic pellets.

Plastic pellets are transported by road, rail, river and sea. The majority of plastic pellets are transported by sea. This is consistent with the transport of other goods, with over 80% of the volume of world trade in goods being carried by sea The main shipping routes are outlined in the *Additional information* section on page 85.

4. Regulations

4.1. Regulations governing industrial processes

Regulations form a functional legal framework through the application of standards and directives to guide actions. In the case of environmental regulations, the main objectives are to protect the environment and contribute to the preservation of natural resources, to safeguard public health, as well as to prevent and mitigate pollution where relevant.

Plastic pellets are currently the focus of various regional and national recommendations and regulations.

In France, the implementation of the OSPAR Convention's recommendations on the reduction of land-based plastic pellet inputs is an integral part of the "*Zero Plastic Waste at Sea*" 2020-2025 action plan (Action 3 of Axis 1 "*Preventing upstream/land-based plastic pollution*"). In addition, in 2021 France published decree 2021-461 of the AGEC law (Anti-waste for a circular economy) specifically targeting industrial sites handling plastic pellets to prevent losses beyond site boundaries. Under this decree, industrial firms using and/or handling more than five tonnes of plastic pellets per year must have the necessary equipment and procedures to prevent losses and leaks of plastic pellets, and undergo inspections every three years by independent certified bodies.
In the United States, in 1992, the Environmental Protection Agency (US EPA) drew up best practice recommendations for manufacturers to reduce plastic pellet discharges throughout the industrial chain

(manufacturers, freight carriers and processors). These recommendations include for instance: improving the handling of plastic pellets to prevent losses on industrial sites, implementing site cleaning to avoid releases into the environment, developing more resistant packaging for transport, and developing the recycling of plastic pellets spilt into the environment and recovered during clean-up operations. In California, the discharge of stormwater by manufacturers handling plastic pellets has been subject to strict regulations since 2008 under the California Water Code.

As part of the EU's Zero Pollution Action Plan which aims to reduce the quantity of microplastics released into the environment by 30% by 2030, plastic pellets are now considered to be among the main microplastics targeted, and are the focus of a text currently under discussion to reduce industrial discharges. Pollution by plastic pellets is also identified by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) and is targeted by as specific action under the 2022-2030 Regional Action Plan for Marine Litter (Action C.1.1 "*Prevent microplastic pollution resulting from plastic pellet, powder and flake loss*"). Action C.1.1 consists in:

- Implementing OSPAR Recommendation 2021/6 to prevent operational losses, in particular through training for industry and certification schemes (e.g. Operation Clean Sweep certification, see Section 2).
- Developing guidance to support clean-up operations after spills of plastic pellets from both land-based and maritime sources.

4.2. Regulations governing transport

In 2024, plastic pellets are not classified as "dangerous goods" (materials or objects likely to present a risk to health, safety, property or the environment) or as "harmful substances" (materials identified as marine pollutants) by the IMDG Code (International Maritime Dangerous Goods Code), ADR (Agreement concerning the International Carriage of Dangerous Goods by Road), ADN (Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways) or RID (Regulations concerning the International Carriage of Dangerous Goods by Rail), with the exception of pre-expanded pellets, also known as expandable polymeric beads (see Box 1).

The current classification of plastic pellets creates operational problems in the event of an accident during transport due to inaccurate information in transport manifests. Based on recent accidents, plastic pellet cargoes may be identified in manifests as "plastic pellets", "pre-production pellets", "plastic resin", "epoxy resin, plastic" or directly by the type of polymer, leading to difficulties in identifying the presence of plastic pellets and assessing the quantities transported.

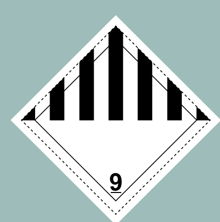
For maritime transport, plastic pellets (with the exception of pre-expanded pellets) are not subject to any specific obligations regarding their packaging or their positioning on the deck of a container ship or merchant vessel and do not necessarily appear on the cargo manifest, which makes it difficult to identify them when an incident occurs at sea leading to their release. They are not covered by the International Convention for the Safety of Life at Sea (SOLAS 74), of which Chapter VII deals with the carriage of dangerous goods, nor by the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78).

On-deck storage of containers of plastic pellets increases the likelihood of losses at sea in adverse weather conditions. Due to the recurrence of losses of plastic pellets during transport by sea, proactive initiatives have been observed since 2023 to change transport methods, such as improvements in practices (e.g. increasing tear resistance of packaging, stowing containers under deck, better identification of the presence of plastic pellets in containers) and/or the request submitted to IMO• to reclassify all plastic pellets as dangerous goods.

The costs incurred by plastic pellet spills, and notably clean-up costs, economic losses and restoration costs, are not governed by any international convention. Feedback from past incidents shows that these costs are borne by the companies responsible for the incident, whether freight carriers or manufacturers. For example, following the loss of containers transporting plastic pellets by the *MSC Susanna* (Durban, South Africa) and the *Trans Carrier* (North Sea), the owners of these vessels covered at least part of the costs incurred by the clean-up operations. In the case of the *X-Press Pearl* incident, the Sri Lankan authorities received $8 million in compensation from the shipowner in 2023, while the total cost of the incident could reach as much as $7 billion. Once the Hazardous and Noxious Substances Convention (HNS Convention•) has been ratified, signatory countries will be covered against spills of expandable polymeric beads because of their classification under the IMDG Code (group (iv) of the HNS Convention, i.e. dangerous, hazardous and harmful substances, materials and articles in packaged form as covered by the IMDG Code). However, other types of plastic pellets, which represent the vast majority of imports and exports (> 90%) will not be covered by the HNS Convention as they are not currently classified under the IMDG Code.

Box 1: Maritime transport of expandable polymeric beads (UN no. 2211)

Expandable polymeric beads are classified in Class 9 "Miscellaneous dangerous substances and articles" of the IMDG code and fall under Packing Group III (low danger). This classification is due to the way in which these “pre-expanded” pellets are manufactured, involving a possible release of pentane during transport, which can create a flammable atmosphere. These pellets may be transported by sea in various types of packaging (e.g. cardboard, plastic) or in intermediate bulk containers (IBCs), subject to compliance with the general and special provisions of the IMDG Code. As no subsidiary risks are identified in the IMDG Code, no specific type of segregation is required for the transport of expandable polymeric beads by ship. There are also no specific requirements in terms of the spatial positioning of this type of cargo on board a ship, meaning that expandable polymeric beads may be stored on deck during transport.



5. Environmental losses

5.1. Sources of plastic pellet losses into the environment

Two sources of environmental losses have been identified: (1) operational losses throughout the plastic pellet production and usage chain, (2) accidental losses during transport.

Operational losses of plastic pellets occur at each stage of the production and usage chain. According to the latest report by the European Commission published in 2023, pellet production (including plastic pellet production during recycling processes), transport and processing reportedly led to the release of an estimated 52,140 to 184,290 tonnes of plastic pellets into the environment in the EU in 2019. This broad range reflects the high degree of uncertainty over the quantities of plastic pellets lost into the environment (further studies will be necessary to finetune this estimation). These operational losses result from handling incidents (e.g. damage to packaging, losses during the filling of silos/trucks/containers/bags). Following a survey sent to manufacturers as part of the Operation Clean Sweep• (OCS) programme, three main areas where plastic pellet losses occur on industrial sites were identified: loading, unloading and handling areas. A risk of loss due to failure to properly close trucks or containers and during cleaning operations has also been identified. Such operational losses on industrial sites can spread beyond site boundaries due to plastic pellets being carried by wind or stormwater run-off if the site does not have preventive measures in place, leading to the contamination of aquatic environments when plastic pellets reach the stormwater network or watercourses.

Accidental pellet losses are sporadic events yet can be significant for the environment in the case of road, rail or shipping accidents. Recent studies of accidents involving plastic pellet losses worldwide have identified 34 accidents of which 32% occurred at sea, 44% were road accidents and 24% rail accidents (Figure 4). Maritime shipping incidents attract the most media attention because of the quantities transported and potentially released if containers are damaged and/or lost overboard, or, in the worst case scenario, if the vessel sinks (e.g. container ship, ro-ro vessel). For example, adverse weather conditions led to the damage to and/or loss of containers carried by the *MSC Zoe* (in 2019) and the *Trans Carrier* (in 2020), resulting in the release of 22.5 and 13.2 tonnes, respectively, of plastic pellets into the North Sea, while a fire causing the sinking of the *X-Press Pearl* (2021) in Sri Lankan waters resulted in the loss of 11,000 tonnes of plastic pellets in the environment. Figure 5 shows a map of recent major shipping incidents.

Figure 4A. Plastic pellets spilled during a shipping accident.

Figure 4B. Plastic pellets spilled during a rail accident.

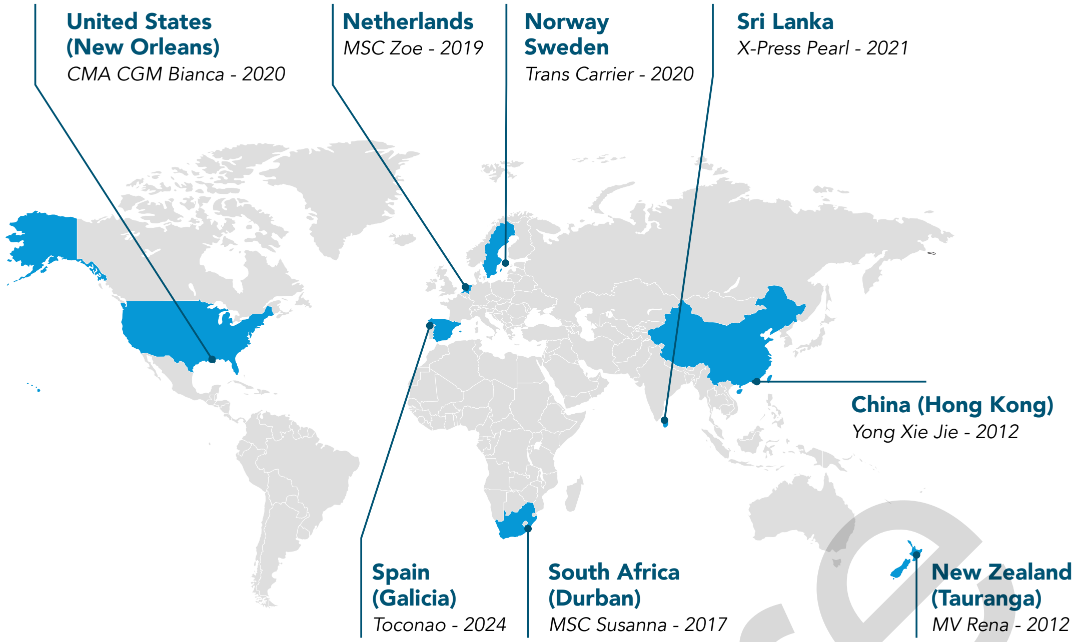


Figure 5. Map showing recent major maritime incidents involving plastic pellets worldwide.

5.2. Chronic pollution of the environment

As a result of chronic plastic pellet losses throughout the production and usage chain or due to accidents, both terrestrial and aquatic environments can be contaminated by plastic pellets, generating ambient pollution of aquatic ecosystems, particularly the marine environment and waterways near industrial sites. It is currently not known how long the main polymers take to completely decompose in the environment.

Plastic pellets are ubiquitous• contaminants in aquatic environments; they have been found on beaches, in sediments, in rivers, in coastal environments and in the digestive tract of marine animals since the 1970s (Figure 6). According to data collected and compiled by the French national network for the monitoring of mesoplastics and large microplastics on beaches, coordinated by Cedre, the median abundance of plastic pellets on the French coastline is 380 plastic pellets per 100 m of beach (2023 data obtained from 23 survey sites). Plastic pellets are one of the main primary microplastics released into the environment. In addition, plastic pellet losses in the environment contribute in the long term to an increase in the levels of secondary microplastics resulting from the degradation and fragmentation of the initial pellets under the effect of abiotic• processes (e.g. solar radiation, abrasion, hydrolysis) or biotic processes (e.g. the effects of micro-organisms) and therefore to the overall risk of plastic pollution in the environment.

Figure 6. Case of chronic pollution.

5.3. Accidental versus chronic pollution

In the event of a spill resulting in plastic pellets being released into the environment or washed up on the shoreline, an important aspect of monitoring consists in differentiating between plastic pellets resulting from the accident and those due to chronic pollution. Monitoring pollution levels will help to determine the time required for clean-up operations, and therefore influence clean-up costs.

It is not possible to differentiate between chronic and accidental losses based on the position of plastic pellets on the shore. In the case of large-scale deposits on the shoreline as a result of accidental or chronic pollution, plastic pellets can be found mainly along the strandline• mixed with other small plastics and natural debris or strewn across vast areas with distinct streaks depending on sea and weather conditions and the beach profile (Figure 7).

Criteria must be established to identify plastic pellets originating from spills at sea as soon as they begin to wash up. In the event of a ship-source spill, a sample of the plastic pellets released at sea may be sent to a reference laboratory before they reach the coast, thereby saving time during the initial characterisation phase.

Pellets can be characterised using two complementary methods: (i) morphological characterisation and (ii) chemical characterisation.

Figure 7. Examples of plastic pellets washed up on a beach in France.

5.3.1. Morphological characterisation

Depending on the characteristics of the lost goods, identifying the spilled plastic pellets may be straightforward or more complex. Initially, the colour and appearance of the spilled plastic pellets generally differentiate them from the plastic pellets typically found due to chronic pollution, which show signs of weathering (e.g. erosion, yellowing). These signs of weathering can be assessed by optical microscopy, electron microscopy and infrared spectroscopy (identification of the carboxylation index•, a marker of weathering due to solar radiation). On the other hand, in the case of a spill, plastic pellets are generally uniform and of the same colour and size, as long as the spill does not involve several types of pellets (Figure 8).

Some plastic pellets have specific colours and are easily identifiable compared to plastic pellets found in chronic pollution, in particular coloured pellets (e.g. red, green, orange) compared with translucent, white and black pellets, which are the predominant colours found in environmental samples (Table 2, Figure 9).

The existence of data on the levels and nature of chronic pollution by plastic pellets (obtained through monitoring programmes or studies, for instance) is an asset in the event of pollution to identify the plastic pellets spilled. If samples acquired as part of monitoring programmes are available, these can be used to carry out morphological analyses to help to identify the plastic pellets targeted by clean-up operations. In addition, this data can be used to determine the baseline pollution level of the affected area, which can be used as a threshold for clean-up end-points.

Figure 8. Photos of plastic pellets from a spill (left) and chronic pollution (right).

	Opaque white	Translucent white	Black	Yellow	Red	Green	Other
Percentage	3.83%	80.12%	14.44%	0.14%	0.45%	0.17%	0.69%

Table 2. Colour of the plastic pellets sampled as part of the French national programme for the monitoring of microplastics on beaches, coordinated by Cedre (15,446 plastic pellets visually analysed).

Figure 9. Example of orange coloured plastic pellets.

Morphological analysis of the shape and size of pellets is one possible method of distinguishing accidental losses from chronic pollution, although this is dependent on the pellets having an original shape and/or size. In general, the size and shape of plastic pellets are not sufficiently distinctive criteria to definitively confirm or rule out a common origin for pellets in the case of unusual deposits observed on a large geographical scale (for instance the case of deposits on the French Atlantic coast in 2023 for which no spill was reported to the authorities).

Furthermore, although morphological aspects can, in some cases, serve to identify chronic pollution during clean-up operations on a site, these aspects evolve over time under the influence of various biotic and abiotic processes, which naturally alter the surface of the pellets. Clean-up efforts to recover plastic pellets can last several years, as was the case following the loss of two containers of plastic pellets by the *MSC Susanna* in the port of Durban, for which clean-up operations on the South African coastline lasted for two years.

The use of analytical techniques, either alone or in addition to morphological analysis, may be required to increase the level of confidence in the identification of spilled plastic pellets.

5.3.2. Chemical characterisation

Chemical analysis of plastic pellets can provide additional information on their nature and composition, although it cannot determine the manufacturer or origin in the case of an orphan spill•.

Chemical analysis can, on the one hand, help to identify the nature of the polymer, which can be a distinctive identification criterion in the case of uncommon polymers (i.e. excluding PE, PP, PS which, for example, represent 100% of the plastic pellets analysed in 2023 as part of the French national programme for the monitoring of microplastics on beaches, coordinated by Cedre). This identification process can be implemented using techniques such as Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy or pyrolysis–gas chromatography–mass spectrometry (Pyrolysis-GC-MS). In addition, these analyses provide large datasets that can be used simultaneously in multivariate statistical analyses, thereby enhancing the ability to identify plastic pellets.

In addition to identifying polymers, plastic pellets comprise a variety of additives that can be analysed using different techniques (e.g. gas chromatography–mass spectrometry, GC-MS). Ideally, a multicomponent analysis performed rapidly by a reference laboratory would provide a detailed chemical profile of the plastic pellets spilled. However, these analyses tend to be long and costly, and it can take up to several weeks to obtain the results. Such timeframes are not always compatible with the need for an emergency response to a spill and for clean-up operations. In the case of an incident involving the loss of a masterbatch• of plastic pellets, as was the case when the *Toconao* lost containers overboard in December 2023 off the coast of Portugal, a quantitative chemical analysis targeting the additives present in the masterbatch pellets can be carried out within a few days by a reference laboratory, provided that it has the method required to analyse the specific additives.

Each type of plastic pellet has a unique formula, which varies depending on the manufacturer or processor, even for the same polymer (Figure 10). Consequently, wherever possible, information on the pellet composition should be obtained from the manufacturer in the event of a spill for which the origin of the pellets is known, in order to facilitate their identification in the environment and distinguish them from ambient pollution when morphological criteria are not sufficiently distinctive.

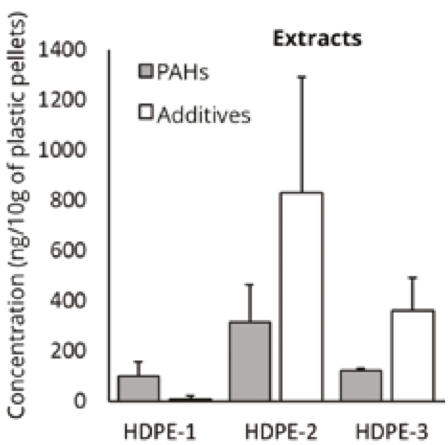


Figure 10. Illustration of the variability in concentrations (ng/10g of plastic pellets) of additives and polycyclic aromatic hydrocarbons (PAHs) in 3 separate batches of plastic pellets made of HDPE (high density polyethylene; chemical analysis targeting 56 compounds).

