OSPAR COMMISSION

# OSPAR Background document on pre-production Plastic Pellets

Environmental Impacts of Human Activites

2018

# Background document on pre-production Plastic Pellets

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the « OSPAR Convention ») was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 march 1998. The contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature, à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande-Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union Européenne.

## Acknowledgement

This report has been prepared by France and Germany

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# Executive summary

Manufacturers of plastic raw materials produce plastics in different forms including pellets, flakes, powders and in liquid forms, hereafter all referred to collectively as "pellets". Therefore, pre-production plastic pellets are one of the base (virgin) materials used to make plastic products. They are transported from the production site to converters, where final plastic products are made by several processes such as re-melting, moulding or extruding these pellets.

Pellet spills can occur during all steps of the production chain, including at production sites and processing plants, and during pellet loading and transport. The mismanagement of accidental or systematic spills during routine operation is one of the reasons why pellets can be found in the environment, particularly in rivers, oceans and on beaches.

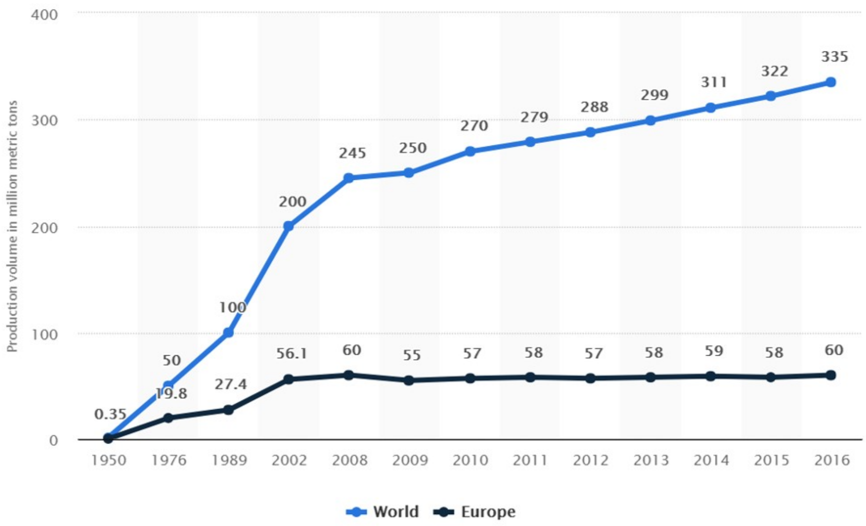
OSPAR's Regional Action Plan (RAP) has been agreed for the period 2014-2021 in order to address marine litter issues. It contains 55 actions which aim to reduce both land based and sea based sources of litter. Action 52 aims for zero pellet losses in the environment. To this end, this background document has been produced.

This background document introduces the issue of pellet loss, gives an overview of existing initiatives and identifies possible measures that could be taken by OSPAR. Finally, this document addresses outstanding issues that could provide fuel for further discussions.

# 1. Introduction

Plastics are an integral part of daily life. They are used for our safety, health, convenience, comfort and well-being. Plastics have replaced traditional materials in many sectors, such as the food packaging industry, medical services and transportation and they play a major role in the digital age.

*Figure 1: Plastic production in the world and in Europe*




*Source : www.statista.com*

However, despite their high utility and capacity for design, the use of plastics can also have significant economic, social and ecological impacts.

According to Galgani et al. (2015), plastic can form up to 95% of the waste that accumulates on shorelines, the sea surface and the seafloor. Known for their durability, plastics persist in the ocean for very long timeframes. Each year an estimated 6 – 10% of the world's plastic production (equivalent of 3.4 to 5.7 million tonnes in Europe), as noticed by Essel et al. (2014) ends up as marine litter.

Plastics can be found in oceans in very small sizes; these are what has come to be known as "microplastics" (less than 5mm in any one dimension). There are two types of microplastic: primary microplastics, which are produced at sizes less than 5mm in one dimension (e.g. cosmetic agents, cleaning agents, pre-production plastic pellets), and secondary microplastics, which are the result of the fragmentation of larger plastic products (e.g. textile fibres, degraded bottles).

Pre-production plastic pellets, flakes and powders, hereafter collectively referred to as "pellets", are on average smaller than 5 mm in size1 and therefore classified as primary microplastics. They are the raw material for all plastic products. The mismanagement of accidental or systematic spills during routine

1 Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, F., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T. (2016). *Harm caused by Marine Litter, MSFD GES TG Marine Litter – Technical Report*; JRC Technical report.

operation is one of the reasons why pellets can be found in the environment, particularly in rivers, oceans and on beaches.

The present background document aims to promote initiatives and the exchange of best practice to achieve zero pellet loss along the whole plastics manufacturing chain from production to transport. It provides an overview of the available knowledge about plastic pellets (characteristics, presence in the environment and impacts) and existing initiatives aiming at zero pellet loss. It concludes with the measures required to achieve OSPAR's zero pellet loss objective in the North-East Atlantic. Measures taken by OSPAR must be in accordance with Annex 1 of the OSPAR Convention, meaning that measures must align with the Best Available Techniques (BAT) and the Best Environmental Practices (BEP) available to combat this source of pollution.

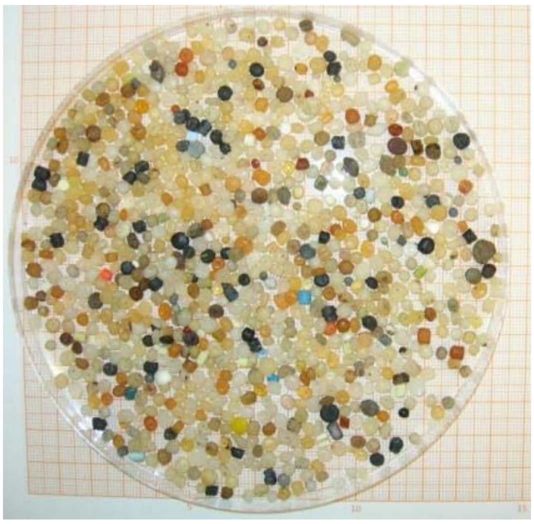
# 2. Characterisation of plastic pellets

## 2.1 Definition and technical properties

Pre-production plastic pellets are one of the base (virgin) materials for conversion into other plastics products. They are transported from production (or recycling) sites to industrial facilities, where final plastic products are made by several processes such as re-melting, moulding or extruding these pellets.

Technically, according to ISO 472:2013, a pellet is a "small mass of preformed moulding material, having relatively uniform dimensions in a given lot, used as feedstock in moulding and extrusion operations". [2]

*Figure 2 : Plastic pellets*



*Source : © SOS Mal de Seine*

Pellets are produced in many colours, including but not limited to: translucent, grey, white, yellowish white to amber, black, blue, red. Colouring can be done at the pre-production stage or during remanufacturing. Pellets are usually regular in shape, however fine particulate powders have more irregular shapes and sizes (Karlsson et al. (2018)).

2 Werner et al. (2016).

## 2.2 Pellet production

### 2.2.1 Quantification and techniques

According to Hann et al. (2018)[3], the European Union (EU) produces between 58-70.6 million tonnes of plastic pellets per year (refer to **table 1**). This equates to up to 1,400 billion pellets entering the environment per year. Within OSPAR countries, plastic demand amounts to 31 million tonnes per year.

Production of plastic pellets is divided in several steps (Plastics Europe, 2016):

- Step 1: Distillation process: the heavy crude oil is separated into lighter groups called fractions composed of a mixture of hydrocarbon chains. The fraction called naphtha is the essential fraction for the production of polyolefins which are used extensively to make plastic polymer
- Step 2: Cracking: the naphtha fraction obtained at the previous step is heated and split to get the basic molecules of plastics. This thermic process called cracking breaks the naphtha fraction into smaller hydrocarbon molecules (e.g. ethylene, propylene, butylene).
- Step 3: Polymerisation: the monomer chains are then linked together thanks to a chemical reaction called polymerisation to make polymers (e.g. polyethylene).

Depending on the type of basic molecule obtained at the cracking step, and the manner in which molecules are linked together at the polymerisation step, different types of plastics with different polymer chain structures can be obtained. This structure determines the physical and chemical properties of the plastics.

Two main polymer families have been identified:

- Thermoplastics: this material softens when it is heated and can be melted and reshaped an infinite number of times.
- Thermosets: this material cannot be melted or reshaped once it has been processed.