6. Behaviour of plastic pellets

6.1. Behaviour on water

The majority of plastic pellets currently manufactured tend to float (80% of world production = polyethylene + polypropylene; these two polymers have a density of less than 1). As a result, their behaviour and drift in aquatic environments are, in theory, strongly influenced by currents, waves, tides, winds and precipitation. However, this tendency to float will depend on the intensity of environmental constraints. On calm waters or in sheltered aquatic areas, "floating" plastic pellets will tend to form slicks at the surface (Figure 11), whereas waves and significant currents, as in the open sea, are likely to disperse the pellets horizontally (scattering them) and disrupt the buoyancy balance, causing the pellets to enter the water column.

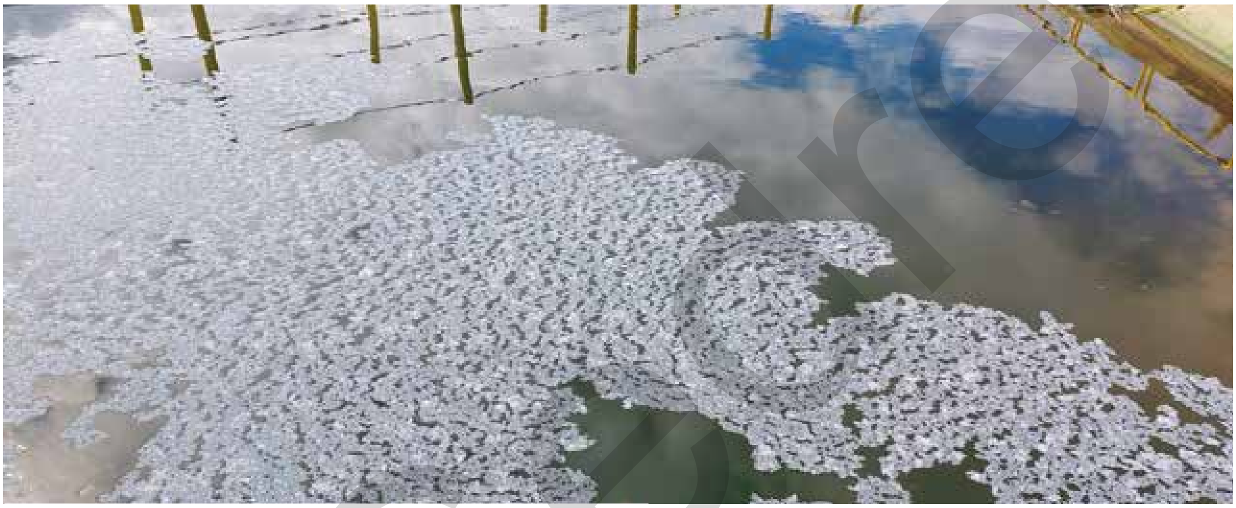


Figure 11. Pellets forming a slick on a sheltered body of water.

Because pellets are light and sensitive to winds, currents and ocean agitation, plastic pellet spills tend to disperse widely. During past incidents, pellets have been known to spread over several hundred kilometres (for example, following the sinking of the *X-Press Pearl* pellets were found along 750 kilometres of the Sri Lankan coast).

In the case of plastic pellets with a density greater than water (e.g. PVC, see Table 1), they will tend to sink and accumulate on the bottom and in the sediment, although processes such as currents and bioturbation can remobilise the pellets and cause them to disperse.

The spread of plastic pellets on the water will depend on whether and how the pellets are packaged (enclosed in a container, enclosed in 25 kg bags, loose in the environment).

In the case of a small spill in an inshore area, if the plastic pellets spilled are not recovered, sinking plastic pellets may behave in a similar way to sand and accumulate in the surf zone, while floating plastic pellets are likely to drift and wash up along the shoreline depending on the intensity and direction of the waves and wind.

6.2. Behaviour on land, riverbanks and beaches

Plastic pellets are light products and thus can be easily (re)mobilised by winds, tides or run-off following a land-based spill or deposits on beaches or riverbanks. Without the rapid implementation of recovery operations, plastic pellets will readily spread and reach waterways and vegetated areas (Figure 12). For example, following a road accident resulting in a spill of eight tonnes of plastic pellets between Boulogne-sur-Mer and Marquise (France) in February 2016, plastic pellets from the spill were found within a 50-kilometre radius of the incident.

Figure 12. Area where plastic pellets have accumulated on the backshore among vegetation.

Waterways and vegetated areas have opposite actions on the fate of plastic pellets:

- Depending on the strength of the currents, floating plastic pellets can spread significantly, carried by waterways. The pellets may wash up on banks or reach estuaries and coastal environments, causing deposits along the shoreline.

- Vegetated areas (e.g. coastal grasslands, peat bogs) act as traps for plastic pellets and prevent their remobilisation. The level of contamination of vegetated areas is difficult to assess as vegetation reduces the visibility of the extent of the pollution.

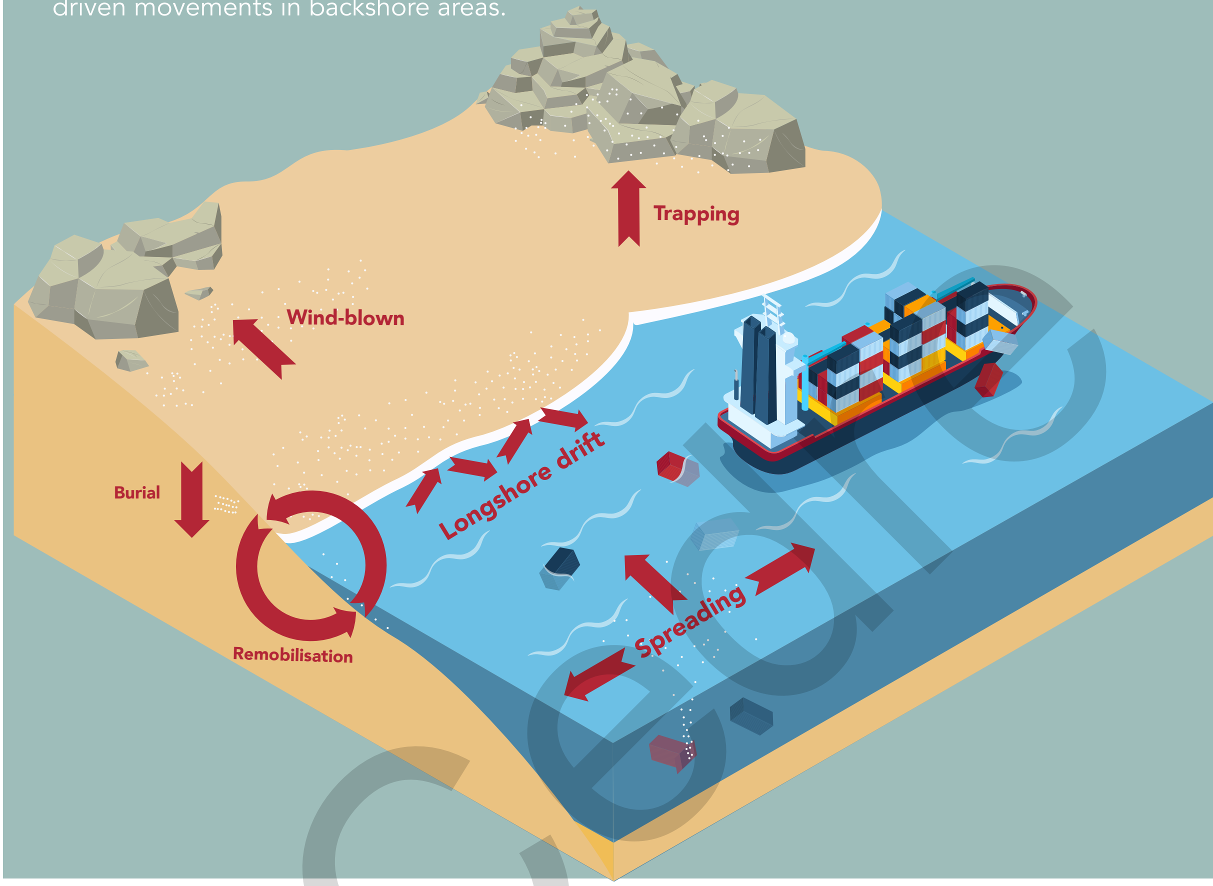
Another important characteristic of plastic pellets spilt on land or present on beaches or riverbanks is the possibility of their being buried in loose soil and sediments under the effect of trampling, wind and waves (Figure 13). Plastic pellets buried in sediments or soil may still be remobilised in the short, medium and long term, under the influence of various factors (e.g. sediment movements, weather conditions, human activities, animal activity, erosion), and are therefore likely to become visible once again and to disperse and contaminate new areas (Figure 14).

Figure 13. Pellets buried under several dozen centimetres of sand.

Figure 14. Remobilisation of pellets buried in soil due to the natural action of moles.

Box 2: Plastic pellet behaviour in coastal areas

Coastal areas are dynamic environments in which pellets can spread quickly along the shoreline, before pollution response operations can be organised. In these complex environments, pellet behaviour can be varied and involve stranding, remobilisation, accumulation, burial and wind-driven movements in backshore areas.



7. Impacts of plastic pellets

7.1. Ecological impacts

The ecological impacts of a plastic pellet spill remain to be clarified and assessed. There is currently no clear consensus on the real effects of a spill on the environment. During past incidents, studies have shown no effect on the living organisms studied (fish, birds).

However, studies carried out in laboratories under controlled conditions point to potential ecological impacts in the event of a large-scale plastic pellet spill in a restricted geographical area. These potential impacts can be divided into three categories:

- **Physical impact on the environment:** the presence of large quantities of plastic pellets could structurally modify habitats (insulating properties, temperature, permeability, water retention, soil aeration, pH) and therefore affect the communities present in the substrate as well as the species using the soil/sediment for certain stages of their life cycle (e.g. marine turtles).

- **Risk of ingestion:** accidental ingestion of plastic pellets is possible by a wide variety of animals (e.g. birds, turtles, fish, marine mammals) and can have multiple potential effects which will be dependent on the quantity of pellets ingested. The most likely potential adverse effect of plastic pellet ingestion is the disruption of food intake by organisms (i.e. impression of satiety), which can have various consequences (e.g. reduced energy available for reproduction or growth) according to experimental results obtained in the laboratory.

- **Transfer of chemical contaminants:** plastic pellets can release some of their additives•, constituent compounds (e.g. polycyclic aromatic hydrocarbons) and degradation and transformation products into the environment as soon as they are released. Given the diversity and nature of the additives used in industrial manufacturing (3,200 additives have properties of concern to the authorities and/or scientists), the chemical risk cannot be ignored in the event of a spill. Studies in controlled environments have shown potential harmful effects of pellet leachates• on various organisms, in particular at young developmental stages. However, the real risk of contaminants being transferred in the long term remains to be assessed. As each type of plastic pellet (composition) is different, the chemical risk must be assessed on a case-by-case basis in the event of a spill. The type of incident is also liable to affect the potential chemical risk (e.g. in the case of a fire during which combustion generates toxic compounds, or in the case of combined spills of both pellets and chemicals/oil).

In the long term, if the pellets are not recovered, small microplastics will be produced in the environment as a result of degradation and fragmentation processes. The potential impacts of these pellets will then be exacerbated, as the small size of these small micro- and nanoplastics makes it easier for them to enter food webs• and release additives.

Like all plastic debris, pellets have the capacity to rapidly (within a few days) adsorb microbial communities that may contain non-indigenous, potentially invasive species and pathogens. In the event of secondary dissemination of the pellets, there is a potential risk of harmful species being introduced into a new ecosystem.

7.2. Socio-economic impacts

The socio-economic repercussions of a plastic pellet spill are complex to assess due to insufficient hindsight on past incidents while compensation procedures are still underway. However, various potential impacts can be considered:

- Impacts on the local economy (e.g. risk of fishing bans, disruption to aquaculture activities, closure of tourist sites, decreased consumption of seafood due to negative image, disruption to road/rail transport during clean-up operations);
- Aesthetic impacts affecting recreational uses (e.g. condition of beaches and shores);
- Economic impacts associated with clean-up operations (e.g. cost of working hours during clean-up operations);
- Economic impacts linked to potential damage to infrastructure (e.g. blockage of pumping systems, creation of secondary incidents due to slippery surfaces because of plastic pellets on roads);
- Impact on the human well-being of local communities faced with the aesthetic deterioration of their environment and potential effects on biodiversity.

II - PREVENTION OF INDUSTRIAL LOSSES IN THE ENVIRONMENT

1. Introduction

Prevention on industrial sites (manufacturers, processors, logistics companies, freight carriers) is based on a proactive approach geared towards anticipating and avoiding incidents/accidents, thereby guaranteeing operator safety, environmental protection and smooth running of the facilities. It can cover a range of measures such as operator training, the introduction of risk management procedures and the application of safety standards.

The prevention of plastic pellet losses by manufacturers can be implemented by the company's department responsible for operator safety and environmental protection, in accordance with Corporate Social Responsibility (CSR) guidelines (see Part 2.2), which can provide a starting point to develop a spill prevention plan and response actions.

In this guide, prevention tools and methods have been identified in relation to three types of losses:
- Prevention of losses on industrial sites;
- Prevention of losses beyond site boundaries and in the surrounding environment;
- Prevention of losses during transport.

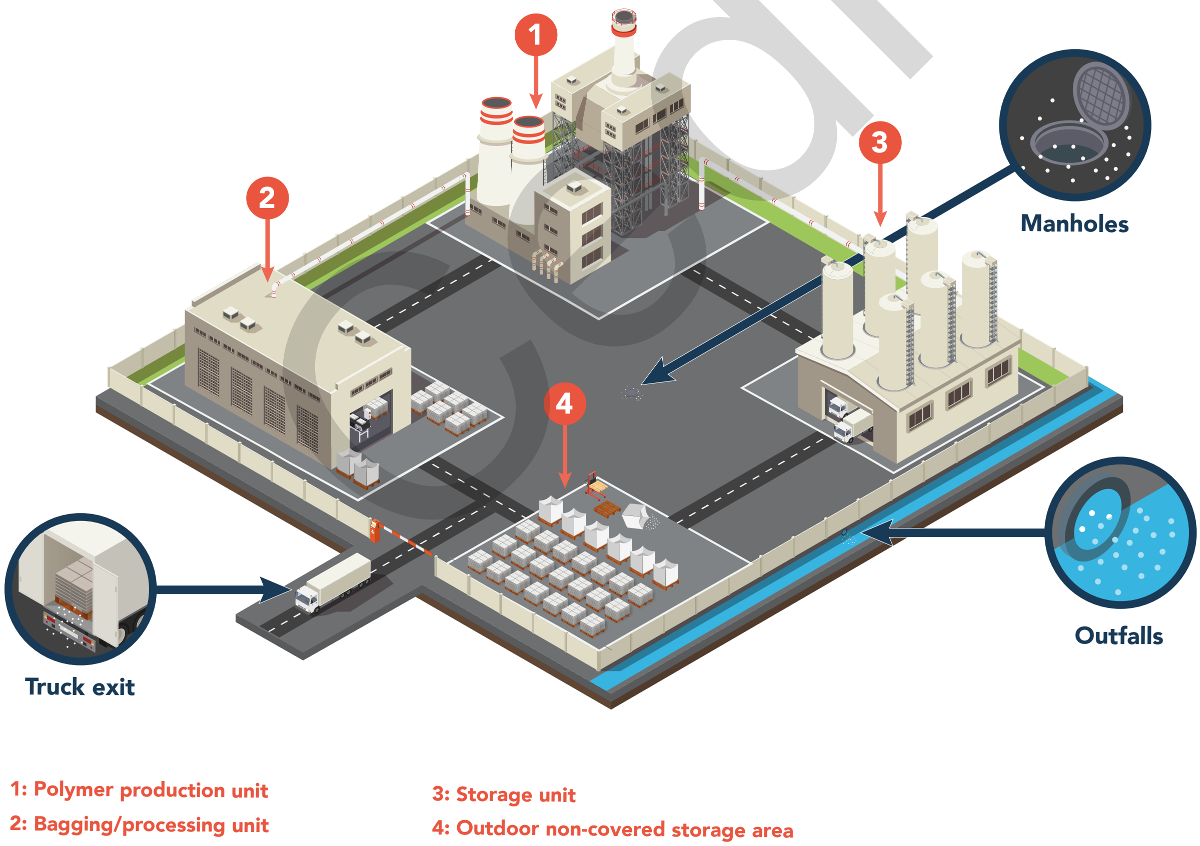


Figure 15. Areas where plastic pellet losses are liable to occur within an industrial site.

2. Prevention initiatives

2.1. Operation Clean Sweep

Operation Clean Sweep (OCS)• is an international programme aimed at preventing plastic pollution in aquatic environments by reducing pellet losses during production and processing activities. This industry-led programme launched in the 1990s encourages companies to implement management measures for plastic raw materials in order to prevent spills and releases during the transport, storage and handling of plastic pellets. By joining OCS, companies commit to adopting best practices, such as using packaging designed to minimise the possibility of breakage and pellet leakage, regularly cleaning work areas and training employees in the safe management of materials.

Reference documents are available to provide industry with a range of solutions depending on their industrial activities in order to reach the objective of zero plastic pellet loss in the environment. A key element of this initiative is the OCS Certification Scheme; to obtain certification, facilities must meet the requirements set out in Figure 16. The objective of this certification is to ensure transparency concerning the efforts undertaken by companies to achieve zero operational loss of plastic pellets throughout the production and usage chain.

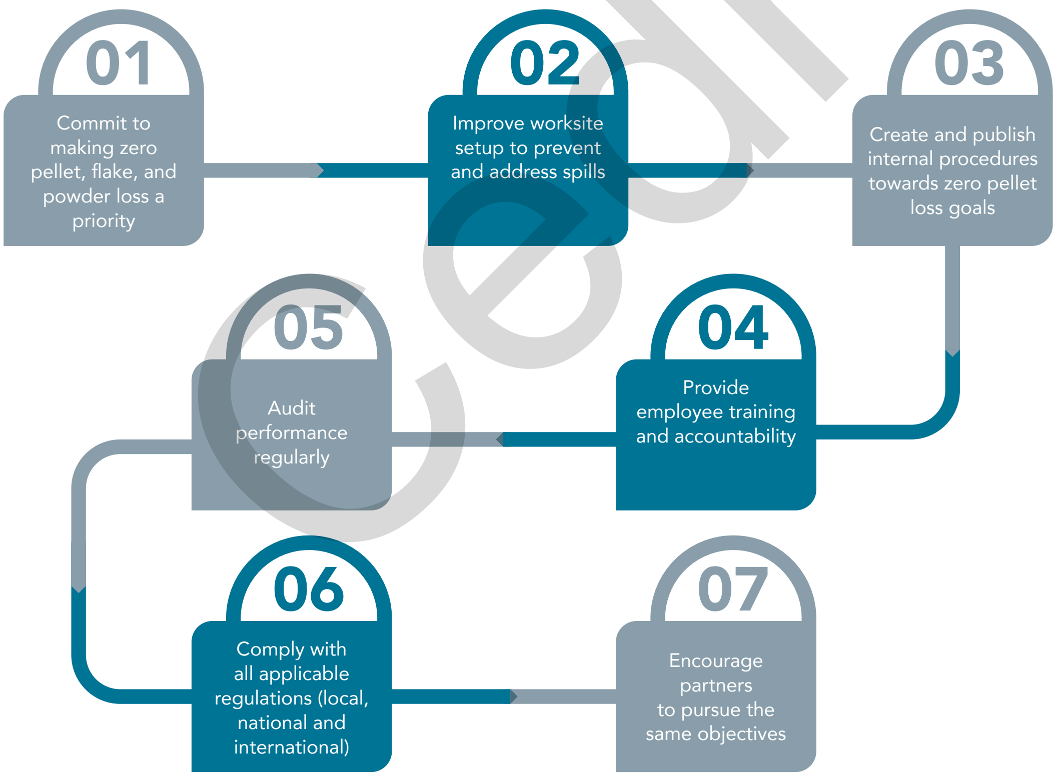


Figure 16. Requirements for obtaining OCS (Operation Clean Sweep) certification.

The OCS provides educational tools (training materials, brochures, posters) to raise awareness among workers on industrial sites (employees, subcontractors, freight carriers) and help them achieve the certification objectives (Figure 17).

Find out more
See the OCS website

Figure 17. Examples of posters produced by the OCS and freely available online to improve awareness of the different stages during which there is a risk of pellet loss.

2.2. BSI PAS 510 standard

PAS (Publicly Available Specification) 510:2021 is a free standard issued by the British Standards Institution (BSI) on good practice to prevent plastic pellet leakage from industrial sites in order to achieve and maintain the OCS target of zero plastic pellet loss. This standard is based on the principles previously defined by OCS, namely prevention, employee training and awareness-raising, and the definition of internal procedures to achieve this target.

Find out more
The PAS 510:2011 standard is available free of charge on the website:
https://knowledge.bsigroup.com/

3. Development of prevention procedures

It is important that industrial facilities develop procedures to prevent plastic pellet losses in order to ensure:

- **Worker safety:** identify potential hazards on the industrial site and implement prevention or mitigation measures to reduce the risk of accidents for operators working on the site (employees, subcontractors, freight carriers);

- **Environmental protection:** limit potential environmental impacts by implementing loss prevention practices and technologies;

- **Regulatory compliance:** depending on the geographical location of the industrial site, regulatory obligations may require sites to develop prevention procedures to guarantee worker safety and environmental protection. In France, according to the industrial site and how it operates, prevention procedures and action plans in the event of incidents/accidents must be described in an occupational risk assessment document (*Document Unique d'Évaluation des Risques Professionnels*, DUERP), which relates to the company's own employees, and in a prevention plan which relates to the employees of external companies operating on the industrial site;

- **Continuity of operations:** effective prevention procedures help to minimise interruptions due to environmental incidents, thereby improving productivity.

Companies must be able to meet the following requirements:

- Identification and presentation of sensitive areas on the industrial site, i.e. all areas where there is a risk of plastic pellet losses or leakage within the facility and into the outside environment (e.g. site boundaries, stormwater networks, truck or container loading/unloading areas, extruder outlets, packaging areas, processing workshops, storage areas);

- Assessment of operational plastic pellet losses along the production and/or processing chain in order to measure the effectiveness of the actions implemented;

- Inventory of available equipment and usage protocols for site operators to respond to plastic pellet losses outside of production, processing and storage lines.

In the responses to a survey sent to plastics manufacturers by Cedre in 2024, manufacturers indicated that the loss prevention approach could be based on the implementation of the "5S" method (Sort, Set in order, Shine, Standardize, and Sustain) aimed at improving organisation, efficiency and safety in the workplace. This quality approach requires regular monitoring to assess the effectiveness of the procedures and measures implemented to achieve the initial objective.

Certain procedures applicable to plastic pellets may be derived from additional company procedures to comply with national regulations. For example, French legislation requires facilities classified for the protection of the environment (ICPE) to have procedures and equipment to retain fire water on the industrial site. These procedures and equipment could also be used to retain pellet losses and thus reduce the costs of compliance with regulatory obligations.

All the procedures implemented must be assessed by the company, through regular internal audits, which may be requested during external audits to validate regulatory obligations or other certifications dedicated to plastic pellet loss prevention. The updating of regulatory procedures and documents (DUERP and prevention plan under French regulations) will serve as evidence of the company's progress in relation to plastic pellets.

4. Preventing losses on industrial sites

4.1. Raising awareness

It is essential to raise awareness among employees by informing and educating them about the prevention of plastic pellet losses and the reasons such measures are necessary (safety, environment, ethics) so as to ensure they understand the issues at stake and the best practices to adopt in their everyday work.

Employee awareness-raising can take various forms:

- Training employees in the prevention of plastic pellet losses by presenting internal policies and procedures and the resources deployed by the company to achieve the objectives. The training module may involve external experts to offer employees a global understanding (e.g. environmental risk, long-term consequences) and/or to set up interactive workshops (e.g. serious games);

- Using internal communication channels (e.g. newsletters, emails, instant messaging) to inform employees of the results of procedures and their efforts. Information boards can also be installed in workshops and other industrial facilities to indicate procedures on an ongoing basis to employees and other site operators (e.g. subcontractors, freight carriers);

- Organising annual seminars on this topic to encourage discussions between employees and those in charge of the actions. These seminars could be organised for a single industrial site or at group level in the case of an industrial group with several production and/or processing sites. Testimonials and feedback from these seminars may be used to raise awareness among other responders and to present new ideas and practices (e.g. equipment purchases, clean-up methods, changes to production, processing and packaging lines);

- Rewarding exemplary employees or teams to encourage all workers to play an active part in prevention and clean-up operations;

- Regularly organising exercises simulating plastic pellet spills on the industrial site to give employees a clear understanding of the issues and prepare them to react appropriately in the event of an emergency;

- Investing in new equipment to facilitate prevention and clean-up operations. Such purchases are evidence of the involvement of company management in plastic pellet loss prevention and help to create a responsible and committed corporate culture.

By combining several of these methods, a company can create a comprehensive and effective awareness programme to effectively engage and inform its employees about the issue of plastic pellets. This phase involving awareness-raising and ensuring understanding of the issues involved in preventing plastic pellet losses is crucial. Feedback from various companies that produce or process plastic pellets highlights the importance of employee acceptance of the approach in achieving results.

Figure 18. Operator training and awareness-raising.

4.2. Modifying and optimising industrial processes

Plastic pellet production, handling and processing must be carried out in enclosed environments to drastically reduce the risk of losses and environmental pollution, while facilitating clean-up in the event of deposits on the ground. Nevertheless, depending on the industrial site, production, bagging and logistics units may be in open or semi-open areas, even although these activities generate air and soil contamination, particularly through (i) the release of dust and fine particles and the loss of plastic pellets during the stages leading to the extrusion/injection of polymers during the production or processing of plastic pellets, (ii) splitting of 25 kg bags during pallet handling at logistics platforms, (iii) incorrect closure of octabins and big bags, (iv) pellet loss during loading/unloading of trucks/tanks/containers transporting pellets in bulk, octabins, big bags or on pallets.

To prevent plastic pellet loss, industrial sites must introduce specific procedures in order to meet regulatory obligations and certification requirements.

Table 3 lists the different methods available to prevent the risk of plastic pellet loss during the various industrial stages.

Available methods	Tech Sheet
Production/processing line Enclose equipment liable to generate dust, shavings and pellets Add extractor hoods	**Tech Sheet 1**
Plastic pellet packaging Perform bagging in a closed environment Add sensors on bagging and palletising lines Protect pallets and optimise bag positioning Change packaging method	**Tech Sheet 2**
Loading and receiving plastic pellets Modify filling valves Computerise and automate the filling system Protect ground during loading/unloading Inspect goods upon receipt	**Tech Sheet 3**

Table 3. Presentation of various methods available to modify industrial processes in order to prevent operational losses.

Box 3: Recycling plastic pellets spilled and shavings and dust generated during the various industrial stages.

Spilled plastic pellets as well as shavings and dust generated during industrial processes are raw materials that can be recycled, provided that they are not contaminated by other substances present on the ground surface in the industrial facility. Two recycling options exist: (1) reuse of the pellets by the company to produce new pellets in compliance with specifications compatible with this process; (2) recycling of the pellets, dust and shavings by a partner company. In the latter case, specific airtight containers (e.g. dustbins, containers) should be installed close to areas where losses are likely to occur so that responders can collect the materials quickly. The scrap containers are then removed and replaced by the partner company responsible for treatment, at a frequency tailored to each industrial site.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4.3. Cleaning industrial ground surfaces and associated equipment

It is essential to clean the ground surfaces of industrial sites to (i) prevent the risk of accidents and injuries (i.e. slipping), (ii) prevent the risk of spreading undesirable substances or products beyond the site boundaries in order to prevent releases into the environment and comply with regulatory obligations, and (iii) ensure a productive working environment by reducing interruptions to production for cleaning or maintenance issues.

To prevent plastic pellet releases, industrial sites must have appropriate cleaning procedures and equipment to recover plastic pellets within the facilities.

Industrial sites generally have easy-to-clean ground surfaces (e.g. concrete blocks, asphalt), with the exception of certain limited areas where long-standing pollution exists (see Box 4). However, these surfaces have the drawback of generally facilitating the spread of plastic pellets by the wind and run-off. Cleaning operations must therefore be carried out very regularly to maintain a clean environment and prevent the spread of plastic pellets throughout the site and beyond the site boundaries. These cleaning operations must be integrated into the company's procedures and be part of the operators' routine in order to successfully achieve results. In general, cleaning at the end of each shift is recommended for indoor operations (provided that precautions are taken to prevent the release of plastic pellets outside the work area), while in outdoor areas, cleaning should be carried out every time spilled plastic pellets are observed to prevent their spread. It is recommended that regular inspections be conducted in outdoor areas where there is a particular risk of plastic pellet loss or where plastic pellets tend to accumulate on the site. In indoor facilities with concrete floors, particular attention must be paid to expansion joints, which are difficult to clean and in which plastic pellets can accumulate. Pressure washing may be required to extract plastic pellets from these joints and recover them. Preventive sealing systems can be installed over these joints if the company considers that the costs of cleaning operations are too high.

There are two main methods of cleaning industrial ground surfaces:

- **Manual recovery:** manual clean-up equipment must be available in the vicinity of all areas identified as "sensitive" by site managers to enable rapid intervention in the event of a spill or operational loss (**Tech Sheet 4**).

- **Vacuum recovery:** vacuum cleaning is an effective method of collecting plastic pellets on the ground, on production equipment or in any gaps or cracks, thanks to the many different vacuum heads and nozzles available on the market. Vacuum systems can be used to recover both small releases and large spills (**Tech Sheet 5**).

Figure 19. Example of vacuum recovery of plastic pellets on an industrial site.

Box 4: The case of long-standing pollution.

Environmental regulations and considerations relating to plastic pellets have evolved over the last few decades and now advocate zero plastic pellet loss. However, long-standing plastic pellet production and processing sites are faced with the issue of pre-existing pollution on and around the sites, in water networks and in the ground (e.g. in areas of vegetation, shale or earth), which can lead to plastic pellet losses into the environment. Site managers are required to treat these specific areas in order to comply with the regulations in force, failing which they may be sanctioned by environmental inspectors and other agents responsible for verifying compliance. These areas can be treated using various methods:

- In water networks: purging the networks using high-pressure water to loosen and remobilise the layers of plastic pellets present. Prior to such an operation, collection systems must be installed to capture plastic pellets at the water network outfall and prevent them from spreading off-site (see Part 2.4.4);

- In the sediment: under the effect of weather conditions (e.g. rainfall) and biological conditions (e.g. action of burrowing mammals), long-standing pollution in the ground at industrial sites can be remobilised, requiring in-depth treatment to eliminate this pollution. Sporadic cleaning can be carried out using manual and vacuum methods. However, depending on the level of pollution, following an assessment of the extent of the contamination, full treatment of the area may be necessary, involving the complete removal of the contaminated sediment and its replacement with a clean substrate, which must be protected against any new contamination by plastic pellets (e.g. installation of edging or barriers). Another option is to lay asphalt that is easier to clean. The level and extent of long-standing ground contamination can be assessed by taking sediment cores. Based on this assessment, the appropriate methods to consider for eliminating the plastic pellets present can be identified.

Figure 20. Plastic pellets on the ground in areas that are difficult to clean (old, deteriorated surfacing material and presence of vegetation) and where pre-existing pollution is present.

4.4. Preventing spreading and losses beyond site boundaries

Despite awareness-raising among operators and improvements in industrial processes and cleaning practices, additional procedures and equipment are needed to reinforce the prevention of plastic pellet losses into the environment and ensure that the targets are met. The final aspect of prevention aims to stop plastic pellets present on the industrial site from spreading across site boundaries through various barriers (e.g. site boundary fencing) or via transfer routes such as the stormwater network or truck exit routes.

Table 4 lists the different methods available to prevent risks of plastic pellets spreading and being released beyond site boundaries.

Table 4. Presentation and description of different methods available to prevent risks of plastic pellets spreading and being released beyond site boundaries.

Available methods	Tech Sheet
Containment of sensitive areas	**Tech Sheet 6**
Mark out areas liable to be contaminated	
Adapt site boundaries	
Adapt the on-site road network	
Prevention of losses beyond site boundaries	**Tech Sheet 7**
Control trucks/Install a blower unit	
Adapt water networks	

Figure 21. Example of a device installed in a drain.

Figure 22. Example of a blower unit for cleaning trucks.

5. Preventing losses during transport

5.1. Land transport

Although there are no specific regulations governing the transport of plastic pellets by land, the implementation of best practices by freight carriers can make a significant contribution to reducing plastic pellet losses into the environment. Establishing an environmentally responsible supply chain requires increased vigilance at every stage of transport, combined with close collaboration with other players in the sector.

Freight carriers can draw on the OCS approach and the introduction of new practices to achieve the target of zero plastic pellet losses into the environment:

- **Use appropriate vehicles.** Vehicles should be airtight to prevent any plastic pellet leakage. Closed tank trucks and containers with airtight seals are preferable. It is important to carry out regular vehicle maintenance to check the condition of seals, connectors and valves.

- **After unloading plastic pellets, systematically clean vehicles** in protected areas (e.g. with tarpaulins or retention tanks).

- **Train drivers and raise their awareness** of the need to monitor loading and unloading operations and the practices to be implemented in the event of spills (e.g. presence of a cleaning kit in the truck/container; installation of tarpaulins under loading/unloading points).

- **Keep a record of any leaks that occur during transport,** whether minor or major, and report the incident to the client. This will help to identify high risk areas and take corrective action.

- **Liaise with producers/logistics companies/processors** to obtain their feedback and expectations on loading and unloading methods and protocols.

5.2. Maritime and river transport

Plastic pellets are transported by sea in 25 kg bags or in bulk in containers. It is important to check that the container is in good condition and is properly closed before the ship leaves to avoid any leakage of plastic pellets on board.

It is prohibited to transport plastic pellets loose in bulk carriers. Aside from this, there are no strict regulations on the maritime and river transport of plastic pellets; however various recommendations exist to prevent their release and improve spill management in the event of a major incident:

- **Position containers of plastic pellets differently on board ships.** Containers carrying plastic pellets are generally positioned at the top of container stacks in potentially exposed areas on ships. Loading these containers under deck or at least in non-exposed areas on deck would reduce the loss of goods during transport;

- **Avoid transporting loose plastic pellets in containers** to stop them from spreading quickly and easily if the container breaks open or is lost overboard;

- **Modify plastic pellet packaging** to ensure that it is of high quality, hermetically sealed and resistant to environmental conditions (e.g. use of tanks);

- **Identify containers carrying plastic pellets using a single nomenclature** so that the ship's manifest can be quickly read and interpreted in the event of an incident/accident.

III - OPERATIONAL RESPONSE TO AQUATIC POLLUTION

There is no single operational response to a plastic pellet spill, but rather a methodological approach which is identical to that applied in the case of an oil or chemical spill (Figure 23).

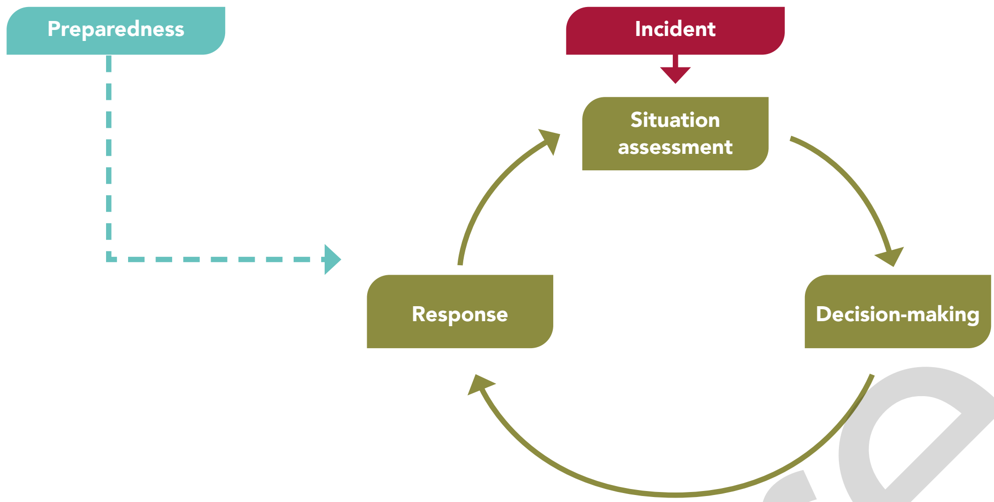


Figure 23. Methodological approach to spill management

The response will depend on the type of plastic pellets (e.g. polymer, density), the type of incident (container loss, shipwreck, vessel grounding, road/rail accident) and the incident location (e.g. open sea, coastal area, port, road). The aim here is to present the operational responses to plastic pellet spills in the environment, covering the various actions to be implemented to deal with the pollution, i.e. alert and notification of the accident, initial measures, situation assessment, decision-making, response operations and waste management (Figure 24). The various operational responses presented in the following sections may be carried out simultaneously and are not necessarily consecutive.