### 2.2.2 Description of the supply chain

Plastic pellets are manufactured in special industrial sites where once created, they are stored in large silos. Following this they are mostly either filled directly into tankers, or packed for transportation (see **Figure 3**)

3 Hann, S., Sherrington, C., Jamieson, O., Hickmann, M., Kershaw, P., Bapasola, A., Cole, G. (2018). *Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products*, Eunomia.

into small bags (20-25 kg), large bags (500-1000 kg), octabins (500-1300 kg), or silo trucks (up to 35 t)[4]. Once packaged, pellets can be transported to storage facilities or, can be transported directly to manufacturing facilities by road, rail, air or maritime transportation.

*Figure 3: different types of packaging for pellets transportation*


*Source: PlasticsEurope (2017). Operation Clean Sweep Report 2017*

Converters then transform these plastic pellets by re-melting and moulding them into the final plastic products. Recaptured post-consumer plastic waste can subsequently be recycled back into pellet form, in order to be reintroduced to the plastic manufacturing cycle.

Throughout this supply chain, plastic pellets can be lost to the environment. Explanations of these leakages and their consequences on the environment are provided in **Section 3** and **Section 4**.

The companies handling pre-production plastics have been categorised as follows by Eunomia in its 2018 report (Hann et al. 2018):

- Producers who create the plastics material from oil, gas and other raw materials;
- Intermediary facilities that handle the material between the producer and processor, including compounders and master batch makers who make specialist mixes of plastics and additives, distributors, storage facilities;
- Processors who convert the pre-production plastics into manufactured products;
- Off-site waste management who handle commercial waste from the categories of company above; and
- Shipping companies who transport the material on boats.

It can also be specified that logistics actor dealing with transport, reloading handling, repacking and storage may also be accountable for the leakages, but remain poorly supervised from authorities.

4 PlasticsEurope (2017). Operation Clean Sweep Report 2017.

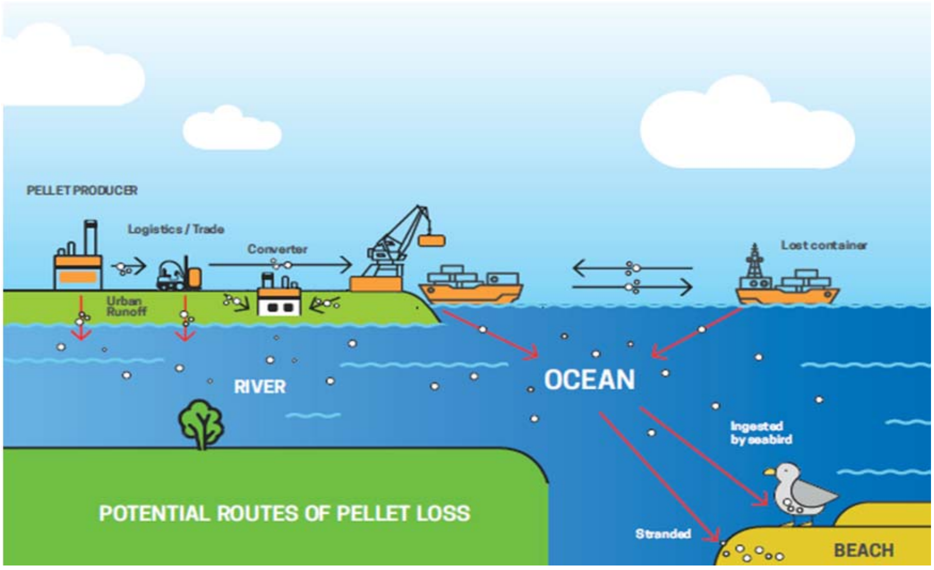
# 3. Pellet loss to the environment

## 3.1 Pellet loss pathways to the sea

According to the Operation Clean Sweep (OCS) Programme Manual[5], there are several steps in the supply chain that present a high risk for plastic pellet loss (see Figure 4):

- General handling: pellets spills can occur because of defective packaging or during filling processes;
- Pellet transport: pellets spills can occur during vehicle cleaning, loading and the sealing of vehicles, as well as during storage, and the unloading of bulk containers;
- Shipping: pellets can be spilt directly into the ocean from damaged or lost shipping containers or from damaged bags;
- Waste disposal: plastic pellets can be disposed of with mixed residual waste or blown away from bins stored outside.

*Figure 4 : Description of the plastic pellets supply chain and pellets losses pathway on the sea*




*Source : PlasticsEurope (2017). Operation Clean Sweep Report 2017*

Two main sources can be identified: losses on industrial sites or during transit.

### 3.1.1 Leakage on industrial sites

As mentioned in **section 2.2.2**, plastic pellets are handled by producers, intermediate facilities (logistics), converting processors, recycling facilities, and the risk of loss in open air within premises exists at each step of the value chain. During logistic operations, pellet spills can occur during, but not limited to, the loading and unloading of pellets using suction pipes for silos and forklifts or cranes for bags or octabins, according

5 OCS is an international program designed to prevent and help keep plastic litter materials out of the marine environment (https://opcleansweep.eu/).

to PlasticsEurope in 2017[6]. These processes can occur in the open air, which increases the risk of pellets escaping to the natural environment.

*Figure 5: Example of losses on industrial sites which have containment facilities*

*Source : © SOS Mal de Seine*

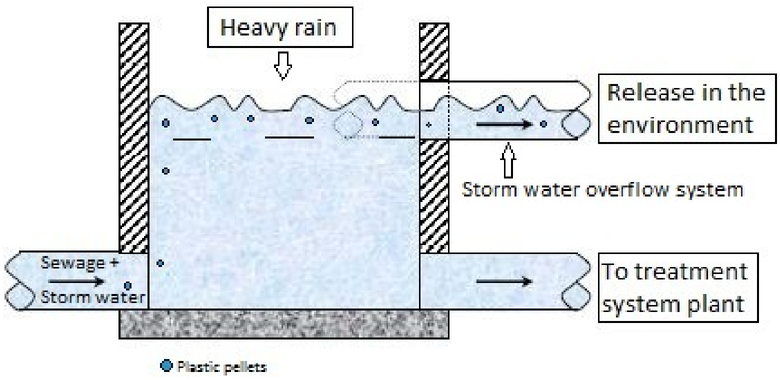
These pellets may then make their way into drains or gutters during bad weather conditions (e.g. wind and rain), which can lead to the following situations:

1) When industrial sewage reach wastewater treatment plants:

The first situation here is when storm water and wastewater are combined into the same system. During routine operations, storm water and wastewater are sent to wastewater treatment plants where plastic pellets and other plastic fragments are mechanically removed. However, when there are exceptional circumstances (eg. heavy rains) the purification basin where wastewater is held can overflow as a safety measure, allowing wastewater carrying pellets to leak into the environment. Some member states require installation of storm water overflow system to allow rainwater evacuation directly into the environment before any remaining storm water is mixed with sewage water (French legislation, decree n°2006-503). Despite this system's efficiency, some plastic pellets float (depending on their density) so any pellets in production sites' storm waters could end up in the environment (refer to **Figure 6**).

6 PlasticsEurope (2017). Operation Clean Sweep Report 2017.

*Figure 6: The storm water overflow system*




2) When storm waters and waster water are not combined into the same system:

In this case, industry is usually permitted to release storm water that is not mixed with sewage directly into the environment (for example, see article R111-12 of the French urbanism code). This can be a problem when this water contains plastic pellets.

3) When industry releases their effluent (not only storm water) directly to the environment:

Industrial activities are regulated by the Industrial Emission Directive (IED). This stipulates that the member state's competent authority set up an emission limit for each operating permit. The permit conditions including emission limit values must be based on the Best Available Techniques (BAT). In order to define BAT and the BAT-associated environmental performance at EU level, the Commission organises an exchange of information with experts from Member States, industry and environmental organisations. The IED requires that these BAT conclusions are the reference for setting permit conditions.

The IED does allow competent authorities some flexibility to set less strict emission limit values. This is possible only in specific cases where an assessment shows that achieving the emission levels associated with BAT described in the BAT conclusions would lead to disproportionately higher costs compared to the environmental benefits due to the geographical location or the local environmental conditions or the technical characteristics of the installation. The competent authority must always document its justification for granting such derogations.