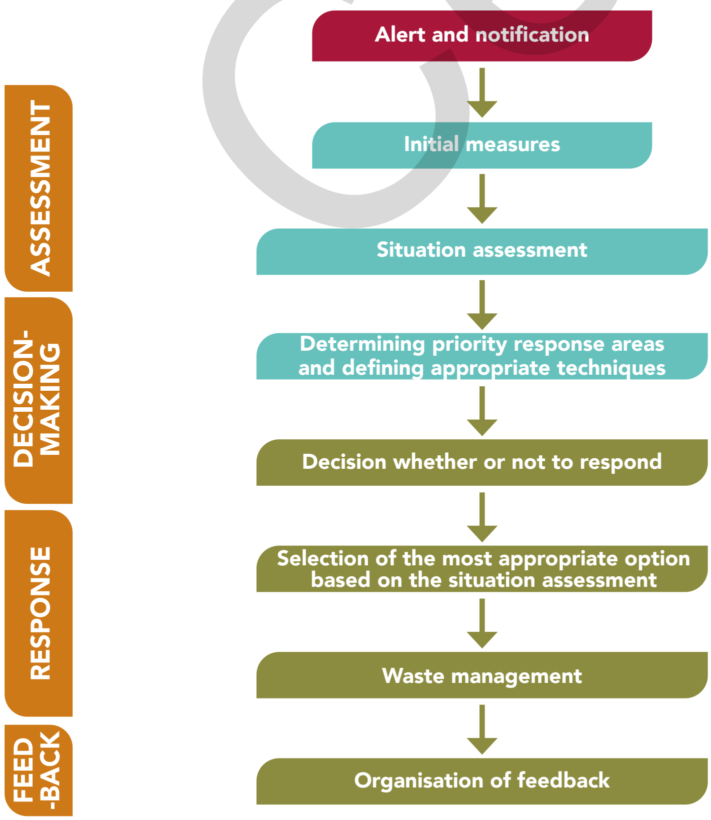


Figure 24. Plastic pellet spill response strategies.

1. Alert and notification procedures

For road and rail accidents, there is currently no specific obligation to declare the presence of plastic pellets among the cargo. As concerns maritime and river transport, over and above exceptional events involving grounding or shipwrecking, the main risk of plastic pellet spills is the loss of containers/ plastic pellets due to weather conditions or loading problems (e.g. poor stowage, insufficient container resistance or incorrect weight declaration). Containers lost overboard pose a navigational hazard for other vessels and/or operators due to the risk of collision. In certain geographical areas, the lack of regulations requiring shipowners to report the loss of cargo is liable to lead to orphan spills• which can affect aquatic environments, while authorities are unable to launch an operational response at sea (Figure 25). However, in 2024, IMO adopted a new amendment to the MARPOL and SOLAS ("Safety of Life at Sea") Conventions, making it mandatory for the master of a ship to report the loss of freight container(s) and inform the coastal state responsible for maritime safety in the affected area. This amendment will enter into force on 1 January 2026.

Reports of plastic pellet losses in the environment or deposits on shores or riverbanks can therefore come from a variety of sources, including private companies (e.g. freight carriers), municipal officials, associations or the general public (e.g. walkers). This means that the level of knowledge about the pollution will vary depending on who has issued the alert. The information must be validated as quickly as possible to determine the alert level and identify the urgency of the situation.

When plastic pellet loss is reported, the following information must be obtained and recorded:

- Information relating to the freight carrier (e.g. name of ship, owner, route taken, ship's representative, road haulier, rail freight company) or the industrial site responsible for the spill;

- Origin of the plastic pellets spilled, name of the manufacturer or company responsible for the goods, quantity lost, cause of the spill;

- Information on the plastic pellets spilled (polymer, density, form, composition) to determine the initial behaviour of the pollution in the aquatic environment (tendency to sink or float). In the case of an orphan spill, a sample of a few grams of plastic pellets can be collected then analysed by infrared spectroscopy to identify the polymer and estimate the density of the product. If possible, a specific analysis (e.g. using a gas pycnometer) may be carried out to accurately measure the density of the pellets released.

The information obtained should be compiled in an initial pollution report, which will help with decision-making on response operations by the authorities.

Figure 25. Orphan spill of plastic pellets on a French beach.

2. Initial measures

The initial emergency response measures will focus on protecting the population, the environment and socio-economic activities. As far as possible, the initial measures to be implemented are as follows:

- Identify the source of the spill and if possible stop/plug the leak. Samples should be taken to characterise the plastic pellets spilled;
- Ensure the safety of operators (e.g. crew members, drivers) and responders;
- Set up an exclusion zone (e.g. block road or rail routes, stop aquaculture or leisure activities);
- Contain the spill;
- Determine priority response areas.

Find out more

See the operational guide by Cedre and Transport Canada:

Accidental Water Pollution by Hazardous and Noxious Substances

3. Situation assessment

There are many different causes of incidents leading to plastic pellet spills, for instance:

- Loss of containers overboard during maritime shipping. The containers may remain intact or break open during the incident, releasing the cargo in the form of loose plastic pellets or 25 kg bags, which have limited resistance to environmental conditions;
- Containers breaking open or suffering damage during transport, resulting in cargo leakage;
- Incident during loading/unloading of containers in port areas;
- Grounding/sinking of a vessel transporting plastic pellets;
- Industrial accident leading to plastic pellet leakage into the environment;
- Road or rail accident involving the loss of cargo;
- Deposits due to an orphan spill of unknown origin.

After the alert has been raised and the first reports of potential plastic pellet pollution have been received, the first step will be to obtain and record information on the nature of the plastic pellets, the quantity spilled, the form of the pollution (open containers or intact, non-leaking containers) and the circumstances surrounding the incident. This information will support decision-making by the relevant authorities.

If the pollution is already present on land, the situation assessment must take into account any factors liable to aggravate the pollution and/or the situation. Below are a few examples:

- Weather conditions: What are the current and forecast conditions? Will they cause the pollution to be rapidly remobilised and spread over a wider geographical area, affecting a broader range of habitats?
- Possible pollution transfer and dissemination routes: Is the pollution liable to contaminate urban networks?
- Accessibility: Are the affected areas easily accessible?

Tech Sheet 8: Situation assessment

Figure 26. Emergency response centre during a situation assessment.

4. Decision-making

The spill should be monitored to assess the risk and thereby support decision-making on response operations. Every incident is unique. Decision-making will depend on the location, weather conditions, the quantity spilled, available response equipment, the availability of human resources, the socio-economic and political context of the affected region, etc.

The response strategies selected by the decision-makers will be the result of a coordinated effort involving experts from different fields in order to align the operational response with the key objectives identified. These key objectives will be:

- To ensure the safety of populations and responders,
- To reduce the environmental and socio-economic impacts of the spill and the response,
- To restore the environment to its original condition as far as possible.

Depending on the sensitivity of the spill area, the decision-making process must assess the benefits and risks of the different possible response strategies (e.g. do nothing, containment and recovery on water, clean-up the shoreline, riverbanks and ground) to avoid exacerbating the situation. To do so, a Net Environmental Benefit Analysis (NEBA) or a Spill Impact Mitigation Assessment (SIMA) can be carried out to support decision-making.

Figure 27. Coordinated efforts to define the operational response to the X-Press Pearl incident.

5. Determining priority response areas

Priority response areas should be identified based on available knowledge, provided by technical experts assisting the authorities, of the environment and socio-economic activities in the geographical area affected by the plastic pellet spill. These efforts to pool knowledge should not be left until an incident occurs, but rather should be made as part of the authorities' preparedness efforts in case of an incident and environmental pollution (e.g. contingency planning, spill simulation exercises). In the absence of specific contingency plans for plastic pellet losses, the authorities can use the documents available for the priority response areas identified as part of oil and chemical spill preparedness.

When determining priority response areas, it is important to take into account the following factors in order to optimise the operational response:
- Characteristics of the pollution and the hydrographic conditions;
- Sensitivity of the different habitats and resources potentially affected by the spill;
- Accessibility of response areas;
- Availability of human resources for response operations;
- Availability of emergency response equipment;
- Waste storage and management options.

6. Response

There are several possible strategies for responding to plastic pellet spills: do nothing, protect sensitive areas, contain the spill or recover the spill. It is often impossible to recover all the plastic pellets released (72% recovery in the case of the *MSC Susanna* and 33% in the case of the *Trans Carrier*; see Section 4 "Case studies and feedback"). Unlike oil, for which natural biodegradation can take place, plastic pellets cannot be biodegraded due to their physico-chemical properties. Similarly, plastic pellets cannot be dispersed using chemical agents, and even if they could, it would be senseless as they are non-biodegradable.

6.1. Do nothing?

Depending on the nature and location of the incident, doing nothing is an option worthy of consideration in order to avoid causing environmental consequences that are more severe than the presence of the plastic pellets themselves (e.g. deployment of excessive machinery and human resources in relation to the scale of the deposits, potentially affecting the habitat structure in the short term and generating significant greenhouse gas emissions, aspects which must be weighed against the benefits of the response operations). However, opting for this strategy presupposes that a proper analysis of the situation has been conducted and that the pollution is being monitored (modelling, surveys) to gain a full understanding of the benefits and consequences of this non-intervention strategy.

The "do nothing" option is generally selected by default when small to medium-scale quantities reach the coast or in the case of a spill on land (e.g. leakage from rail cars/trucks) as the pellets are remobilised and rapidly spread, causing the situation to evolve and meaning that response operations cannot always be implemented. The key to managing deposits lies in quick reaction times by the authorities in implementing an operational response.

When alerts are received from merchant ships reporting the loss of plastic pellets at sea, the "do nothing" strategy is generally the only feasible option due to the very limited detection capacities for plastic pellets at sea and the low reliability of current modelling tools. Response operations should therefore focus on affected shores, rather than on deploying equipment and personnel at sea and in coastal waters, depending on the weather conditions and the quantities of plastic pellets spilled.

Before selecting the "do nothing" option, various elements must be taken into account during the decision-making process:

- What are the estimated quantities spilled and present at sea/on the shoreline/on the ground?
- What were the sea and weather conditions at the time of the incident and over the following days?
- Can equipment be deployed without exacerbating the situation (environmental impact)?

6.2. Protecting sensitive areas and containing the spill

If there is a risk of significant quantities of plastic pellets reaching a sensitive environment (or to prevent a spill from spreading), protective measures must be considered. Depending on the type of incident and the location of the spill, such measures will:

- Trap the plastic pellets in order to recover them on water or on the ground;
- Prevent plastic pellets from entering ecologically sensitive environments that are difficult to access without causing damage to the area (e.g. coral reefs, mangroves, marshes, water systems) or environments of socio-economic importance that require protection (e.g. aquaculture areas where significant quantities of plastic pellets could affect pumps and gear).

The most commonly used protection and containment systems fall into two categories:
- Booms;
- Plugging/sealing systems.

Tech Sheet 9: Protecting sensitive areas and containing the spill

Booms can be installed in a variety of configurations:

- Deployment of manufactured containment booms at the entrance/exit to a port, lagoon or estuary to prevent floating plastic pellets from entering or leaving the area;
- Deployment of “custom-made” barriers in watercourses that are difficult to access to contain the spill;
- Laying of a boom on the banks of a watercourse to prevent the plastic pellets from entering the aquatic environment;
- Installation of containment booms on land to stop plastic pellets spilled on the ground (e.g. asphalt, forest areas) from spreading and entering transfer routes to aquatic environments (e.g. stormwater networks).

The effectiveness of a boom will depend on the weather conditions and the state of the water body (e.g. current, waves, water depth), which can affect the behaviour of plastic pellets and of the boom. If these conditions cause plastic pellets to enter the water column, the effectiveness of booms in containing the plastic pellets will be reduced (or even nil) except in the case of silt curtains with a skirt that covers the entire water column in the specific area. In sheltered areas (e.g. ports), containment pods can be used instead of booms.

Find out more
See the operational guides published by Cedre:
"*Manufactured Spill Response Booms*"
and "*Custom-Made Spill Response Barriers*"

Figure 28. Boom deployed on a riverbank.


Figure 29. Static mechanical recovery of plastic pellets using a weir skimmer.

6.3. Recovery on water

Sea and weather conditions permitting, plastic pellets can be recovered from the water surface using two methods:
- Static mechanical recovery;
- Dynamic recovery.

Static mechanical recovery
Static mechanical recovery should be carried out inside a specifically created containment area or in areas where pellets tend to accumulate under the effect of currents, wind or response actions (use of fire hoses or portable blowers).

The pellets are then recovered using pumping equipment (the design of mechanical weir or vortex skimmers means that they can selectively recover plastic pellets from the water surface based on their difference in density to that of water) or manually (e.g. using scoop nets). Before using a mechanical skimmer, it is important to ensure that the pumping system is capable of handling solid particles.

If mechanical skimmers are unavailable or in the case of large quantities of plastic pellets, other systems can also be deployed and requisitioned from industry or the agriculture sector, such as vacuum systems for plastic pellet pumping, storage, settling (and water discharge) and transfer to waste management areas.

Tech Sheet 10: Recovery from the water surface by static mechanical recovery

Find out more
See the Cedre operational guide: "*Skimmers*"

Dynamic recovery

Dynamic recovery can be carried out using various types of equipment:

- **Recovery drones:** Recovery drones, or unmanned surface vehicles, can be used to recover plastic pellets from water bodies in sheltered areas. These drones are capable of collecting all the matter present on the water surface using nets, a grabber or a suction head (the matter must subsequently be sorted to separate the plastic pellets from the other materials collected). The range and resistance to sea and weather conditions of such drones vary from one manufacturer to another. Some drones are capable of operating in autonomous mode to clean a predetermined area without an operator.

- **Recovery vessels:** In sheltered areas, clean-up vessels can be equipped with a specialised recovery system (e.g. mechanical skimmer, suction head) to recover floating plastic pellets from the water surface. Such vessels must have an onboard storage capacity.

Recovery drones and vessels can be used to recover significant quantities of plastic pellets, as well as for residual treatment and final clean-up of a polluted area.

Tech Sheet 11: Recovery from the water surface by dynamic recovery

It is also possible to carry out manual dynamic recovery using nets, scoop nets or buckets, from vessels (e.g. fishing boats, workboats) or light craft available locally (e.g. canoes, kayaks, pirogues, rafts, stand-up paddle boards). The choice of vessel or craft will depend on local availability and the geographical location of the spill (e.g. width and current of the watercourse, accessibility). An onboard storage capacity is required or otherwise the use of another boat for storage can be considered, depending on the quantities involved.

Figure 30. Recovering plastic pellets from the water surface using recovery drones controlled by a remote operator.

6.4. Cleaning shores and ground surfaces

6.4.1. Clean-up methods

In the event of a spill on land or a spill into water for which recovery on the water is not feasible or is insufficient, the authorities should organise and manage clean-up of the ground or shores affected by the plastic pellets, in order to limit their environmental and socio-economic impacts.

There are five main methods for recovering plastic pellets, separating them from other debris or remobilising them to facilitate their recovery on the shore or ground:
- Manual recovery;
- Vacuum recovery;
- Separation by sieving (manual or mechanical);
- Sink-float separation
- Flushing•.

Depending on the location of the incident and the clean-up conditions, these methods can be applied alone or combined. In accordance with IMO recommendations (2023), Table 5 summarises the plastic pellet collection strategies according to the contaminated substrate.

The following Tech Sheets describe the different methods and their implementation:

Tech Sheet 12: Manual recovery
Tech Sheet 13: Vacuum recovery
Tech Sheet 14: Sink-float separation
Tech Sheet 15: Separation by manual sieving
Tech Sheet 16: Separation by screening
Tech Sheet 17: Remobilisation by flushing

Recovery techniques	Exposed rocky shores	Sandy beach	Gravel beach	Riprap structures	Marshes	Mangroves	Asphalt	Forest area	Vegetated area
Manual recovery	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟡	🟡
Vacuum systems	🟢	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢
Separation by sieving	🔴	🟢	🟢	🔴	🟡	🟡	🟡	🟡	🟡
Density separation (including mechanical excavation)	🔴	🟢	🟢	🔴	🔴	🔴	🔴	🟡	🟡
Flushing	🟢	🟡	🟡	🟢	🟢	🟢	🔴	🔴	🔴

Table 5. Methods available for recovering plastic pellets (🟢 = Suitable method; 🟡 = Possible method; 🔴 = Unsuitable method; adapted from IMO, 2024).

6.4.2. Clean-up organisation

An effective organisation of clean-up/recovery operations will contribute to the ultimate success of the response. It is therefore important to devote the necessary time to organising operations before clean-up efforts begin. During this phase, the space required to set up the operational response should be determined and the optimal organisation to ensure that spill response operations run smoothly and efficiently should be defined.

Clean-up operations must be organised so as to ensure:
- Operator safety;
- Preservation of the environment on and around the site;
- Correct operation and cleanliness of the equipment used;
- Optimisation of the different stages involved in plastic pellet recovery.

When organising clean-up operations, it is therefore important to define the resources required for each site:
- How many operators are required for operations?
- What equipment is required for operators and recovery?
- Do temporary facilities need to be set up on site (e.g. waste storage area, base camp, decontamination zone, scaffolding, toilet facilities) or road access points created?

6.4.2.1. Operator safety and personal protective equipment

All operators must be made aware of and trained in the risks involved to ensure their safety during clean-up operations. Regular reminders should be issued in the case of long-term operations.

No personal protective equipment• (PPE) is specifically required at present for spills only involving plastic pellets. However, depending on the plastic pellet recovery method used on the site, all operators must be equipped with the necessary PPE to ensure their protection (e.g. safety footwear, helmet, hearing protection and gloves for driving worksite vehicles or operating vacuum systems, beach cleaners, etc.). PPE is essential in order to minimise risks in potentially hazardous working environments. On-site responders must be trained in the use of PPE. It is also important to ensure that PPE is properly maintained and regularly replaced to ensure it remains effective. Clean-up site managers should therefore provide PPE and check that operators are using it correctly.

Spill response operations are liable to generate stress and fatigue for operators; it is therefore important to provide them with suitable, satisfactory working conditions. Clean-up site managers must therefore:
- Ensure hygiene conditions on site (e.g. presence of toilet facilities nearby);
- Oversee compliance with rest and hydration rules according to the arduousness of the tasks performed;
- Provide appropriate facilities and equipment (e.g. eating and break areas that are in the shade or protected against harsh weather, according to conditions);
- Define a response plan suited to on-site conditions.

Site managers must ensure safety and security on worksites and access points. Particular attention should be paid to the general public, who are likely to be attracted to the site to watch what is going on, potentially disrupting operations or generating new risks. Clean-up sites must therefore be clearly marked out (e.g. using barricade tape and signs) and supervised (e.g. surveillance by night security guards if necessary, protecting and securing equipment and products liable to attract malicious acts).

Find out more
See the Cedre operational guide: "*Oiled shoreline clean-up*"

Figure 31. Shaded area set up for operators' breaks.

6.4.2.2. Organised and measured clean-up

Successful clean-up operations are dependent on an effective organisation which will optimise recovery. Clean-up areas must therefore:

- Be marked out to organise responder movements;
- Have an entrance and exit zone with a decontamination area to prevent spreading plastic pellets outside the site (e.g. set up an area for cleaning footwear to remove any pellets potentially trapped in the soles);
- Clearly define areas for primary waste storage pending its transfer to intermediate and/or final storage facilities.

The worksite organisation must respect and preserve the environment in the area to avoid creating adverse effects in addition to, or even more severe than, the pollution itself. Operations will therefore seek to:

- Prevent soil and habitat degradation (e.g. damage to dune structure, impacts on the structure of mangroves and marshes, trampling of flora of ecological interest, installation of facilities in areas home to protected flora/fauna);
- Prevent soil contamination due to trampling, the use of inappropriate machinery causing the plastic pellets to become buried and the transfer of plastic pellets outside the worksite by operators or during the transfer of collected waste (e.g. damaged or ripped storage capacities).

These objectives must be tailored to each specific incident according to local conditions (e.g. environment, substrates, ecological richness).

It is therefore important to monitor worksites on a daily basis in order to provide the authorities with reliable information on changes in pollution levels, the quantities collected and the effectiveness of the methods implemented by operators. Day-to-day monitoring of the pollution can be carried out using the same methodologies as were initially used during the first surveys and situation assessments. In France, the ARGEPOL (Archiving and management of data in the event of shoreline pollution) web-based platform developed by Cedre facilitates the automatic production of documents and maps for transmission between operators, site managers and authorities.

Site managers should hold daily briefings with operators at the start of the day to keep them informed of progress and to review the operations conducted the previous day and those planned for the day ahead. A reminder of the safety rules and response principles should also be issued at these daily briefings.

6.4.2.3. Clean-up end-points

Major plastic pellet spills have shown that clean-up operations are lengthy and time-consuming, ranging from a few weeks to several years depending on the environment affected and the intensity of the spill. Although volunteers (e.g. associations, members of monitoring networks, general public) can be involved in these operations, they necessarily require qualified personnel and costly equipment (costly to purchase and/or to maintain) and therefore call for substantial financial resources. It is crucial to determine the right point at which to stop clean-up operations, i.e. the point at which the level of pollution is deemed "acceptable", with no significant ecological impacts, or at which it is impossible to continue operations without running the risk of generating more severe consequences than the pollution itself.

There is no general consensus on an "acceptable" level of pollution at which clean-up operations can be stopped following a plastic pellet spill. The end-point for operations will be defined based on a consensus between local authorities and insurers, taking into account the type of environment and local specificities. Different end-point values have been used during previous spills involving shoreline clean-up operations:

- *MV Rena* spill: < 150 plastic pellets/m²;
- *MSC Susanna* spill: < 50 g of plastic pellets/operator/day;
- *Trans Carrier* spill: < 500 mL of plastic pellets/operator/day.

If pre-spill data on the presence of plastic pellets (obtained for example through monitoring programmes or scientific projects) is available for the area/region affected by a plastic pellet spill, this information could help to determine the baseline level of pollution prior to the incident. This baseline could be used by the authorities as the clean-up end-point criterion.

6.4.3. Waste management

During recovery operations, the plastic pellets can be stored in bags, drums or other containers, that should be as airtight as possible and sufficiently strong in order to avoid accidental losses due to wind or leakage during handling by operators. Initially, these containers can be stored at primary storage sites such as on the upper beach/banks or at the roadside before being transported as soon as possible to protected sites where the waste from different clean-up sites is pooled, i.e. intermediate storage sites (for a few weeks to a few months) and/or final storage sites (for several years, necessary when the quantities of waste exceed treatment capacities and/or require the construction of specific facilities). At final storage sites, it must be possible to repack the collected waste in order to facilitate its handling and to identify potential recovery or treatment streams.

When handling waste, it is essential to avoid secondary contamination (i.e. transfer of the contamination from site A to site B, initially unaffected by the spill) during collection and transport of the plastic pellets from one storage site to another. To prevent this secondary contamination, the use of records and logs is highly recommended for greater traceability of waste movements from one storage site to another, up until its arrival at the reuse, recycling, recovery or disposal streams.

Figure 32. Primary storage area.

Figure 33. Intermediate storage area.

There are currently no specific regulations governing the management of waste resulting from spills of plastic pellets, beyond it being prohibited to export non-recyclable plastic waste, and to export recyclable plastic waste without the consent of the importing country (Basel Convention). Similarly to oil and chemical spills, it is recommended that authorities develop and maintain a waste management plan so that they are not caught unprepared in the event of a major spill. Recommendations should be considered when faced with local challenges and specificities relating to:

- Logistical considerations (e.g. storage area, mode of transport, treatment sites);
- Environmental considerations (e.g. prevention of secondary contamination);
- Economic considerations (e.g. cost of waste storage and treatment).

It is recommended that the waste management hierarchy concept be applied in order to optimise the various aspects of the management plan:

- Prevention: have a contingency plan to avoid and reduce waste generation;
- Reuse: reuse the protective equipment employed during response operations and reuse plastic pellet waste in the industrial cycle if possible (e.g. garden furniture manufactured from the plastic pellets collected following the *MSC Susanna*);
- Recycling/Recovery: optimise the choice of recycling/recovery streams in order to convert contaminated plastic pellets into pellets that can be reused in the industrial cycle or in energy production;
- Disposal: where not reusable, recoverable or recyclable, dispose of the plastic pellet waste in landfills or by incineration without energy recovery.

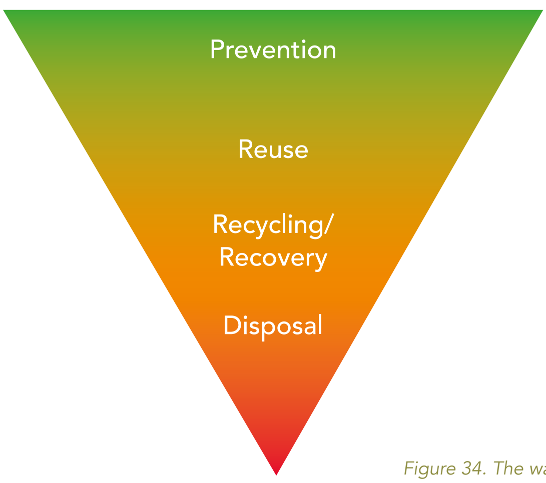


Figure 34. The waste management hierarchy.

The authorities should identify all possible ways of processing the plastic pellets collected after a spill within their territory and hold discussions with the plastics sector to determine the contamination limit in order for the plastic pellets to be eligible for reuse or recycling. It is also important to identify potential locations for washing collected plastic pellets, where relevant.

Find out more
See the Cedre operational guide: "*Oil Spill Waste Management*"

6.5. Response to spills involving several pollutants

During transport, particularly maritime shipping, plastic pellets are not necessarily the only cargo on board. When an incident occurs, the authorities can therefore be faced with spills of multiple pollutants, making the response more complex, whether in terms of assessing the situation, operator safety, worksite organisation, the definition of collection and clean-up methods, or waste management.

In the event of a spill involving several pollutants, the first step is to identify all the products involved in addition to the plastic pellets. The response priorities should be determined on the basis of this first step, which should identify and inventory/classify the risks associated with each product. Based on the information obtained, appropriate operations can be implemented.

At the water surface, plastic pellets can adsorb• chemicals and oil. They must therefore be handled with care during recovery and clean-up, taking into account the risks identified for the other products spilled.

Before launching clean-up operations in these specific and unique cases, the authorities must consider a number of points to facilitate operations, such as:
- Does the presence of plastic pellets affect the choice of recovery and clean-up methods for the other spilled products? This will help to refine the choice of recovery techniques for chemicals and oil (e.g. choice of pump for skimming systems, choice of skimmer type);
- Do the other spilled products affect the recovery of the plastic pellets (e.g. pellets trapped in viscous oil slicks preventing the use of vacuum systems or beach cleaners)?
- Can the plastic pellets recovered be cleaned or will they need to be treated directly as non-reusable, non-recyclable hazardous waste?

Figure 35. Plastic pellets in oil on a water surface.

Figure 36. Plastic pellets trapped in oil on a sandy substrate.

IV - CASE STUDIES AND FEEDBACK

1. *X-Press Pearl*, 2021 (Sri Lanka)
Shipping incident involving various products

Figure 37. Fire on board the X-Press Pearl *near to the port of Colombo (Sri Lanka).*

On 20 May 2021, a fire broke out on board the *X-Press Pearl*, a 2,565 TEU• container ship, near the port of Colombo (Sri Lanka). The blaze, fanned by strong winds, raged from 20 May to 2 June, when it burned itself out after destroying the entire ship. Despite attempts to tow the vessel, it finally sank to the bottom on 17 June in waters 21 metres deep, some four nautical miles off the coast of Sri Lanka and nine nautical miles from Colombo. The vessel was carrying:
- 348 tonnes of bunker fuel;
- 1,040 tonnes of caustic soda;
- 210 tonnes of methanol;
- 474 tonnes of copper;
- 11,000 tonnes of plastic pellets (various polymers: polyethylene, polypropylene, polystyrene).

Figure 38. Pellets and burnt residues from the X-Press Pearl *incident.*

This incident is the largest plastic pellet spill to date and illustrates the possible diversity of pollutants involved and liable to interact in the event of a container ship incident. One specificity of this incident was that it involved a large-scale fire affecting the form and composition of the plastic pellets on board (resulting in burnt plastic residues of varying sizes), with the risk of the pellets melting and combining with the other objects and products on board the ship at the time of the fire.

In the first hours after the incident, huge quantities of plastic pellets began to wash up on the Sri Lankan coast, to such an extent that in some places along the coast the deposits were piled more than a metre high. Initially, strandings of plastic pellets and burnt residues were concentrated mainly over 300 kilometres of the Sri Lankan coastline in the vicinity of the spill (west and south of the country). In autumn 2021, the Sri Lankan authorities reported that more than 750 kilometres of coastline had been affected by plastic pellet deposits from the *X-Press Pearl*.

During this incident, no response operations were organised at sea to collect the plastic pellets. The pellets were recovered onshore after they had washed up in the form of intact bags, loose pellets and burnt plastic residues of varying sizes.

The clean-up phases were coordinated by the Marine Environment Protection Authority of Sri Lanka (MEPA•) with the support of the Sri Lankan armed forces and the technical assistance of ITOPF• and OSRL•, enabling the clean-up of 250 sites by 25 June 2021 with as many as 500 to 1,000 people deployed per day. Several techniques were tested during the shoreline clean-up operations, including:
- Manual recovery (using shovels and brushes),
- Separation of plastic pellets by sieving,
- Sink-float separation of plastic pellets,
- More sporadically, both trommels• and beach cleaners were used to separate the plastic pellets from the surface layer of sand.

In terms of impacts, a study showed the presence of various metals in samples of plastic pellets taken following the incident, notably copper, lead and cadmium. This may have been caused by the adsorption• of metals present in the environment, which may themselves have resulted from the incident. Bisphenol A (BPA), an endocrine disruptor, was also detected in all of the burnt samples. The PAH• concentrations found in the samples were 100 times higher in the burnt samples than in the 'intact' plastic pellets. Mortalities among turtles, fish and marine mammals were noted following the incident, although the cause and effect relationship with the spill of plastic pellets has not been clearly demonstrated, despite plastic pellets being found during necropsies. These mortalities could be linked to spills of the other products on board the *X-Press Pearl* (e.g. acid, caustic soda).

The following lessons were learned from this incident:

- Recovering all the plastic pellets released into the environment is an impossible task. It is essential to quickly define clean-up end-points to avoid creating environmental disturbances due to responder actions;

- Plastic pellet clean-up operations are long, tedious and therefore costly. The main methods chosen by the authorities, i.e. manual recovery, sieving, sink-float separation, are time-consuming and physically demanding;

- A fire affecting the cargo is liable to alter the form, size and composition of plastic pellets, affecting recovery during clean-up phases. The dark colour of the burnt residues meant that they were easily confused with natural particles, complicating identification and survey phases. In addition, the burnt residues proved to be more friable, requiring greater care during clean-up operations in order to limit the fragmentation of these residues and making it necessary to adapt techniques in order to collect different sizes of pieces;

- Treatment options for the plastic pellets recovered were difficult to identify, further complicated by the lack of information on the level of contamination of the pellets and their possible interaction with the other products on board.

2. *MSC Susanna*, 2019 (South Africa) Cargo loss in a port

On 10 October 2017, as a result of adverse weather conditions, two containers (49.5 tonnes in total) of polyethylene pellets were lost overboard from the *MSC Susanna* in the waters of the port of Durban (South Africa).

The weather conditions prevented any attempts to implement response operations at sea and recover the containers in the hours following the incident. One container was recovered the following day and the second on 20 October 2017. The two containers were damaged and almost empty when they were retrieved.

Despite the spill having occurred in a relatively enclosed area, 300 kilometres of coastline were contaminated between Durban and Richards Bay due to the lack of response actions and the tendency of plastic pellets to spread, driven by currents and winds.

Onshore response operations consisted in collecting the plastic pellets mainly using sieves and by manual recovery. No evidence of any environment impacts was found during this incident.

The following lessons were learned from this incident:

- Clean-up operations were long, tedious and costly, despite the limited quantities of plastic pellets spilled into the environment. In total, the operations lasted three years in order to reach the end-point value set by the South African authorities of 50 g of plastic pellets per operator per day. In total, these operations resulted in the recovery of 35.8 tonnes of plastic pellets (72% of the quantity spilled), corresponding to more than 1.1 million hours worked;

- A recovery stream for the plastic pellets was found during this incident which only involved plastic pellets. Some of the plastic pellets were reused to produce garden furniture.

3. *Yong Xin Jie 1*, 2012 (China)
Cargo loss at sea

On 23 July 2012, following adverse weather conditions, the *Yong Xin Jie 1* lost six containers of polypropylene pellets (~150 tonnes) overboard, some 2 kilometres off the coast of Hong Kong (China). During the search operations at sea, five containers were recovered, four of which were badly damaged and had released their cargo at sea.

In the days following the loss of the containers, plastic pellets washed up on various islands in the Hong Kong archipelago, causing clean-up operations to be launched along the coastline from 26 July.

Clean-up operations involved several thousand volunteers to conduct shoreline surveys and recovery operations. The main clean-up method used was manual recovery by volunteers, resulting in the recovery of 105 tonnes of plastic pellets.

Meanwhile, local fishermen observed abnormal mortalities of juvenile fish with plastic pellets in their digestive tract, but no tangible evidence was found to confirm the link between the incident and these observations (the plastic pellets may have entered the digestive tract *post-mortem*).

This first major ship-source spill of plastic pellets, which attracted considerable media attention, highlighted the authorities' lack of preparedness to manage this type of incident, as well as a lack of knowledge on this pollutant. This incident also revealed the lack of a clear international regulatory framework for the financing and compensation of response operations.

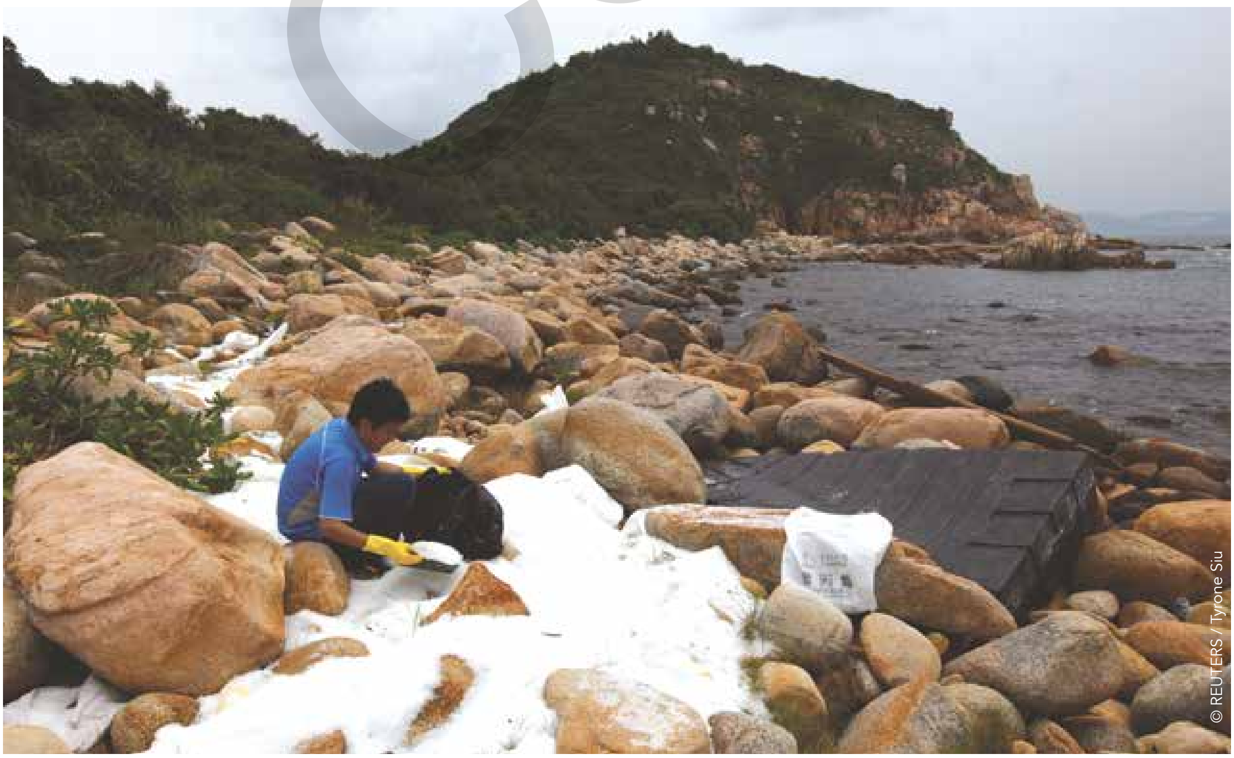


Figure 39. Recovering plastic pellets in Hong Kong following a spill from the Yong Xin Jie 1.