Furthermore, the IED contains mandatory requirements on environmental inspections. Member States must set up a system of environmental inspections and draw up inspection plans accordingly. For futher information, visit the European commission website: www.ec.europa.eu.

Some companies install screening or drains to filter plastic pellets to avoid plastic pellet losses to the environment (figure 7). These filtration systems are usually effective in capturing plastic pellets. However, even if these facilities are effective for pellets in normal operating conditions, pellets present on the floor of the facility may be swept up by storm waters can bypass filtration systems and thereby directly enter the environment when there is heavy rain.

*Figure 7: effluents discharging into the canal connected to the sea by an oil and gas company, France*

*Source : © SOS Mal de Seine*

Some countries have set up specific emission limit for pellets under national legislation. For example, the Austrian legislation includes an emission limit of up to 30 mg $^{l-1}$ of plastics directly into the environment. According to Lechner et al. (2015), this corresponds to 94.5 tonnes of plastic per year.

In conclusion, despite preventive measures being in place, there remains a small potential for pellets to be swept by the rain and the wind directly in to the environment, from which they may reach waterways (refer to **figure 8**). In order to fully understand the issue, one action could be to assess the quantities of pellets which may be leaked into the environment during or after exceptional weather conditions.

*Figure 8: pellets and powders losses next to a chemical company site*

*Source : © SOS Mal de Seine*

### 3.1.2 Losses during transportation

Pellets are easily spilled during transport, including by road, ship and air. When moving pellet bags to any means of transport, the thin plastic containing them can be pierced by forklifts, enabling spillage.

Accidents during transport can also lead to large-scale pollution. These include road accidents and loss of containers from ships directly into the marine environment during exceptional weather conditions. The latter happened in October 2017 in Durban Harbour, South Africa, where two plastic pellet containers were left submerged in the harbour for 24 hours during a severe storm. The public authority did not act quickly and 49 tonnes of pellets were lost to the marine environment; clean-up operations along beaches are still ongoing. A similar problem happened in Hong Kong in 2012 where at least five containers full of plastic pellets were lost at sea and beaches were polluted.

## 3.2 Estimated quantities

Exact quantities of pellets lost from industrial sites are unknown by industry. For example, based on manta-trawl surveys, SOS Mal de Seine have quantified pellet losses in the water discharged by a chemical company in France, at approximately 2,2 tonnes per year.

Concerning losses during transportation, as mentioned in **section 3.1**, and according to the information collected from Plastic Soup Foundation, two containers were lost in South Africa, each one filled with 990 bags of polyethylene pellets in October 2017, while at least five containers were lost in Hong Kong in 2012. Hann et al. (2018) (refer to **Table 1**) estimates that the three biggest sources of pellet losses are producers, intermediary facilities and converters/processors, and that the estimated total pellet losses per year in Europe amounts to between 16,888 tonnes and 167,431 tonnes.

*Table 1: Estimated quantities of pellets losses in Europe*

| | Material handled (tonnes) | Loss rate | Quantity lost (tonnes) |
|---|---|---|---|
| Producers | 58,000,000[a] – 70,565,000[b] | 0.010% - 0.040%[c] | 5,800 - 28,226 |
| Recyclers | 6,896,340 – 7,662,600 | 0.010% - 0.040%[c] | 690 – 3,065 |
| Intermediary Facilities | 52,925,399 – 265,026,636[d] | 0.010% - 0.040%[c] | 5,293 – 106,011 |
| Processors | 48,563,380[a] – 66,776,366[e] | 0.010% - 0.040%[c] | 4,856 – 26,711 |
| Offsite Waste Management | 1,079,950 – 7,984,111 | 0.010% - 0.040%[c] | 108 – 3,194 |
| Shipping | 10,082,674[g] | 0.001% - 0.002%[h] | 141 - 225 |
| Total | | | 16,888 – 167,431 |

**Notes:**

a) From Plastics Europe (2016) *Plastics – the Facts 2015: An analysis of European plastics production, demand and waste data*. Includes CH and NO.

b) From Eurostat External Trade Database (EASY COMEXT Interface) data, 2015

c) From Carsten Lassen (2015) *Microplastics - Occurrence, effects and sources of releases to the environment in Denmark*, Report for The Danish Environmental Protection Agency, 2015, and Mepex (2014) *Sources of microplastic pollution to the marine environment*, Report for Norwegian Environment Agency, April 2014.

d) Based on Plastics Europe (2016) *Plastics – the Facts 2015: An analysis of European plastics production, demand and waste data*, and European Commission Trade Export Helpdesk Statistics accessible. Lower estimate assumes the material is handled once, the upper estimate assumes the material is handled four times.

e) Based on Eurostat External Trade Database (EASY COMEXT Interface) data, 2015 and European Commission Trade Export Helpdesk Statistics at

f) Using material handled tonnages for producers, recyclers, intermediary facilities and processors and an estimate of the proportion of feedstock as waste from Eunomia (2016), *Report for Fidra on Study to Quantify Pellet Emissions in the UK*, March 2016. )—0.6% of material handled for low and 1.9% for high estimate.

g) Based on European Commission Trade Export Helpdesk Statistics accessible and Eurostat News release 184/2016, Half of EU trade in goods is carried by sea, 28 September 2016,

h) Based on Marine Insight (2014) *Survey: How Many Containers are Lost at Sea?*,

Total microplastics generated from the loss of plastic pellets

**16,888 – 167,431 tonnes per year**

*Source : Hann et al. (2018), Eunomia.*

According to the Werner et al. (2016), 0.01% to 0.1% of the total plastic demand of OSPAR countries is lost. As stated in **section 2.2.1**, the plastic demand in OSPAR countries is 31 million tonnes per year so the pre-production pellet loss in the OSPAR Maritime area for 2015 is estimated to be between 3 100 and 31 000 tonnes which in turn, equates to 62 000-620 000 millions of pellets.

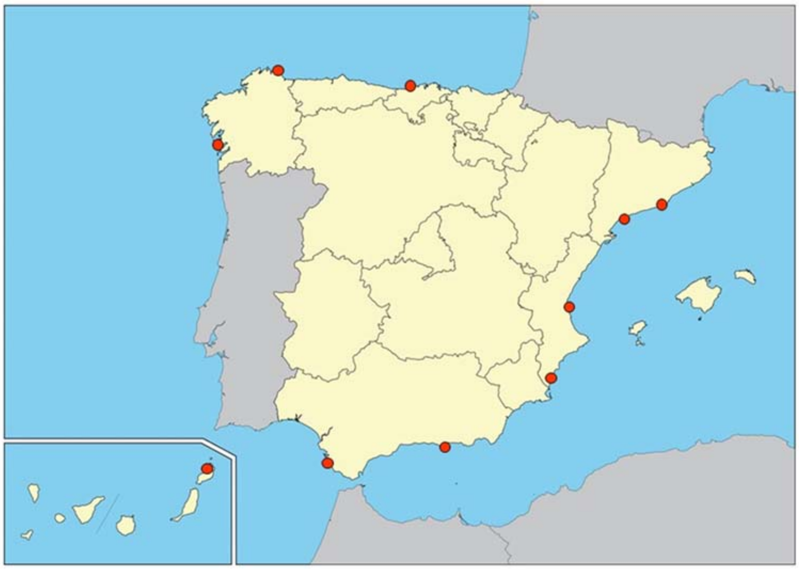
## 3.3 Occurrence of plastic pellet losses

The monitoring program of OSPAR provides a standardised method for conducting surveys of marine litter on beaches for 100 m of beach, as found in the OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014–2021[7]. This survey allows pellets to be noted as present or absent on beaches that have been cleaned but it does not provide the quantities of plastic pellets. Moreover, this occurrence is rarely mentioned by contracting parties.

In the Marine Strategy Framework Directive's (MSFD) scope, contracting parties of EU have to set up two types of monitoring. One for macroplastic beach litter and the other one for microplastic litter including the occurrence of plastic pellets and their quantities. This microplastic monitoring is now mandatory for all EU member states (this is the indicator 10.1.3 for the Good environmental status (GES)). For some member states this is currently under development.

In 2016 Spain started the MSFD subprogram BM-6 on microplastics on beaches. This monitoring program includes 10 different beaches (four within the OSPAR area) and, in each one surveys are conducted in spring and autumn, taking five samples per beach.