4. Pas-de-Calais, 2016 (France)
Road accident

On 23 February 2016, the unloading valve of a tanker truck was accidentally opened, releasing 8 tonnes of plastic pellets, which spread over an 8-kilometre stretch between Boulogne-sur-Mer and Marquise (Pas-de-Calais, France).

The local authorities took action as soon as the incident was reported, stopping all road traffic so that response operations could be carried out and to prevent risks for drivers (slippery surface). The areas to be cleaned were marked out and industrial sweepers and vacuum systems were deployed.
It took two weeks for clean-up operations to reach a state deemed acceptable by the authorities.

Feedback from this incident highlighted three lessons learnt in relation to road accidents:

- Road traffic must be stopped as soon as possible to prevent the risk of additional accidents. In this case, the plastic pellet spill caused two additional accidents because the road surface was rendered particularly slippery by the plastic pellets;

- Recovery of plastic pellets using vacuum systems is relatively easy on asphalt•;

- The stormwater network and weather conditions are liable to cause the plastic pellets to spread significantly. In this case, pellets from the incident were found within a 50 km radius.

V - TECH SHEETS

The various techniques/methods identified are outlined in Tech Sheets that are divided into two categories:

- Tech Sheets 1 to 7: Preventing plastic pellet losses into the environment from industrial sites.

- Tech Sheets 8 to 19: Responding to a plastic pellet spill.

They present the main characteristics of the techniques and methods, the potential benefits and risks, the conditions of use and the resources required.

TECH SHEET 1
ADAPTATION/MODIFICATION
OF PLASTIC PELLET PRODUCTION/PROCESSING LINES

AIM

To reduce operational losses of plastic pellets and plastic dust during plastic pellet production or industrial processing.

PREREQUISITES

Identify critical/sensitive points on production and processing lines for the release of pellets and dust.

POSSIBLE SOLUTIONS

- **Section off equipment liable to generate dust, shavings and pellets as part of the production chain** in order to help prevent their spread within the unit and beyond. Partitions can be installed around production lines, with access systems for workstation maintenance. Retention tanks be laid under equipment that generates dust, shavings and pellets to facilitate cleaning in hard-to-reach spaces within production, processing and logistics units.

- **Add extractor hoods** to prevent losses into the atmosphere of plastic pellets and fine particles which could be potentially hazardous for operators in the case of repeated exposure.

USAGE PRECAUTIONS

- **Section off equipment liable to generate dust, shavings and pellets:**
    - **Selection of partition materials:** choose materials that are impact-resistant, durable, resistant to industrial conditions and that can withstand exposure to chemicals and temperature variations, such as PVC or aluminium.
    - **Equipment accessibility:** incorporate secure access systems in partitions for regular and easy equipment maintenance without disrupting production.
    - **Compatibility with industrial chains:** ensure that partitions do not interfere with the production flow, operator movements or emergency intervention.
    - **Partition maintenance:** regularly inspect partitions for signs of wear, cracks, and other damage, and carry out any necessary maintenance.
    - **Cleaning of retention tanks:** retention tanks placed under the equipment must be emptied and cleaned out regularly to prevent the accumulation of pellets, shavings and dust.
    - **Operator training:** train staff in cleaning and maintenance procedures for partitions and retention tanks to ensure effective results.

- **Add extractor hoods:**
    - **Regular maintenance:** maintain extractor hoods and extraction systems in accordance with the manufacturer's recommendations to ensure they remain in good working order.
    - **Traceability of operations:** keep a log indicating the date of the operation, the type of operation (inspection, cleaning, maintenance) and the quantity of dust/shavings/pellets recovered, in order to monitor the effectiveness of the systems in place.
    - **Operator training:** train operators in the use of extractor hoods and in recognising signs of malfunction (abnormal noises, reduced suction power).

TECH SHEET 2
OPTIMISATION OF PLASTIC PELLET PACKAGING

AIM

To reduce operational losses of plastic pellets during packaging operations at production and logistics sites.

POSSIBLE SOLUTIONS

- **Carry out bagging in a closed environment:** creation of a closed facility for packaging operations to prevent the spread of pellets throughout the site and potentially beyond site boundaries, carried by wind, run-off or water systems.

- **Add sensors on bagging and palletising lines:** addition of sensors at various points on the logistics line for the automatic detection of pellet losses on the line (bagging error, packaging failure) with automatic stopping of the line for clean-up. This also reduces the risk of plastic pellets spreading into the environment and of damage to the bagging system as a result of pellets entering equipment workings.

- **Protect pallets and optimise the structure:** bags bursting during on-site transport and loading and unloading operations is one of the main sources of plastic pellet spills on industrial sites.

- **Change packaging:** the types of packaging currently used can have limited resistance, leading to losses during the various handling stages. The use of new types of packaging would help to prevent losses (use of reinforced, puncture- and tear-resistant bags, use of solid, closed, leak-proof containers.

USAGE PRECAUTIONS

- **Carry out bagging in a closed environment:**
  - **Facility design:** ensure that the facility is air-tight to prevent the spread of pellets to the outside. It should also be weather-resistant and fitted with an appropriate ventilation system.
  - **Regular cleaning:** clean the area regularly to prevent pellets from accumulating in hard-to-reach spaces.
  - **Operator training:** operators should be trained to work in a closed environment, in particular in relation to safety and emergency procedures.
  - **Restricted access:** restrict access to this area to authorised persons only, in order to minimise the risk of accidents.
  - **Equipment maintenance:** bagging equipment in a closed environment must be regularly inspected and maintained to prevent leaks of plastic pellets.

- **Add sensors on bagging and palletising lines:**
  - **Choice of sensors:** select sensors suited to the industrial environment (dust, vibration and temperature resistance).
  - **Regular calibration:** regularly calibrate sensors to ensure they remain accurate and to prevent false positives or detection failures.
  - **Functional tests:** carry out periodic tests to check that the sensors and the automatic line stop system are operating correctly.
  - **Procedure development:** establish rapid response protocols in the event of pellet losses being detected, with operators ready to intervene to clean and restart the line.
  - **Integration into the management system:** connect sensors to the production management system for real-time monitoring and incident logging.

- **Protect pallets and optimise the structure:**
    - **Pallet quality:** use good quality pallets, without protruding nails or splinters, to minimise the risk of damage to palletised bags of plastic pellets.
    - **Protective liner:** lay a rigid plastic liner that is sufficiently thick to protect the pallets and bags.
    - **Pallet inspection:** inspect each pallet before loading the bags to detect and correct any potential defects.

- **Change packaging:**
    - **Compatibility with equipment:** ensure that the new types of packaging are compatible with the existing equipment (bagging lines, handling, transport, etc.).
    - **Pilot-scale trials:** set up pilot-scale trials to test the robustness of the new types of packaging in real-life conditions, prior to large-scale deployment.
    - **Performance monitoring:** monitor the performance of new packaging in terms of reducing pellet losses, adjust if necessary and have the packaging validated by clients.

TECH SHEET 3
LOADING AND RECEIVING PLASTIC PELLETS

AIM

To reduce operational losses of plastic pellets during loading and receipt.

POSSIBLE SOLUTIONS

- **Modify/replace filling valves on plastic pellet silos** so that they are compatible with the filling valves on tanker trucks and containers. This adaptation should ensure optimal loading of vehicles while minimising the risk of losses.

- **Automate truck and tanker filling systems** by using a computerised system to guarantee adequate and optimal filling while preventing spills during filling.

- **Protect the ground during loading and unloading** of trucks by positioning trucks and containers over containment berms with track belts so that carriers can conduct loading and unloading operations in a protected area.

- **Inspect goods upon receipt** to ensure that there are no plastic pellets that could potentially be spread across the receiving site (open 25 kg bags, incorrectly filled/closed big bags or octabins). Depending on the company's procedures, the delivery may be refused, resulting in additional costs for the seller due to the dispatch of a new order.

USAGE PRECAUTIONS

- **Modify/replace filling connectors on plastic pellet silos:**
    - **Connector compatibility:** ensure that new connectors are compatible with truck and container filling systems, taking into account industry standards and technical specifications.
    - **Resistant materials:** choose valves made of materials that are resistant to wear, corrosion and high pressure, in order to extend their lifetime and minimise the risk of leaks.
    - **Operator training:** train operators in the correct use of the new valves, in particular safe connection/ disconnection procedures.

- **Automate filling systems:**
    - **System selection:** choose an automation system that is compatible with the equipment installed at the industrial facility.
    - **Continuous monitoring:** install sensors and monitoring systems to detect any anomalies during filling and to immediately stop the process if a problem occurs.
    - **Operator training:** train staff in the use and maintenance of the automated system and in emergency procedures in case of system failure.
    - **Validation tests:** carry out periodic tests to check that the system is operating correctly and complies with the defined filling levels.

Protect ground during loading/unloading:

- **Choice of containment berms:** use containment berms with track belts that are robust enough to withstand the weight of trucks and provide optimal protection in the event of a pellet spill.
- **Precise positioning:** introduce procedures to ensure that trucks are positioned correctly over the containment berms with ground markings and wheel guides if necessary.
- **Cleaning and maintenance:** regularly clean out containment berms to prevent the accumulation of pellets or debris.
- **Inspection after each operation:** inspect containment berms after each loading/unloading operation to detect any damage or residual losses, and take corrective action immediately.
- **Spill preparedness:** have rapid response kits available in case of a spill to limit the extent of contamination and to implement effective clean-up (see **Tech Sheets 4 and 5**).

- Inspect goods upon receipt:

- **Inspection procedures:** develop standardised inspection procedures to check the integrity of bags, big bags, octabins and other containers of pellets upon receipt.
- **Rejection criteria:** define clear criteria for rejecting goods in the case of non-compliance (open bags, damaged containers) and inform suppliers (quality requirements).
- **Record-keeping and traceability:** keep a record of inspections with photos, notes and reports detailing any issues detected, to ensure traceability and facilitate the management of disputes with suppliers.
- **Communication with suppliers:** establish clear communication with suppliers to report recurring issues and work together to improve packaging and transport practices.

TECH SHEET 4
MANUAL RECOVERY OF PLASTIC PELLETS ON AN INDUSTRIAL SITE

AIM

To provide manual recovery equipment to enable a quick response in the event of a spill or operational loss of plastic pellets on an industrial site. Manual recovery is mainly recommended for the recovery of occasional or chronic losses of small quantities.

POSSIBLE SOLUTIONS

- **Prepare clean-up kits** for use by operators and position them strategically at identified sensitive points around the industrial site.

USAGE PRECAUTIONS

- **Kit contents:** ensure that each clean-up kit contains the necessary tools, such as brooms, brushes and pans, airtight storage containers or tanks, suitable for the manual collection of plastic pellets.

- **Visibility and accessibility:** position clean-up kits at identified sensitive points around the industrial site, such as filling, storage, bagging, handling or loading/unloading areas. They must be easily accessible to operators in the case of a spill.

- **Clear identification:** use a distinctive colour and clear markings for clean-up kits, so that they are easily noticeable. A sign may be displayed beside the kits reminding operators of the importance of their use in the event of a spill.

- **Operator training:** train operators in the correct usage of the clean-up kits, including pellet collection methods, the use of airtight containers for temporary storage of recovered pellets, and safety procedures to be followed during clean-up.

- **Regular inspection of the kits:** implement an inspection routine to check that each clean-up kit is complete and in good condition. Replace any missing or damaged tools immediately.

Quick response kit

TECH SHEET 5
VACUUM RECOVERY OF PLASTIC PELLETS ON AN INDUSTRIAL SITE

AIM

To provide vacuum recovery equipment in order to respond to a spill or operational loss of plastic pellets on an industrial site. Vacuum systems can be used to recover both small releases and large spills.

POSSIBLE SOLUTIONS

- **Use of industrial sweepers:** ideal for large surface areas, effective for routine cleaning as well as for dealing with significant spills on the ground (large-capacity hopper, reducing the emptying frequency and meaning that large volumes of debris can be handled). They are highly efficient but are more costly and require more maintenance than portable vacuum systems.

- **Use of portable vacuum systems:** suitable for routine cleaning of workstations and hard-to-reach spaces. Commercially available portable industrial vacuum systems can be battery-powered or fuel-driven. Both types of power supply have their advantages (batteries may be interchangeable between the company's different equipment, battery-powered equipment tends to be lightweight with low noise levels while fuel-driven models are more powerful) and disadvantages (battery run time, cost of batteries, battery charging time, noise level of fuel-driven equipment). The choice between fuel-driven and battery-powered tools will depend on the user's specific needs. For intensive usage requiring constant power and extended autonomy (in the case of a large spill or intensive cleaning of an area with long-standing contamination), fuel-driven tools are preferable. For less demanding uses (daily cleaning of workstations or occasional use for small spills), where the priority is to have equipment that is portable and easy to operate, battery-powered tools are a good option.

USAGE PRECAUTIONS

- **Use of industrial sweepers:**

    - **Choice of model:** choose a sweeper suited to the needs on the site, taking into account the surface area to be cleaned, the frequency of use and the types of surfaces (indoor and outdoor). The sweeper must be able to handle plastic pellets without causing further dispersion.
    - **Hopper capacity:** ensure that the sweeper has sufficient internal storage capacity to minimise interruptions for emptying, particularly when dealing with large spills.
    - **Type of sweeper:** select a model suited to the site (push, walk-behind or ride-on sweeper), taking into account budgetary constraints and the desired operator ergonomics.
    - **Regular maintenance:** carry out regular maintenance on sweepers to ensure they remain in good working order, including cleaning brushes, emptying hoppers and checking mechanical parts to prevent breakdowns during operation.
    - **Operator training:** train operators in the safe and efficient use of sweepers, with particular emphasis on emptying and maintenance procedures to prevent the accidental dispersion of pellets during use.
    - **Supervision of cleaning results:** introduce procedures to monitor the effectiveness of cleaning after the sweeper has been used, checking that the pellets have been collected and that the surfaces are clean.
    - **Cleaning schedule:** organise regular cleaning sessions outside main production hours to minimise disruption to operations while ensuring a clean environment.

- **Use of portable vacuum systems:**

    - **Choice of model:** choose between battery-powered or fuel-driven vacuum systems depending on specific needs (autonomy, power, portability), and taking into account the specific constraints of the industrial site (noise, hard-to-reach spaces).

- **Appropriate use:** use portable vacuum systems for specific areas such as workstations and hard-to-reach spaces, or for minor spills, while ensuring that they are powerful enough to collect the plastic pellets effectively.
- **Battery management:** for battery-powered models, ensure that the batteries are regularly recharged and maintained, and that spare batteries are available to avoid interruptions to cleaning. Organise a battery rotation schedule to maximise battery life.
- **Maintenance and cleaning:** carry out regular maintenance on portable vacuum systems and regularly check the condition of components to prevent breakdowns.
- **Cleaning schedule:** define cleaning routines adapted to the needs of each area, taking into account the intensity of activities and the risk of spills, to ensure a quick response in the event of a spill.

Vacuum recovery of plastic pellets on an industrial site.

TECH SHEET 6
CONTAINMENT OF AREAS SENSITIVE TO PLASTIC PELLETS ON AN INDUSTRIAL SITE

AIM

To install containment equipment around sensitive areas on an industrial site in order to prevent the spread of plastic pellets and reduce the risk of them entering the environment.

POSSIBLE SOLUTIONS

- **Mark out sensitive areas:** Asphalt surfaces and concrete blocks are the easiest surfaces to clean. Install concrete kerbs/blocks or similar barriers around these areas to reduce the risk of plastic pellets spreading and identify the areas to be cleaned on a daily basis.

- **Adapt site boundaries:** industrial sites are generally surrounded by fencing and/or barbed wire to prevent public access. The addition of kerbs (where not already present) together with tarpaulins or fine-mesh netting on fences will significantly reduce the risk of plastic pellets escaping or being transported due to environmental conditions (rain, wind).

- **Adapt the on-site road network:** large industrial sites may have a substantial road network, which will need to be protected to reduce the spread of plastic pellets on the site and thus reduce the risk of transfer beyond the site's boundaries. The installation of kerbs along the side of roads and of flaps on safety barriers already in place are effective methods of preventing the spread of contamination from one area to another within the site.

USAGE PRECAUTIONS

- **Mark out sensitive areas:**
  - **Clear markings:** ensure that sensitive areas are clearly and visibly marked, for example with road marking paint, warning signs or reflective markers, concrete kerbs/blocks or similar barriers to alert operators and cleaning staff.
  - **Accessibility:** provide easy access to sensitive areas to allow regular and rapid cleaning by installing access points or passageways for sweepers and other cleaning equipment.
  - **Daily cleaning:** introduce a daily cleaning schedule for sensitive areas, using appropriate equipment to effectively collect plastic pellets.
  - **Monitoring and inspection:** carry out regular inspections to ensure that any kerbs or barriers are intact and working as intended. Repair any damage or breaches immediately to prevent the pellets from spreading.
  - **Awareness-raising for staff:** train staff in the importance of keeping pellets contained within defined areas and in the need to immediately report any leaks or the spread of pellets outside defined areas.

- **Adapt site boundaries:**
  - **Choice of fencing materials:** use industrial-grade, UV-resistant and weather-resistant tarpaulins or fine-mesh netting to ensure that they effectively prevent plastic pellets from spreading beyond the site's boundaries.
  - **Regular maintenance:** introduce a regular maintenance schedule to check the integrity of tarpaulins and nets, and replace or repair them in the case of tears, holes or wear.
  - **Boundary inspection:** carry out frequent inspections of site boundaries to ensure that the barriers installed effectively prevent plastic pellets from escaping and that no vulnerable areas have been overlooked.
  - **Coordination with the authorities:** where necessary, work with the authorities to ensure that the measures taken comply with current environmental and security regulations.