*Figure 9 : Beaches included in the Spanish monitoring program*



*Source: CEDEX*

The whole processing and analyses of the samples are carried out in the laboratory, where the microplastic concentration and their main attributes (size, shape and colour) are determined.

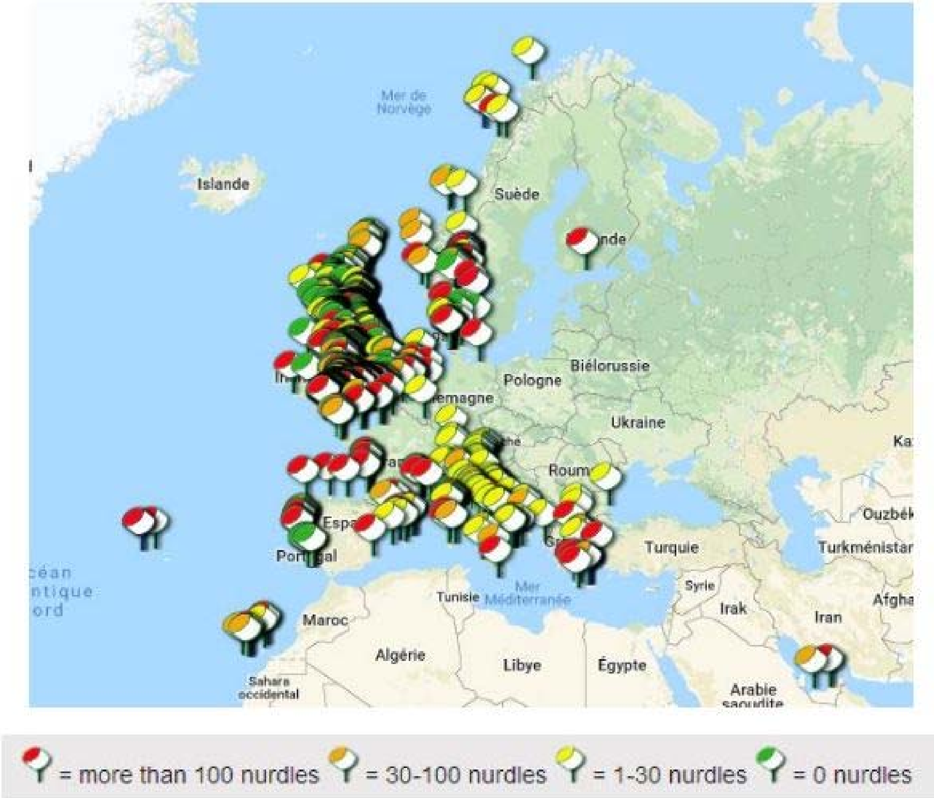
In 2016 pellets were detected on four of the ten beaches, with a massive presence on one specific beach (average concentration of 47.8 pellets/kg or 419.2 pellets/$m^2$) and a high presence on two other beaches (concentrations of 15 and 5.4 pellets/kg.). The concentration on the two last beaches could be explained due to their proximity to possible industrial sources of pellets. However, the first case is absolutely isolated from direct sources and the only explanation for the pellets presence there is oceanographic transport (waves, currents, winds) from areas of oceanic accumulation. For the whole set of beaches included in the program, the total pellet content represented 64% of the microplastic particles detected in 2016.

Beside these monitoring programs, the occurrence of plastic pellets in the marine environment has been observed since the 1970s (Carpenter et al. (1972)). Since then plastic pellets have been found in surface

7 OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2021

water samples and on beaches and river banks all over the world including sites which are not close to petrochemical or polymer industries, as shown in data collected by several Non-Governmental Organisations (NGOs) such as SOS Mal de Seine and Fidra (**Figure 10** and **Figure 11**).

*Figure 10: Occurrence of pellets collected by citizens who reported their observations*




*Source : Nurdle Hunt website https://www.nurdlehunt.org.uk/take-part/nurdle-map.html*

Both these groups have implemented observation protocols for plastic pellets. SOS Mal de Seine developed a simple method: they observed plastic pellets on beaches, riversides and near industrial sites in order to understand the dispersion of plastic pellets and also collected samples. A visual density criteria was developed to characterise each observation site. Fidra developed the Great Nurdle Hunt project, where citizens collect plastic pellets, so-called "nurdles", count them and report their observations.[8]

Both SOS Mal de Seine and Fidra have created maps reporting all collected observations of plastic pellets (**Figure 10** and **Figure 11**).

Other NGOs are also collecting data. As an example, the Spanish NGO Ambiente Europeo is monitoring microplastics on beaches using a citizen science program.

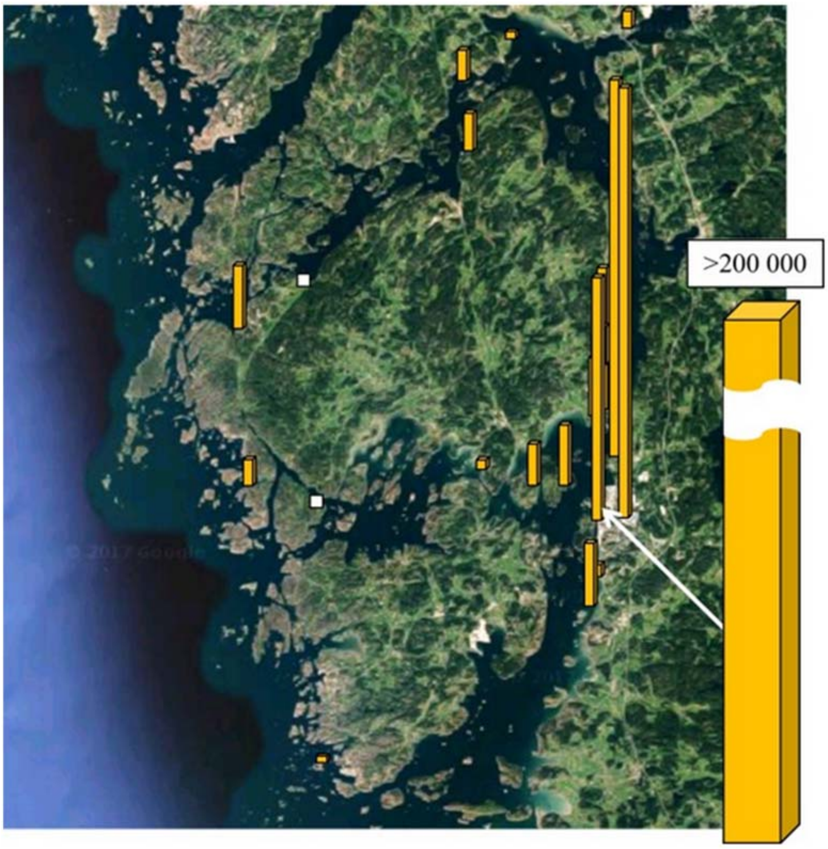
*Figure 11: Occurrence of pellets in France (plastic pellets can be : existing, missing, very discreet, discreet, few, intermediate, high occurrence, very high occurrence)*

8 www.nurdlehunt.org.uk/take-part/nurdle-map.html


*Source: SOS Mal de Seine*

There is also an example of the presence of pellets along the Swedish coast in a study done by Karlsson et al. (2018). **Figure 12** shows pellets found on beaches in the study area and their prevalence can be observed despite the protections in place in these areas. The protocol used to estimate the abundance was based on manually counting number of pellets sighted per hour, and also was applicable to non-standard OSPAR reference beach types, such as rocky shores archipelago.