- **Adapt the on-site road network:**
  - **Regular cleaning of roads:** introduce a regular cleaning schedule for the site's internal roads, using industrial sweepers that are suitable for collecting plastic pellets, particularly in areas where pellets are frequently transported.
  - **Road inspection:** carry out frequent inspections of roads and safety barriers to ensure that the kerbs and flaps installed are in good condition.
  - **Awareness-raising for drivers:** train drivers and industrial vehicle operators in the importance of reporting any pellet spills and of complying with safety protocols to prevent the spread of pellets.

Examples of containment (netting, concrete kerb, flaps)

TECH SHEETS

TECH SHEET 7
PREVENTION OF PLASTIC PELLET LOSSES BEYOND SITE BOUNDARIES

AIM

To provide equipment to prevent plastic pellets from spreading beyond the boundaries of an industrial site.

POSSIBLE SOLUTIONS

- **Control trucks/Install a blower** to ensure there are no plastic pellets on the outer surfaces of the vehicle, which could lead to environmental contamination. This visual inspection can involve the use of a portable blower, but requires a significant amount of operational time, given the number of trucks leaving the sites each day. A blower unit can be installed as an exit barrier to automate truck cleaning.

- **Manage industrial water and stormwater systems:** industrial water and stormwater systems are potential escape routes for plastic pellets; it is therefore necessary to install systems to prevent plastic pellets from escaping via such routes or to filter industrial water and/or stormwater that is liable to carry pellets into the environment. A range of equipment is available to protect water system outfalls:
    - Installation of fine-mesh (1 mm) baskets in drains or replacement of drains with filter inserts with a mesh smaller than the pellets. It is important to note (and this is also valid for the screens presented below) that basket systems are not suitable for recovering dust and fine particles which can clog such systems very quickly;
    - Installation of screens in water systems;
    - Installation of filter tanks at water system outfalls;
    - Installation of containment booms or silt curtains on the water at the outfall to contain any pellet leaks;
    - Installation of a filtration system to treat industrial water and stormwater (hydrodynamic filter, microbubble filter) to remove any plastic pellets from water systems.

USAGE PRECAUTIONS

- **Control trucks/Install blower unit:**
    - **Exit barrier design:** if a blower unit is installed, it must be designed to handle the different dimensions of outgoing trucks. It is important to ensure that the blower reaches all critical points of the vehicle (wheels, chassis).
    - **Systematic visual inspection:** in addition to the use of the blower, a systematic visual inspection should be carried out to spot any residual plastic pellets missed by the blower. Operators should be trained in the critical points to be inspected.
    - **Blower maintenance:** set up a regular maintenance schedule for the blower to ensure it remains effective, avoiding breakdowns and guaranteeing adequate air pressure.

- **Manage industrial water and stormwater systems:**
    - **Choice of filtration devices:** select equipment suited to the type and size of plastic pellets produced on site. Filters must have a fine enough mesh (1 mm maximum) to catch the pellets without clogging the filtration systems.
    - **Regular inspection and cleaning:** carry out regular inspections of filtration systems and baskets to prevent clogging and ensure effective filtration of plastic pellets. Baskets should be cleaned out regularly to prevent overflow.
    - **Monitoring of weather conditions:** monitor weather conditions so as to anticipate rainfall that could increase the risk of water contamination (risk of overflow, etc.). If heavy rainfall is forecast, it may be necessary to temporarily reinforce the filtration systems while ensuring good drainage.
    - **Boom maintenance:** maintain containment booms and silt curtains, inspecting them regularly to ensure that they are properly in place and effective against potential leaks of plastic pellets.
    - **Staff training:** raise awareness and train staff in the importance of managing water systems and the correct use of filtration and retention systems. They must be capable of responding quickly in the event of a spill.

Filtration equipment for water systems

Example of a blower unit

TECH SHEET 8
SITUATION ASSESSMENT
FOLLOWING A PLASTIC PELLET SPILL

AIM

To guide operators and authorities in rapidly and precisely assessing environmental pollution by plastic pellets to support decision-making for an effective and rapid operational response. Continuous assessment of the situation is crucial in order to adjust the response in real time and reduce the environmental impact.

IDENTIFICATION OF THE SPILL SCENARIO

- **Scenario A:** Incident at sea, alert raised before the plastic pellets reach the coast.
- **Scenario B:** Incident at sea or in inland waters. Alert raised after the plastic pellets start to wash up on the shore.
- **Scenario C:** Incident on land, resulting in contamination of the ground, riverbanks and coastal areas.

INITIAL ASSESSMENT AND POLLUTION MONITORING

Scenarios A and B: Modelling and forecasting

- **Aim:** Forecast potential plastic pellet trajectories.
- **Available resources:** drift models.
- **Input data:** weather conditions, currents, plastic pellet characteristics (especially density)
- **Expected results:** short-term forecasts (2 to 3 days) to target potential response areas at sea.

Scenarios B and C: Field surveys

1. Surveys of affected areas

- **Aims:**
  Locate and quantify the pollution.
  Identify the types of substrate affected (e.g. sand, rocks, vegetation).
  Identify socio-economic risks (e.g. tourist areas, critical infrastructure).
  Assess response possibilities (e.g. access, available equipment)
- **Available resources:** on-foot surveys, aerial surveys (e.g. using drones), surveys from vessels.

2. Pollution monitoring

- **Aims:** Monitor the pollution by assessing contamination levels
- **Available resources:**

Manual recovery of plastic pellets

Procedure: manually collect as many plastic pellets as possible in 2 minutes from an affected area.

Assessment:

High	Moderate	Low
> 30 g of pellets collected	[5-30] g of pellets collected	< 5 g of pellets collected

Plastic Pollution Index (PPI)*

Procedure: manually collect all the plastic pellets within one or more 1 × 1 × 0.05 m quadrat. The PPI is then calculated by multiplying the ratio obtained (number of plastic pellets/sampled area) by a correction coefficient of 0.2.

Assessment:

Very high	High	Moderate	Low	Very low
PPI > 3	2 < PPI < 3	1 < PPI < 2	0.5 < PPI < 1	PPI < 0.5

ASSESSMENT OF BURIED PELLETS

- **Aim:** determine whether any plastic pellets are buried in the affected area.
- **Methods:** dig trenches or transects to determine the depth of burial.
- **Caution:** dig to a depth of at least 1.5 m, depending on local sediment dynamics.

Survey and assessment of pollution levels

Subsurface inspection to check for buried pellets

TECH SHEET 9
PROTECTION OF A SENSITIVE AREA AGAINST PLASTIC PELLETS AND SPILL CONTAINMENT

AIMS

To protect sensitive areas (ports, protected areas, water intakes, aquaculture facilities) and prevent the spread of plastic pellets.

CHOOSING A SPILL RESPONSE BOOM

- **Manufactured containment booms for use on water:** for easily accessible areas such as port entries/exits, lagoons and estuaries. Lay the booms at the entrance or exit to the area to be protected, making sure they are positioned so as to prevent floating plastic pellets from entering or leaving.

- **Custom-made barriers for use on water:** for watercourses or areas that are difficult to access. Build and position barriers according to the specific characteristics of the terrain and the resources available. Make sure the barrier is firmly anchored and capable of containing the spill.

- **Booms and barriers for use on land:** for contaminated land areas, such as asphalt surfaces (in particular to prevent transfer to water systems), forest areas, etc.

INSTALLING AND MAINTAINING BOOMS

- **Preparation:**
  - Before installing the boom, assess the site characteristics (accessibility, currents, substrate, bathymetry, water level variations) to determine the optimal configuration. Boom laying (mooring, deployment) must be planned and prepared in advance during contingency planning by the authorities. It is important to regularly test contingency plans through spill response exercises.
  - Train operators in boom deployment techniques in real conditions and ensure that the necessary equipment is available.

- **Deployment:**
  - Use boats to deploy booms on the water, taking care to prevent rupture.
  - In the case of silt curtains, ensure that the skirt covers the entire water column for optimal effectiveness.

- **Maintenance:**
  - During operations, regularly monitor the condition of the booms to check their integrity and effectiveness.
  - Adapt boom usage according to changing weather conditions (currents, waves), which could affect their performance.

CASE OF WATER SYSTEMS

- **Tarpaulins and drain covers:**

to seal drains and other water system inlets. Cover drains with tarpaulins or drain covers to prevent plastic pellets from entering.

- **Filters and nets:**

to prevent plastic pellets from entering water system inlets and/or outlets. Place nets or filters at critical points to intercept plastic pellets and facilitate their recovery.

Example of a drain cover

TECH SHEET 10
RECOVERY OF PLASTIC PELLETS ON THE WATER BY STATIC MECHANICAL RECOVERY

AIM
To recover plastic pellets from a water body using a static response strategy.

PREREQUISITES
- Check that the containment area has been set up to collect floating plastic pellets.

- Check that the environmental conditions are suitable for the use of a skimmer.

STATIC RECOVERY METHODS
Mechanical recovery
- Use mechanical weir or vortex skimmers.
- 2 to 3 operators required to operate the skimmer and store the recovered plastic pellets.

Advantages/disadvantages:

☺ Easy to set up;
☺ Good selectivity;
☺ Limited ecological impacts provided operators have been trained;
☺ Equipment readily available in various sizes in spill response stockpiles;
☺ Good recovery rate (> 100 kg/h if the water body is clean, the recovery rate will depend on the presence of litter, algae and other matter on the water surface);
☹ Requires a containment area to be set up;
☹ Requires a calm water body.

Manual recovery (for small quantities)
- Use tools available to operators (scoop nets, nets).

Advantages/disadvantages:

☺ Easy to set up;
☺ Simple to implement;
☺ Good selectivity;
☺ Low ecological impacts;
☺ Readily available equipment;
☹ Time-consuming and low recovery rate without containment.

Alternative systems
- Vacuum pumping systems to be used only in cases of large quantities of plastic pellets in the water body. Such systems can be requisitioned from farmers.

Advantages/disadvantages:

☺ Availability (e.g. from farmers);
☺ Can handle large volumes;
☺ Storage system associated with pumping;
☹ Pump heads difficult to handle;
☹ Low selectivity;
☹ Use limited to areas accessible to heavy vehicles.

Example of static recovery in a containment area

TECH SHEETS

TECH SHEET 11
RECOVERY OF PLASTIC PELLETS ON THE WATER BY DYNAMIC RECOVERY

AIM
To recover plastic pellets from a water body using a dynamic response strategy.

DYNAMIC RECOVERY METHODS
Recovery drones
- Deployment in sheltered areas.
- Use of nets, grabbers or suction heads.
- 2 or 3 operators required to deploy and operate the drone and empty the recovery system.

Advantages/disadvantages:
☺ Easy to use;
☺ Can handle large volumes;
☺ Quick to deploy;
☺ Can access hard-to-reach areas
☺ Storage system associated with pumping;
☹ Post-recovery sorting required depending on the type of recovery and the state of the water body;
☹ Requires a calm water body;
☹ Low range and autonomy with certain models.

Recovery vessels
- Can be used in different conditions (ports, coastal areas, rivers) depending on the size of the boats available.

Advantages/disadvantages:
☺ High recovery capacity;
☺ Can handle large volumes;
☺ Storage system associated with pumping;
☹ Reduced mobility in narrow areas;
☹ Equipment not readily available;
☹ High operating costs.

Manual dynamic recovery
- Use of nets or scoop nets deployed from small local boats (canoes, kayaks, pirogues). Can be carried out in sheltered areas or on calm stretches of water.
- Check that the boat and onboard storage capacities are watertight to avoid any secondary contamination.

Advantages/disadvantages:
☺ Easy to set up;
☺ Access to areas that cannot be accessed by boats;
☹ Strenuous physical activity for operators;
☹ Labour-intensive, depending on the level of pollution.


Examples of dynamic recovery

TECH SHEET 12
MANUAL RECOVERY OF PLASTIC PELLETS

AIM
To efficiently recover plastic pellets from different types of substrates (beaches, rocky areas, forest floor) by hand or using manual tools.

USES
Substrates: all (provided the site can withstand high levels of trampling).
Level of pollution: very light to very heavy.
Number of operators: depends on the level of pollution.

POSSIBLE SOLUTIONS
Collection equipment: scrapers, rakes, shovels, brooms.

Separation after collection: Tech Sheet 14 & Tech Sheet 15.

Advantages/disadvantages:

- ☺ Easy to set up;
- ☺ Good selectivity;
- ☺ Limited ecological impacts provided operators have been trained;
- ☹ Requires a large number of operators;
- 😐 Recovery rate dependent on pollution level and number of operators.

Manual recovery and operations in sandy areas.

TECH SHEET 13
VACUUM RECOVERY OF PLASTIC PELLETS IN THE ENVIRONMENT

AIM

To efficiently recover plastic pellets from different types of substrates (beaches, rocky areas, forest floor) by vacuum recovery.

VACUUM RECOVERY USING PORTABLE SYSTEMS

Portable vacuum systems are versatile tools which can be used to recover plastic pellets from different substrates thanks to a wide variety of models (e.g. hand-held or leaf vacuums) and suction nozzles (e.g. hard, flexible) in order to reach the different areas where plastic pellets may be deposited. According to the area to be cleaned, adaptations may be necessary to optimise the use of the equipment (e.g. adding filters) to protect it against abrasion and corrosion and to limit the intake of macro-debris. Depending on the model used, it is essential not to forget additional batteries or generators to allow for prolonged used. A combination of different methods can be employed to optimise clean-up operations in each area. For example, in areas with dry and wet sand, rakes and brooms can be used to gather the plastic pellets together, thereby facilitating the vacuum recovery phase. It may be advantageous to use battery-powered rather than petrol-powered vacuum systems in certain areas, as they are less noisy for wildlife. Generic household or professional vacuum systems can be used if no industrial alternatives specifically designed for plastic pellets are available in the authorities' stockpiles. Certain models of portable vacuum systems can be fitted with wheels in order to move them around certain surfaces, in addition to the "backpack" version for use in hard-to-reach areas.

USES

Substrates: all (provided the vacuum system is fitted with appropriate filters according to the substrate).
Level of pollution: very light to very heavy.
Number of operators: 1 to 2 operators per vacuum system, depending on the model.
Remember to bring spare batteries to avoid downtime.

Advantages/disadvantages:

- ☺ Readily available (leaf vacuum systems belonging to local authorities, household vacuums);
- ☺ Light-weight;
- ☺ Limited ecological impacts provided operators have been trained;
- ☺ Can be transported to hard-to-reach places;
- ☹ Low to moderate selectivity depending on the substrate and level of pollution;
- ☹ Low storage capacity;
- ☹ Generally fragile equipment;
- ☹ Spare batteries or fuel required.

Examples of recovering plastic pellets using portable vacuum systems.

RECOVERY BY A VACUUM VEHICLE

Vacuum recovery by vehicles (trucks, industrial sweepers) fitted with suction heads is effective for heavily contaminated areas, but requires vehicle access or a barge to transport the vehicle.

USES

Substrates: all (provided that the equipment can be transported).
Level of pollution: moderate to very heavy.
Number of operators: at least 2 operators per vehicle.

Advantages/disadvantages:

- ☺ Autonomous and multifunctional (vacuum recovery, storage, transport of collected plastic pellets);
- ☺ High flow rate;
- ☹ Low to moderate selectivity depending on the substrate and level of pollution;
- ☹ Cannot be implemented in remote areas (requires a barge or road access).

Vacuum recovery operations inevitably lead to the collection of significant quantities of organic matter (leaves, gravel, sand, soil). Selectivity will depend on the level of pollution (the higher the level of contamination, the more selective the technique will be). A separation operation may therefore be necessary to reduce the quantity of waste to be treated (**Tech Sheet 14 & Tech Sheet 15**).

Examples of vacuum vehicles.

TECH SHEET 14
SINK-FLOAT SEPARATION

AIM

To separate plastic pellets from a substrate (sand, gravel, soil) based on the difference in density between the plastic pellets, the substrate to be cleaned and water, resulting in the collection of the plastic pellets at the surface or the bottom of the separation tanks. This separation technique is less energy-intensive than manual sieving, but its efficiency and selectivity will depend on the contaminated substrate and the nature of the plastic pellets. Depending on the incident, sink-float separation may prove ineffective.

USES

Sink-float separation (also known as density separation) can be used as a stand-alone technique or in tandem with another recovery method such as sieving (**Tech Sheet 15**), vacuum recovery (**Tech Sheet 13**) or manual recovery (**Tech Sheet 12**) to optimise the separation of plastic pellets from other matter (e.g. sand, soil, vegetation, gravel).

Substrates: sand, gravel, soil.
Level of pollution: very light to very heavy.
Separation tanks:

- Small scale: use of buckets for localised areas and small quantities of plastic pellets.
- Medium scale: use of bins or tanks for larger areas.
- Large scale: creation of separation pits using ditches, natural watercourses or temporary pools. Construction machinery (mini-excavators, backhoe loaders) may be required to dig the pits. When creating separation pits: position the pits close to a water source to facilitate filling and check that their installation does not have a negative impact on the local ecosystem, particularly on protected land or sensitive coastal areas.

Number of operators: depends on the number of separation units (for example, the number of bins) and the type of unit (the creation of separation pits will require additional manpower to operate the construction machinery).
Recovery of plastic pellets: use of nets or scoop nets.

Advantages/disadvantages:

☺ Easy to set up (use of buckets, bins, pools);
☺ Very effective for floating plastic pellets;
☺ Little operator training required;
☹ Low to high selectivity depending on the substrate;
☹ Requires access to water and removal of sunken materials;
☹ Requires a second separation stage;
☹ Requires considerable human resources depending on the area to be cleaned;
☹ Cannot be used in protected land or coastal areas (e.g. bird nesting grounds, sea turtle breeding grounds);
☹ Requires precautions to be taken to prevent ecological and geomorphological impacts when using construction machinery to dig separation pits.

Sink-float separation.

TECH SHEET 15
PLASTIC PELLET SEPARATION BY MANUAL SIEVING

AIM
To separate plastic pellets from a substrate (sand, gravel, soil) by hand sieving.

USES
Sieving involves using a mesh selected according to the diameter of the particles to be recovered. When the recovered materials contain natural matter (e.g. leaves, gravel), a sink-float separation stage is possible depending on the nature of the plastic pellets or double-mesh sieves may be used to increase selectivity.

Substrates: sand, gravel, soil, silt, clay (substrates must be dry).
Equipment: commercially available (e.g. mesh riddles), can be manufactured (wood and wire mesh). Metal sieves are preferable to plastic sieves as they tend to be stronger.
Level of pollution: very light to very heavy.
Number of operators: at least two people per sieve. A sufficient number of operators is required to allow for rotation as this operation is physically strenuous. To reduce physical exertion, rotary sieves, hand or motorised trommels, or sieves installed on vibrating tables available from local manufacturers can be used during operations wherever possible.

Advantages/disadvantages:

- ☺ Easy to set up;
- ☺ Good selectivity on suitable substrates;
- ☺ Little operator training required;
- ☺ Limited environmental impact;
- ☺ Easy deployment of equipment in hard-to-reach areas;
- ☺ Possibility of using motorised equipment;
- ☹ Duration of operations;
- ☹ Ineffective on damp soil and sediment;
- ☹ Requires considerable human resources depending on the area to be cleaned;
- ☹ Operations strenuous when using manual sieves (significant physical effort for operators);
- ☹ Use limited to areas accessible to tractors/trucks/barges in the case of motorised equipment.

Example of sieves used to recover plastic pellets.

Examples of motorised trommels for collecting plastic pellets.

TECH SHEET 16
PLASTIC PELLET SEPARATION BY MECHANICAL SCREENING

AIM
To collect plastic pellets by screening the surface layer of the beach.

USES
When incidents occur, different types of shores can be affected, particularly beaches, which can attract considerable media coverage because of their importance for tourism and recreational activities. Screening is a technique commonly employed to clean the surface layer of sandy beaches, particularly during the summer months (removal of litter and seaweed). The principle of screening is similar to that of sieving: beach cleaners operate by means of a vibrating screen which separates the sand from the matter to be collected according to the mesh size of the screen. The sand passes through the screen, while the recovered materials travel up the vibrating screen before dropping into a collection hopper.
Beach cleaners must be adapted (installation of fine-mesh metal screens suitable for pellets, adaptation of pick-up blades) to recover plastic pellets. The efficiency of screening will depend on the performance of the equipment, but also on how it is used by the operators (operating speed, screening depth). Poor usage of beach cleaners can lead to plastic pellets being buried in the sediment, making recovery more difficult.

Substrates: dry, fine sand. Depending on the sediment, an additional separation step may be necessary (**Tech Sheet 14**).
Equipment: beach cleaners may be tractor-towed, self-propelled or walk-behind.
Level of pollution: very light to very heavy.
Number of operators: depends on the type and number of beach cleaners on site.

Advantages/disadvantages:
- ☺ Motorised equipment;
- ☺ Good selectivity on beaches with fine, dry sand, provided appropriate screens are available;
- ☹ Ineffective on wet sediment;
- ☹ Cannot be used in sloping areas (risk of clogging);
- ☹ Reduced efficiency on heterogeneous sediment (reduced selectivity and significant sediment removal);
- ☹ Requires extensive operator training;
- ☹ Significant environmental impact if used systematically and excessively.

Recovering plastic pellets using a walk-behind beach cleaner.

TECH SHEET 17
REMOBILISATION OF PLASTIC PELLETS BY FLUSHING

AIM
To remobilise plastic pellets trapped in riprap and pebbles.

USES
Flushing involves using low-pressure water to remobilise trapped plastic pellets. This technique should be coupled with a containment method (e.g. a boom) in order to subsequently recover the remobilised pellets (using skimmers or nets).

Substrates: riprap, pebbles.
Equipment: fire hose or Venturi-effect hose, transfer pump, containment system (**Tech Sheet 9**), recovery equipment (manual or mechanical; **Tech Sheet 10** & **Tech Sheet 11**).
Level of pollution: very light to very heavy.
Number of operators: 2 operators per hose to allow for rotation.

Advantages/disadvantages:
- ☺ Readily available equipment;
- ☺ Limited environmental impact;
- ☹ Risk of destruction of soft substrates and old stone structures;
- ☹ Strenuous physical activity for operators, requires a sufficient number of operators to allow for rotation throughout the day.

Flushing out plastic pellets trapped among pebbles.

VI - FURTHER INFORMATION

1. Glossary and acronyms

Abiotic process: A process that does not involve any biological reaction.

Additive: Substance added to plastic materials to modify, improve or stabilise their properties during manufacture and use. Additives play an important role in optimising the performance, durability and appearance of plastics, giving them specific characteristics such as flexibility, UV resistance, colour and fire resistance.

Adsorption: Retention of a pollutant (oil, chemical; fluid or viscous) on the surface of plastic pellets.

ARGEPOL: "Archivage et gestion de données dans le cadre d'une pollution littorale".
Interactive mapping system developed by Cedre to monitor pollution both at sea (aerial observation, drift forecast modelling results, tracking of drifter buoys) and onshore (pollutant washing up on the shore, waste recovered, personnel and equipment deployed, clean-up progress). Using ARGEPOL, different environmental elements can be displayed, such as information on the sensitivity of coastal areas to help to determine the most appropriate response strategy to preserve the most sensitive areas. Thanks to a mobile version, pollutant deposits on the shoreline can be recorded from the field via a smartphone or tablet.

Asphalt: Petroleum-based material used mainly for road surfaces and urban infrastructure.

Carboxylation index: Marker of the ageing of plastics by the action of solar radiation.

Compounding: Industrial process which involves adjusting the formula and properties of basic plastic pellets to meet the specific requirements of a given use.

Flushing: Clean-up technique that remobilises a pollutant using low-pressure jets to channel it to a collection point.

Food web: All feeding interactions between living beings in an ecosystem.

HNS Convention: Aims to ensure prompt and effective compensation to those who have suffered from damage to person and/or property. This includes cost of clean up and economic losses resulting from the maritime transport of hazardous and noxious substances.

ICPE: French Classified Facilities for the Protection of the Environment. Relates to facilities likely to have an impact on and present a danger to the environment, public health or public safety.

IMO: International Maritime Organization.

ITOPF: International Tanker Owners Pollution Federation.

Leachate: Liquid solution resulting from the leaching process, which consists of extracting soluble substances from a solid material using a liquid.

Masterbatch: Pellets enriched with pigments/additives dispersed in a plastic material. They are mixed with other pellets during the manufacturing of plastic objects to add colour or additives to the plastics.

MEPA: Sri Lanka Marine Environment Protection Authority.

Operation Clean Sweep (OCS): Industry-led initiative to achieve the target of zero plastic pellets loss.

Orphan spill: Spill of unknown origin.

OSRL: Oil Spill Response Limited.

PAH: Polycyclic Aromatic Hydrocarbon.

Plastic pellets: Plastic pellets are an intermediary between the raw material (oil, gas, bio-based substances) and the finished plastic product.

PPE: Personal Protective Equipment.

PPI: Plastic Pollution Index.

Strandline: Accumulation by the sea of natural or anthropogenic litter, washed up on the foreshore at the highest point reached by the high tide.

TEU: Twenty-foot Equivalent Unit. Units used to calculate the volume of containers loaded onto a ship or stored in a terminal, as well as to express the cargo capacity of a container ship.

Transformation product: Substance formed as a result of a chemical reaction during the production or use of a product.

Trommel: Rotary screening machine consisting of a long inclined drum composed of perforated metal sheets with holes of increasing diameters, driven by a slow rotary movement around its axis.

Ubiquitous product: Product found in several environmental compartments.

2. Additional information

2.1. Production

2.1.1. Statistics

In 2023, world production of thermoplastics, and therefore of plastic pellets, exceeded 310 million tonnes (Mt), confirming the continuous growth of the plastics industry over the last 70 years (in 1950 world production was 2 Mt). OECD projections predict that if plastic use practices by industry and human societies remain unchanged, world production of thermoplastics will reach 780 Mt by 2060. Asia accounts for 54% of world production (China 32%, Japan 3%, other Asian countries 19%), while North America and Europe are responsible for 17% and 14% of the production of thermoplastics respectively.

Polymers	Abbreviations	Production (Mt)	Examples of uses
Low Density Polyethylene	LDPE	58.2	Reusable bags, agricultural films
High Density Polyethylene	HDPE	58.9	Toys, shampoo bottles, household containers
Polypropylene	PP	77.8	Food packaging, automotive components, corks
Polyethylene terephthalate	PET	26.6	Water and drinks bottles
Polystyrene + Expanded polystyrene	PS+EPS	22.4	Food packaging, industrial insulation
Polyvinyl chloride	PVC	53.9	Window frames, insulating panels
Acrylonitrile butadiene styrene	ABS	9.5	Hubcaps
Polylactic acid	PLA	0.3	Food packaging

Abbreviations, production (Mt) and key uses of the main polymers produced worldwide in 2023 (input data: OECD).

2.1.1. Industrial processes

Plastic pellets are generally produced near to refineries or areas where the raw materials, whether fossil fuels (oil, gas) or natural materials, are extracted in order to facilitate the supply of the products required for their manufacture. In 2022, 90% of plastics produced were of fossil fuel origin.
The production of plastic pellets from fossil fuels involves six main stages:
Stage 1: **refining** of petroleum to obtain the fractions required (e.g. naphtha for polyolefins).

Stage 2: **cracking** of the required fraction to obtain monomers (e.g. ethylene, styrene, propylene). In the case of naphtha, steam cracking produces ethylene or propylene, which are then used for polymerisation to produce polyethylene or polypropylene.

Stage 3: **polymerisation** is the association of several monomers by polyaddition or polycondensation to form polymers. The length of the molecules is controlled by the addition of hydrogen or by the temperature applied. Copolymers (e.g. hexene, ethylene) can be added. The polymerisation reaction produces a plastic in powder form or dissolved in a solution.

Stage 4: **extrusion**. The plastic is heated in an extruder where it is melted and pressurised to then pass through a die in order to produce plastic filaments. During the extrusion process, additives are incorporated. The filaments are cut directly by blades at the extruder output to form solid pellets after cooling.

Stage 5: **packaging and shipping**.

Stage 6: **compounding**. Once the "primary" plastic pellets have been received by the client, new additives/polymers can be added to form new pellets called compounds, which are then sold on and shipped to end clients to make finished plastic products. Compounding• is performed to adjust the properties of basic plastic pellets to meet the specific requirements of a given use. The compounding stage is not mandatory and depends on the characteristics required for the final product (a processor can use the basic plastic resins). The finished products are subsequently marketed and used in human activities. Some of the plastics produced will be recycled and can be used to produce new plastic pellets (in 2022, 9% of world plastic production came from chemical or mechanical recycling).

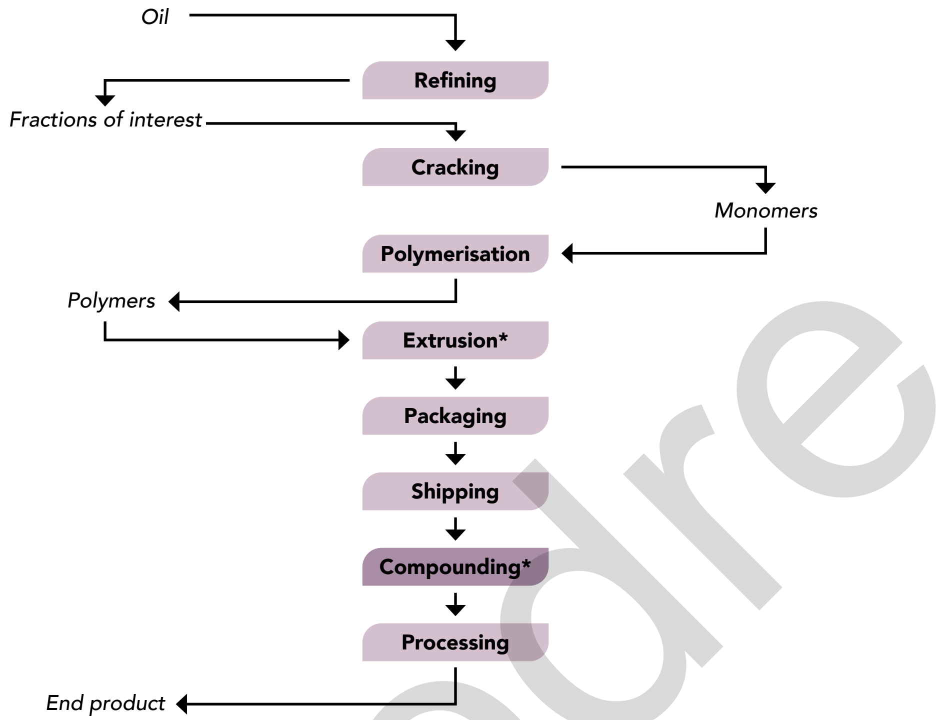
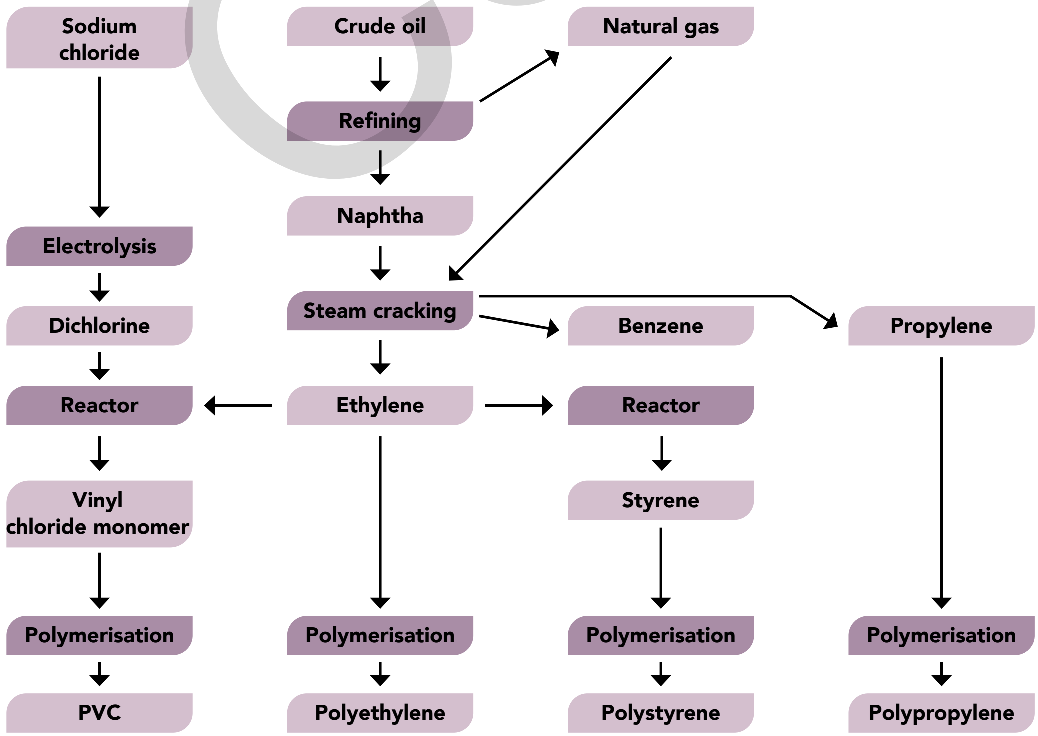


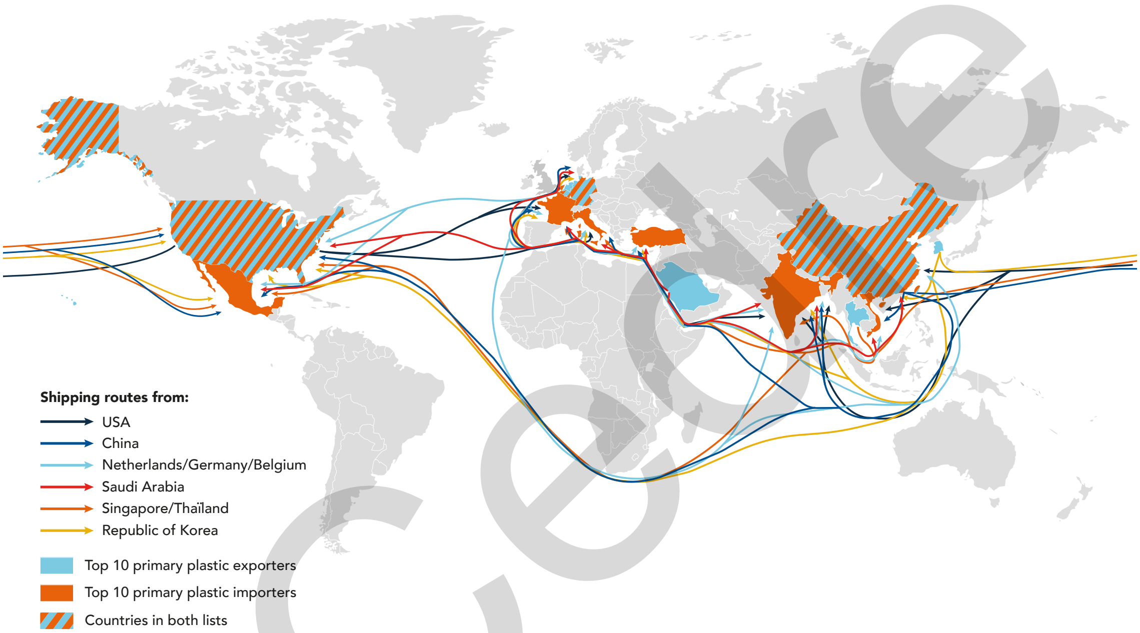
*Diagram of the plastics production chain. The * indicates the stages at which additives may be added. The dark purple box (Compounding) is not a systematic stage in the production chain.*



Conventional synthesis routes for the main polymers.

2.2. Main shipping routes used for plastic pellets

The map below shows the main routes used for the maritime transport of plastic pellets. The Middle East/ South Asia axis appears to be the primary transport route for plastic pellets, linked to the fact that China is the number one importer of polyethylene (12.5 Mt/year) and polypropylene (4.5 Mt/year), the majority of which comes from the Middle East (48% for polyethylene and 23% for polypropylene). Significant flows also exist within Asia itself: for example, 10%, 19% and 10% of polyethylene, polypropylene and polystyrene imported by China come from South Korea. However it is important not to over look trans-Pacific trade (e.g. 5% of the expanded polystyrene exported by Taiwan, the top exporter of this polymer, is shipped to Brazil) and trans-Atlantic trade (e.g. 6% of the PVC exported by the US, the top exporter of this polymer, is shipped to Egypt) as these are also significant routes.



Schematic illustration of the primary routes for the transport of plastic pellets according to import/export data. Map adapted from Kerrison (2022).

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