*Figure 12: Results from measurements along the Swedish coast.*




*The heights of the yellow bars are relative to the number of pellets found per hour and person. White squares show examined sites where no pellets were found*
*Source: Karlsson et al. (2018).*

Finally, the port of Antwerp in Belgium also has a monitoring project, in collaboration with PlasticsEurope, that aims to quantify pellets in the port. During each clean-up, pellets are counted and hotspots determined. The main goal of the monitoring is to identify the port's pollution hotspots to prioritize these for intervention measures. Clean-ups are then planned especially at these hotspots.[9]

# 4. Environmental impacts of pre-production plastic pellets

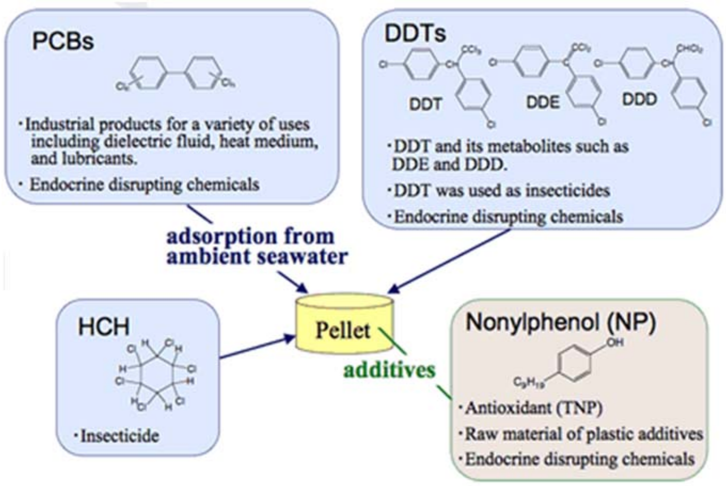
## 4.1 Chemical compound

Several studies address the issue of additives in plastic pellets. Mato et al. (2001), show that plastic pellets consist of various types of polymers (e.g. polypropylene, polyethylene, polystyrene) having different surface structures. According to this study, polypropylene has the ability to adsorb pollutants from the ocean. The study examined samples from four locations along the Japanese coast. The result of the chemical analysis is that polychlorinated biphenyls (PCBs), DDT, and nonylphenol (NP) were detected on polypropylene (**figure 13**). According to the study, the source of PCBs and DDT is seawater, and for NP is

9 PlasticsEurope (2017). OCS Port of Antwerp activity report 2017

plastic additives and/or degradation products. Plastic pellets can therefore represent a transport system for toxic chemicals into the food chain.

*Figure 13: Presence of pollutants in plastic pellets*




*Source: International Pellet Watch*

However, some studies consider that while there is ample evidence that microplastics accumulate high concentrations of POPs, this does not result in microplastics being important for the global dispersion of POPs. Similarly, Lohmann et al. (2017) concluded that there is scant evidence that microplastics are an important transfer vector of POPs into animals, but may be for plastic additives (e.g. flame retardants).

## 4.2 Impacts on marine wildlife

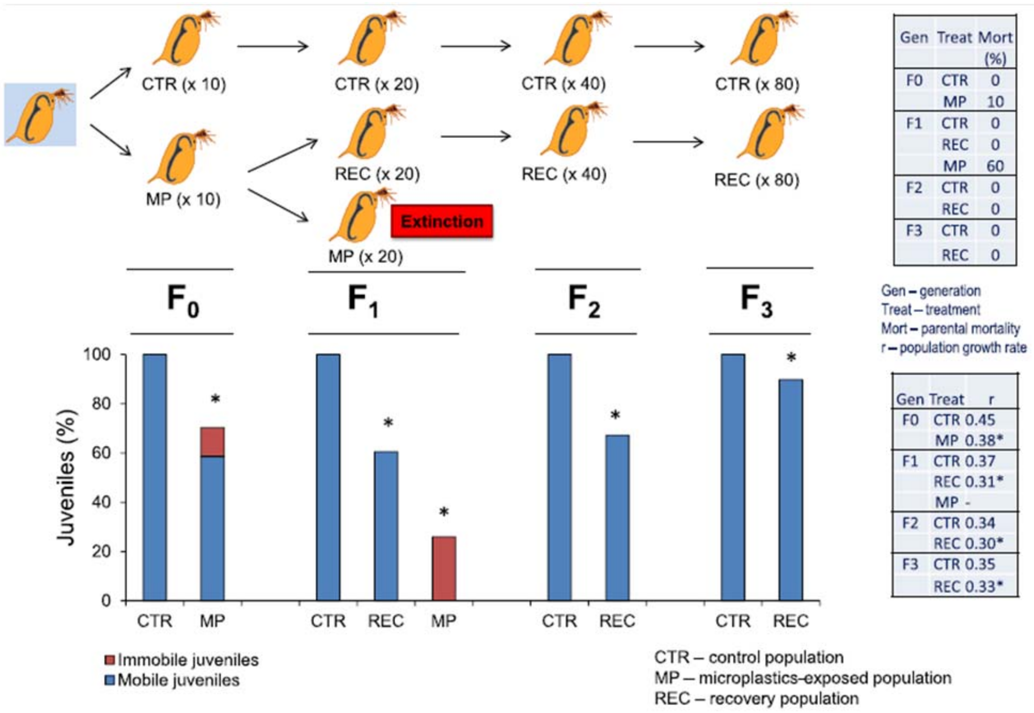
According to Kühn et al. (2015)*, s*ince 1997 the number of species observed to be affected by either entanglement or ingestion of plastic has increased from 267 to 557 among all groups of wildlife. According to the same study, 100 percent of marine turtle species, 66 percent of marine mammals, and 50 percent of seabirds have been observed to be affected.

The ability for polymers to float depends on their density; if the plastic's density is lower than sea water's, it will float. According to the study of Moret-Ferguson et al. (2010), heavier plastics (e.g., polyvinyl chloride) are accumulating in bottom sediments and lighter plastics (e.g., polyethylene [PE], polypropylene [PP]) are found floating on the sea surface. As plastic pellets are mainly constituted of either polyethylene or polypropylene, they float unless they become heavily biofouled (the gradual accumulation of organisms such as algae, bacteria, etc, on the plastic) and then sink and accumulate in sediments .

According to Werner et al. (2016), harm is caused by plastic pellets when they float or are in the water column, where they can be eaten by marine animals (e.g. seabirds, mammals, and fishes) either intentionally because they resemble prey items in shape or colour or unintentionally when filter feeding animals take up seawater. Ingestion of pellets as any microplastic can cause physical harm such as internal injuries and impaired ability to breath, swallow, digest food properly, or immediate death. In certain cases, plastic debris cannot pass through the digestive system, which can lead to malnutrition or starvation by creating a false feeling of fullness, known as pseudo-satiation.

In addition to ingestion issue, the study of Martins et al. (2018), shows that the recovery of chronic exposure of daphnia magna (a kind of zooplankton) to microplastic may take several generations and the continuous exposure over generations to microplastics may cause population extinction. The freshwater used for this experiment had a concentration of microplastic higher than those reported for most environments but lower than some polluted waters. The main conclusion of this study is that continuous exposure to high microplastics concentrations may lead this type of zooplankton to extinction in a short generation time, and in 21 days this population may need several generations to recover completely from toxic effects induced by microplastic. (Refer to **figure 14**)

*Figure 14: Transgenerational effects of microplastics in Daphna magna model populations*




*Source : Martins et al. (2018).*

Moreover, the study of Teuten et al. (2007) shows that plastic has the potential to transport hydrophobic contaminants and Rochman et al. (2013) indicates that plastic ingestion can transfer hazardous chemicals to fish and induce hepatic stress.

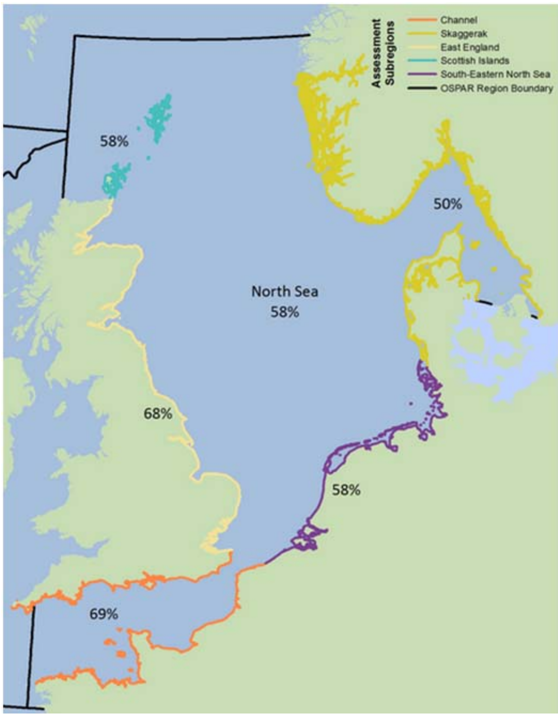
## 4.3 Impacts on fulmars

Fulmars live in the northern part of the OSPAR area and they feed exclusively at sea by foraging on surface waters. These seabirds frequently ingest floating plastic debris, including plastic pellets, as they capture prey from the sea surface (OSPAR Commission (2011), *Litter in the marine environment, plastic particles in fulmar stomachs*.)

The main issue is that fulmars, like other seabirds, accumulate plastic items instead of regurgitating them. According to the OSPAR Intermediate Assessment 2017[10], of all fulmars analysed, 93% had some plastic in their stomachs.

**Figure 15** shows the proportion of fulmars that have more than 0.1g plastic in the stomach in different monitoring regions of the North Sea over the period 2010 to 2014.

*Figure 15: Proportions of fulmars having more than 0,1g plastic in the stomach in different monitoring regions of the North Sea over the period 2010 to 2014*




*Source : OSPAR Commission (2017).Intermediate Assessment 2017 - Plastic Particles in Fulmar Stomachs in the North Sea.*

# 5. Existing measures

## 5.1 Measures led by NGOs

Several environmental NGOs are working to reduce marine litter. With regard to plastic pellets, their presence in the environment has been monitored by the NGOs SOS Mal de Seine, Fidra and Fauna & Flora International (FFI). These three organisations have implemented monitoring programmes and engage with authorities and industry to promote better practice when handling pellets[11].

Fidra has worked with the plastics industry since 2012 to raise awareness and understand the barriers for those wishing to engage on the issue of pellet pollution. Fidra collaborates with trade associations, decision makers and, regulators to identify a solution that will build upon Operation Clean Sweep (OCS) (refer to

10 OSPAR Commission (2017).Intermediate Assessment 2017 - Plastic Particles in Fulmar Stomachs in the North Sea.

11 For further information about SOS Mal de Seine, please consult: www.maldeseine.free.fr.

**section 5.2.1)**, a voluntary industry-led approach, to apply best practice measures across the supply chain in a way that is transparent and scalable[12].

FFI has engaged constructively with the plastics industry and with regulators in the UK and across Europe to promote wider uptake and implementation of OCS since 2012. FFI has been working to overcome limitations in the OCS scheme by encouraging the introduction of annual compliance audits and open reporting that feed into yearly OCS membership renewal (rather than automatic membership for life) to enable all stakeholders to see which companies have fully implemented best management practices for preventing pellet loss at their sites[13].

SOS Mal de Seine is in contact with the French Ministry of Environment and participates in raising awareness concerning plastic pellet loss, and several other NGOs are actively involved in promoting awareness and regulatory action at the European level.

## 5.2 Measures introduced by industry

### 5.2.1 Operation Clean Sweep

Operation Clean Sweep® (OCS) is a voluntary, international toolkit designed to prevent losses of plastic pellets during handling (by various entities in the plastics industry) and their release into the aquatic environment.

PlasticsEurope rolled out Zero Pellet Loss (ZPL), a voluntary initiative aimed at improving awareness, promoting best practices and providing guidance and tools to support its members in the implementation of the necessary pellet loss prevention measures. To align and concentrate all industry efforts globally under a common approach, in 2015 the ZPL initiative was integrated into the global Operation Clean Sweep® (OCS) programme, which had been developed in 1991 in the US by the Plastics Industry Association (formerly SPI).

Today OCS has been introduced to 23 countries around the world and by companies in 34 states in the USA.

A programme open to all industry players, designed for industry to prevent the loss of pellets into the environment, Operation Clean Sweep® (OCS) aims to assist each link in the plastics industry, resin manufacturers, transporters and converters to implement good handling practices for pellets and maintenance of industrial sites. Each signatory implements the most appropriate solutions for their sites and processes.

OCS includes six commitments[14]:

1. Improve worksites set-up to prevent and address spills;
2. Create and publish internal procedures to achieve zero pellet loss goals;
3. Provide employee training and accountability for spill prevention, containment, clean up and disposal;
4. Audit the performance regularly;
5. Comply with all applicable state and local regulations governing pellet containment; and
6. Encourage other partners to pursue the same goals.

PlasticsEurope publishes a yearly report on the progress of OCS implementation by plastic companies, and identifies where OCS needs further improvement. This programme also promotes the sharing of best

12 For further information about Fidra, please consult: www.nurdlehunt.org.uk/whats-the-solution.html.
13 For further information about FFI, please consult: www.fauna-flora.org/documents
14 PlasticsEurope (2017), Operation Clean Sweep Report 2017.

practices between plastic companies during workshops. This report provides a summary of OCS implementation and monitoring.

Goals related to OCS are the following:

1. PlasticsEurope's target is to have 100% of its member companies sign the OCS pledge to which OCS is applicable by the end of 2018.
2. Develop by 2018 a transparent, harmonised monitoring scheme for the collection of relevant and comparable information from all signed members to measure progress of the industry. Reports on progress will be published and made available to the EU institutions and key stakeholders on a yearly basis.
3. In 2019 PlasticsEurope will explore the feasibility to develop a common assessment tool with its members.
4. Based on the successful collaboration with the Antwerp port authority in 2017, PlasticsEurope is aiming at engaging with at least one other major European port by the end of 2018, and by 2030, at securing that all major industrial plastic pellet handling ports in the EU have taken measures to implement OCS.
5. PlasticsEurope will expand the work of the platforms with the supply chain and relevant stakeholders both at global, EU and national levels with a view to accelerate the implementation of OCS in the plastics value chain.

### 5.2.2 Plastic 2030 Voluntary Commitment of PlasticsEurope

PlasticsEurope have developed an initiative to tackle marine litter, and have set targets designed for the plastic manufacturing industry, which aim to achieve a fully circular and resource efficient economy.

This commitment is focused on three main objectives:

1. Increasing re-use and recycling: it aims to ensure high rates of re-use and recycling with the ambition to reach 60% for plastics packaging by 2030, and 100% by 2040
2. Preventing plastics leakage into the environment by setting up educational projects across Member States to increase awareness on sustainable consumer behaviour and by strengthening the Operation Clean Sweep;
3. Accelerating resource efficiency: by complementing with other actions aimed at enhancing plastics' resource efficiency and accelerate innovation for circularity.

### 5.2.3 Best practices guidelines and guidance publications

The plastics industry is committed not only to ensuring that proper pellet loss measures are established on their own premises, but also to taking the next step and engaging with logistics service providers, transportation partners and customers. This is vital for preventing pellet loss during transport to plastic converters and distributors. It is extremely important to engage with transportation partners and logistics service providers (LSP) and ensure that they implement pellet spill prevention measures, as many losses may occur at transport interfaces (loading, unloading, handling). In this regard, best practice procedures have been developed by several associations such as CEFIC, ECTA, PlasticsEurope and its member companies in order to address relevant environmental and safety aspects and highlight the need for prevention and mitigation of pellet losses[15].

## 5.3 Measures implemented by public authorities

### 5.3.1 Measures from States

The Marine Strategy Framework Directive of 2008 (MSFD) aims to work towards Good Environmental Status (GES) in each Member State. This is measured across a number of environmental indicators, including Descriptor 10: "Properties and quantities of marine litter do not cause harm to the coastal and marine environment". Work towards GES for this indicator across the EU has varied between different sources of marine litter, including microplastics and pellets.

In France it is hoped that the national Roadmap for a Circular Economy" of 2018 will make it mandatory to have appropriate containment systems at industrial sites to avoid pellet leakages.

In their "Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures", The Netherlands reported a measure that highlights the voluntary effort of cosmetics companies to avoid the use of plastic microbeads – an eco-friendly behaviour that will enable 80% of the products of Dutch Cosmetics Association members to be plastic microbeads-free.[16]

Germany also highlights the issue of micro-plastic particles used in cosmetic products and abrasives, and aims at preventing the introduction of primary micro-plastic particles into the environment through requirements on their use, prohibition of the use of abrasives in environmentally open areas, and the establishment of alternative products.[17]

Finland developed a sewage treatment methods that should eliminate most of the micro-litter found in municipal waste water, such as those used in cosmectics and personal care products (toothpastes and scrub for example).[18]

The UK is currently developing a proposal for a plastic bag ban and a ban of products that contain micro-beads.[19]

Spain aims to reduce the generation of microplastics from primary sources, i.e. plastic microparticles produced industrially as raw material. This is addressed by specific measures. One aims to improve the identification and quantification of microplastics, improve knowledge about ingestion, tissue distribution and effects of microplastics on benthic and pelagic organisms and the effects of contaminants that could contain microplastics. Another seeks to carry out a study at the national level of possible sources of microplastics based on an analysis of the production, import and consumption of such products; then, the analysis of the possible measures for their reduction at the source and their technical feasibility will be developed.[20]

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15 Best Practices Guidelines & Guidance Publications, see: www.ecta.com/Best-Practices-Guidelines.

16 Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures, Netherlands Report, Version 4 - February 2018

17 Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures, Germany Report, Version 4 - December 2017

18 Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures, Finland Report, Version 4 - February 2018

19 Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures, UK Report, Version 5 - February 2018

20 Article 16 Technical Assessment of the MSFD 2015 reporting on Programme of Measures, Spain Report, Version 5 - April 2018

In Austria, to reduce plastic pollution, the regulations regarding waste water emission to the environment classify plastic as a filterable substance and provide an upper limit of plastic discharge into running waters of 30mg $l^{-1}$. As mentioned in **section 3.1.1**, Lechner et al. (2015), analysed this regulation to show how many pellets can be released into the environment under this ordinance and to verify if the Austrian company, which discharged industrial microplastics in the river Danube in 2010, was complying with the regulation. The study reveals that under this ordinance, a company can release 94.5 tonnes per year, which represents 2.7 million single use plastic bottles.

### 5.3.2 Actions conducted by the European Union

The EU plastic strategy was adopted by the European Commission on the 16th January 2018 in order to establish a circular economy across the EU. To achieve this goal, measures have been and will be taken to reduce plastic waste by recycling and reusing more of every type of plastic to reach the principal aim which is to recycle all plastic packaging on the EU market by 2030. Under this new strategy, a monitoring framework has been adopted and five pillars of action determined. One of those is about marine litter and how to avoid the presence of waste at sea.

Under this scope, the European Commission asked the consultancy Eunomia to investigate options for reducing releases of microplastics emitted by (but not intentionally added in) products to the aquatic environment and in this, pellets were identified as a key source of microplastic pollution. In the report, two main measures were identified to prevent plastic pellets from entering the environment: amend the polymer production Best Available Techniques reference documents (BREF) and create a pre-production plastic pellet regulation that mandates supply chain standards.[21]

Measures for reducing leakages of preproduction plastic pellets are under preparation at the EU level as part of the implementation of the EU Plastic Strategy.

# 6. Costs of plastic pellet pollution

## 6.1 Coastal clean ups (beaches and banks of the Seine)

The collection of plastic pellets on beaches is complex because these particles are difficult to see due to their size or vegetation which may hide them. The Cornish Plastic Pollution Coalition cleaned Whitsand Bay at Tregantle with dustpans and brushes.

21 Hann et al. (2018)

*Figure 16 and 17 : Trying to sweep up the tangle of microplastics with dustpans and brushes*

*Source: Cornish plastic pollution coalition report 2017*

Rob Arnold invented a machine that can separate microplastics from sand and most organic material, which was used during the deep clean of Whitsand Bay at Tregantle.

*Figure 18: Mini sand-screening machine used for removing litter from beaches. Also used in case of oil spills for collecting tar balls, this machine is potentially available for microplastics*

*Source : ©Cedre*

SOS Mal de Seine Association highlighted their concern about the lack of capacity of public authorities to deal with the occurrence of large-scale pollution of pre-production pellets on beaches (e.g. due to a container loss), as these clean-up operations should be carried out within an hour of an incident to prevent widespread pollution by wind, rain, and/or tides. Hong Kong experienced large-scale pollution in 2012 and despite the cleaning undertaken by Chinese volunteers with rudimentary tools, the shoreline remains polluted.

*Figure 19: The massive pollution of Hong Kong in 2012*

*Source : Tracey Read DB Green Hong Kong*

The clean-up cost of pre-production plastic pellets on beaches is still unknown precisely but considering they are part of beach litter, beach clean-up costs should be considered.

Beach clean-ups of all kinds of litter are undertaken by volunteers, NGOs, private companies and social integration workshops, by public authorities or by local authorities. The French organisation Rivages de France recommends manual cleaning rather than cleaning with machines, to preserve biodiversity, natural habitats and minimise habitat disturbance. According to this organisation, a Natura 2000 contract for manual beach clean-up may cost around 42,000 euros to cover clean-up operations 15 times per year for five years (at La Faute Sur Mer, French municipality, this contract was concluded with a social integration workshop). According to the French agency for biodiversity (AFB), the cost of beach clean-ups in France varies between 6,720 euros (municipality of Villeneuve-Loubet) and 1,000,000 euros (city of Marseille) per year. The average cost of cleaning up all forms of litter in a city like Le Havre is 200,000 euros per year.

Moreover, technical cleanup solutions are in a very experimental stage. The examples mentioned above and in part 5 are not applicable to all different kind of environments. The effectiveness is not always certain depending on the size of the litter. Many polymers and small sizes microplastic would eventually sink.

## 6.2 Cost of monitoring ingestion by species

Monitoring costs of plastic pellet ingestion by species is unknown. However, AFB revealed that the costs of monitoring microplastic ingestion by loggerhead sea turtles carried out by la Rochelle Aquarium were 50,000 euros in total for four years. Another pertinent example is the monitoring of microplastic ingestion by fulmars provided by ornithological groups, which costs 33,300 euros for one winter season.

# 7. Options considered

This section aims to give an overview of possible solutions that could be implemented.

In order to prevent the accidental loss of plastic pre-production pellets and the associated coastal and marine pollution, a series of ambitious targets and measures need to be set. In fact, despite several existing initiatives (from the plastic industry, NGOs, public authorities, etc.), there are still large volumes of plastic pellets entering the environment. This matter concerns the entire OSPAR Maritime Area. Thus, it could be relevant to implement concerted measures within OSPAR and to assess their efficiency in the OSPAR Maritime Area.

The measures suggested in this section may require complementary legal, technical and economic feasibility analyses in order to propose them as formal OSPAR decisions, recommendations or agreements.

## 7.1 Types of measures that could be taken

The potential measures identified to prevent plastic pellet loss vary in degree of legal strength, ranging from the development of specific laws or regulations to the setting out of voluntary agreements. Details of the different levels being considered are as follows:

**1. The development of specific laws or regulations**

The full implementation, enforcement and modification of existing laws or regulations, or the establishment of new laws and regulations at national, European or international levels, could be considered in order to provide a better framework for plastic pellet production, loading, handling, storage and transport. This option would require a full impact study and broad consultation with stakeholders.

**2. Green deals**

This tool would allow contract-based links to be set up between public authorities and the private sector. Considered as "soft law", this option is characterised by the absence of legal obligations while setting targets and providing a means of control. This option would also require broad consultation with stakeholders.

**3. Voluntary agreements**

Voluntary agreements can be implemented by plastic industries themselves, especially through their professional federations as is the case with the Operation Clean-Sweep (OCS) programme, or by independent consultants working with plastic industries and local authorities. Voluntary agreements are more effective if they are based on strong partnerships, established at a local scale, with motivated and charismatic project leaders and good communication of actions. However, this option can suffer from a lack of control over the effectiveness of commitments. Furthermore, commitments can be partial and not include all the aspects of the considered agreement.

**4. A combination of the above**

It may be most effective to support the development and implementation of voluntary actions by industry, to be followed after a number of years by legislative action if voluntary action fails to effect change. This has a number of benefits. It places the onus on industry, i.e. those with greatest understanding of the relevant processes, to develop methods that are practical and cost-effective. The majority of the burden is carried by large international organisations that can then support smaller organisations to follow their lead. The expectation of impending legislation provides an incentive to make changes, and ultimately ensures a level playing field by imposing changes on organisations that choose not to take action.

## 7.2 Specific examples of potential areas where measures could be taken

The following areas for action have been identified as offering potential measures to reduce the loss of plastic pellets in to the marine environment. In most cases these could be implemented on either a voluntary or mandatory basis. As pellet loss is a widespread and long-term problem, it may be advisable to implement several or all of the options below. It will be important to assess the likely effectiveness of each option and which options are compatible together.

**1. Adopting a supply chain approach**

All companies involved in making, using or transporting these pellets need to commit to following specific guidelines that prevent pellet loss throughout all stages of making plastic products (i.e. throughout the plastic 'supply chain'). To demonstrate that the guidelines are being respected, these companies must report and be audited on how successfully they are implementing these guidelines.

This 'supply chain approach' would require regular assessments to check that pellet loss prevention measures are implemented properly at all sites; that all staff are trained to exceptionally high standards to prevent and mitigate pellet loss; and that companies are working together across the supply chain to communicate and demonstrate best practices with regard to the handling of pellets. Only then will people and companies be able to buy plastic products with the confidence that their plastic supply chain is pellet loss free.

To achieve this goal, any voluntary or regulatory commitments to eliminate pellet loss from the supply chain, must:

1. Apply to all companies handling plastic pellets regardless of company size or location, including but not limited to raw material providers (e.g. polymer producers), suppliers (e.g. haulage and distribution companies), converters (e.g. plastic manufacturers), buyers (e.g. retailers and brand owners) and the recycling industry alike;
2. Stipulate that all sites, facilities and operations handling pellets are regularly audited by an accredited third party on implementation of pellet management best practices based on the Operation Clean Sweep (OCS) toolkit;
3. Require all sites, facilities and operations handling pellets to regularly and transparently report on implementation of pellet management best practices based on the OCS toolkit;
4. Take into account the international nature of the pellet loss problem to be able to form part of a coordinated solution that adequately captures all stages of the plastic supply chain and works effectively on a local, national, regional and international scale;
5. Include provisions to facilitate the sharing of information on origin, quantities and types of pellets at point of sale or transfer of all pellet batches to ensure maintained record keeping and communication between all actors in any given supply chain.

**2. Whole supply chain certification schemes**

According to Hann et al. (2018), supply chain accreditation (which is the same measure as certifications schemes) is likely to have the largest reduction impact (600,000 tonnes cumulative reduction to surface waters between 2017 and 2035).

This consists of tackling the entire supply chain by requiring those placing plastics on the market to ensure that their entire plastics supply chain has implemented best practice measures to prevent pellets loss. Hann et al. proposed enforcing this measure by using certification organisations with independent audits, repeated annually.

**3. Monitoring programmes**

All potential measures should be combined with efficient monitoring programmes. Indicators should be monitored or developed:

- to assess the evolution of the quantities of plastic pellets in the coastal and marine environment. Contracting-parties can monitor these quantities through the existing indicators in the OSPAR area, such as plastics in the stomachs of northern fulmars or microplastics found in sediments (indicator under development).
- to assess the effectiveness of the best practice implementation from industries. For example, the number of companies (including producers, converters and transporters) that sign the OCS pledge or the number of industrial sites where OCS is implemented, could be relevant indicators.

Another useful indicator that could be strengthened may be the amount of microplastics found on beaches. However, if this monitoring proves to be too expensive to be done regularly, targeted monitoring actions could be launched, to accurately quantify proportion of pellets found on beaches amongst other microplastics.

**4. Auditing schemes**

Control methods will need to be implemented to ensure the efficiency of the measures taken. To serve these goals, each industrial site that produces, handles, or converts pellets would need to be regularly audited. These inspections should be conducted by independent, accredited auditors, which could be composed of representatives of plastic federations, independent experts (as in the Catch Plastics programme) and/or public authorities.

Audits should be scheduled annually, and compliance must be demonstrated. Non-compliance must be addressed and rectified within 28 days. Notice of audits should be limited to 7 days. Random spot checks should also be carried out to ensure that best practice is being upheld. No prior notice should be given for spot checks.

Within the framework of voluntary agreements, a certification system could be implemented to create a level playing field across the industry as a whole and to ensure a 'standard amongst standards' exists. If a more legally binding framework is developed, warnings, fines and other penalties could be imposed on companies that are not in compliance with prevention, containment and clean-up requirements.

**5. Training and raising awareness**

To effectively alter behaviour and train employees in the plastic pellets industry, it would be necessary to engage all companies that are actively involved in the handling of pellets in the development and dissemination of best practice guidelines and tools, such as outlined in the OCS toolkit.

Raising awareness among all companies that are directly or indirectly involved in plastic pellet production, handling and transport about the risks that spilt pellets pose in terms of environmental impact and hazards in the workplace would reduce the risk of pellet loss and would enable better management in the case of losses occurring. Professionals who could benefit from such training include state services, field staff, producers, transporters, recyclers, and port staff.

Support from public authorities for the OCS programme may also be an effective method to raise awareness around this matter.

Finally, labelling on containers may raise awareness of the potential for accidental losses of these products and enable better management in case of loss.

**6. Loss prevention, containment and clean-up procedures**

- **Containers' solidity (boxes, big bags, plastic bags)**

After production, pellets are packaged for storage and transportation to plastic converters or other customers in a number of different ways (refer to **Figure 3**).

The solidity of containers used to store and transport plastic pellets is constantly improved by the plastics industry in order to search new packaging solutions.  At present the use of cardboard and thin plastic films for storage and transportation is standard practice. Plastic bags are impact-tested as standard but are not assessed for tear-resistance. Torn sacking is known to be a source of pellet loss during operations, for example, when sacks are being lifted by folk-lift trucks. Increasing tear resistance of plastic and cardboard packing as standard may reduce potential for pellet loss.

Alternatively, the use of flexible plastic and cardboard packaging could be restricted and the following effective alternatives could be promoted:

- returnable and recyclable rigid polyethylene (use of high density polyethylene, HPDE) barrels with a single opening sealed by metallic hoops

- intermediate bulk container (IBC) also called IBC tote or bulk tank

However, the 25 kg bags have several advantages for industry: indeed, they are used for their flexibility, they allow more storage capacity (which reduce CO2 emission), they prevent contamination of pellets thanks to hermetic atmosphere because some rigid containers can cause dust contamination to the product, etc. Moreover, replacing the 25 kg bags with rigid containers would have a huge impact on the industry for benefits. Presently bags are used throughout the value chain, and replacing them would mean machinery and processes would have to be replaced at many levels e.g. producers, carriers, logistic companies, transformers, etc.

- **Confinement and clean-up structures at industrial sites**

These are outlined in the good practices proposed by OCS. Overall, a need is identified to produce and publish site-specific procedures for prevention, containment and clean-up.

Implementing surface water drainage filters in all facilities and catch-traps for pellet spills at all potential leakage points could be an effective solution, provided that the screening mesh is smaller than the smallest pellet or flake handled at each facility. This system would need to be regularly maintained and monitored to avoid risks of clogging.

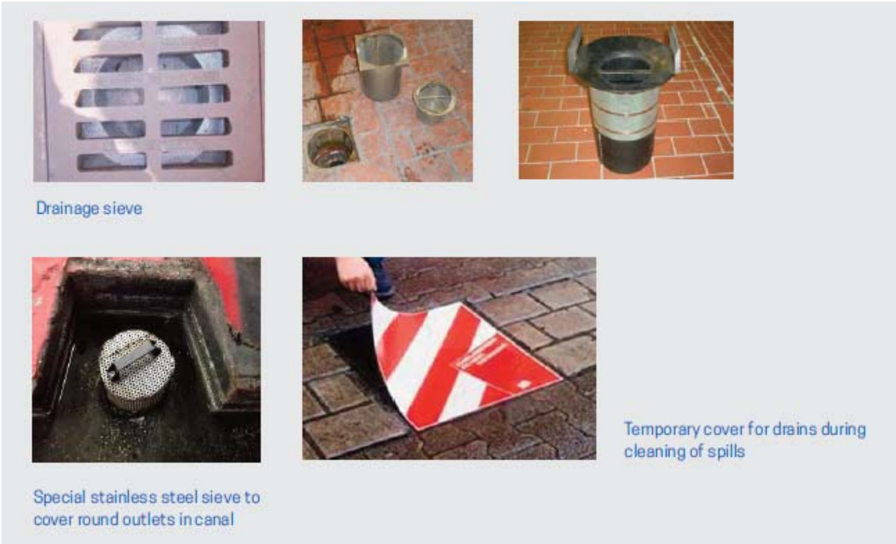


*Figure 20: Examples of pellets containment and filtration systems employed by OCS signatories*

*Source : PlasticsEurope*

Facility-wide containment systems could be set up in each production, handling or converting site, such as those required for fuel stations. For this to work it would be essential that industrial site were designed to allow run-off to end up in storm drains, protected by screens.

Particular attention would also need to be given to loading and unloading operations with hopper cars, hopper trucks or bulk trucks, to ensure proper handling and adequate cleaning.

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