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FOLLOW-UP WORK EMANATING FROM THE ACTION PLAN TO ADDRESS MARINE PLASTIC LITTER FROM SHIPS

Guidelines on clean-up of plastic pellets from ship-source spills

Submitted by Norway, South Africa, ITOPF and P & I Clubs

SUMMARY

Executive summary:	This document contains examples guidelines on the clean-up of plastic pellets from ship-source spills.
Strategic direction, if applicable:	4
Output:	4.3
Action to be taken:	Paragraph 3
Related documents:	MEPC 77/8/3; PPR 9/15/1, PPR 9/15/2, PPR 9/INF.20 and PPR 10/13/3

Introduction

1 Having noted the information contained in document PPR 9/INF.20 (Norway), as well as widespread support for guidelines on the clean-up of plastic pellets from ship-source spills, PPR 9 invited interested Member States and international organizations to submit documents with draft guidelines on this matter to a future session of the Sub-Committee, using the draft outline set out in the annex to document PPR 9/15/2 (Norway) as a starting point.

2 This information document invites the Sub-Committee's attention to the annexed guidelines, which were developed using the draft outline set out in the annex to document PPR 9/15/2 (Norway) and draws upon the collective knowledge gained following several recent pollution incidents involving plastic pellets.

Action requested of the Sub-Committee

3 The Sub-Committee is invited to note the information provided in this document and in the guidelines set out in the annex.

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Guidelines on the clean-up of plastic pellets from ship-source spills

This document has been written and collated by several organisations following a proposal submitted by the Norwegian Coastal Authority (NCA) to the ninth session of the International Maritime Organisation's Sub-Committee on Pollution Prevention and Response (PPR 9) in 2022.

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Contents

List of Acronyms

ALARP: As Low As Reasonably Practical
ATR-FTIR: Attenuated total reflectance – Fourier transform infrared
ATV: All-Terrain vehicle
BACI : Before – After – Control – Impact
BPA: Bisphenol A
CCI: Clean Coast Index
CEFAS: Centre for Environment, Fisheries and Aquaculture sciences (UK)
DDT: Dichlorodiphenyltrichloroethane
DFFE: National Department of Forestry, Fisheries, and the Environment (South Africa)
ESG: Environmental Sustainability Goals
EEZ: Exclusive Economic Zone
FTIR: Fourier-transform infrared spectroscopy
GHG: Greenhouse Gas
GIS: Geographical Information System
GIT: Gastrointestinal tracts
HDPE: High density polyethylene
HNS: Hazardous Noxious Substances
IGP&I: International Group of P & I Clubs
IR: Infrared
IMDG International Maritime Dangerous Goods
IMO: International Maritime Organisation
ISO: International Organisation for Standardisation
ISPRA: Istituto Superiore per la Protezione e la Ricerca Ambientale
LCP: Local Contingency Plan
LDPE: Low density polyethylene
LLMC: Limitation of liability for Maritime Claims
LPLC: Lowest Practicable Level of Contamination
MARPOL: International Convention for the Prevention of Pollution from Ships
MSC: Mediterranean Shipping Company
MV: Motor Vessel
NCA: Norwegian Coastal Authority
NCP: National Contingency Plan
NEBA: Net Environmental Benefit Analysis
NGO: Non-Government Organisation
NR: Nile Red
PAH: Polycyclic aromatic hydrocarbon
PBDE: Polybrominated diphenyl ethers
PCB: Polychlorinated biphenyl
PE: Polyethylene
PET: Polyethylene terephthalate
PFAS: Per- or poly-fluorinated alkyl substances
POP: Persistent organic pollutant
PP: Polypropylene
PPE: Personnel protective equipment
PPI: Plastic Pollution Index
PPR: Pollution Prevention and Response
PS: Polystyrene
PVC: Polyvinylchloride
Pyr GC-MS: Pyrolysis Gas Chromatography Mass Spectrometry

ROV: Remotely operated vehicle
SCAT: Shoreline Clean-up assessment Technique
SIMA: Spill Impact Mitigation Assessment
SOLAS: The International Convention for the Safety of Life at Sea
TGA: Thermogravimetry
UV: Ultraviolet
WRC: Wreck Convention/The Nairobi International Convention on the Removal of Wrecks

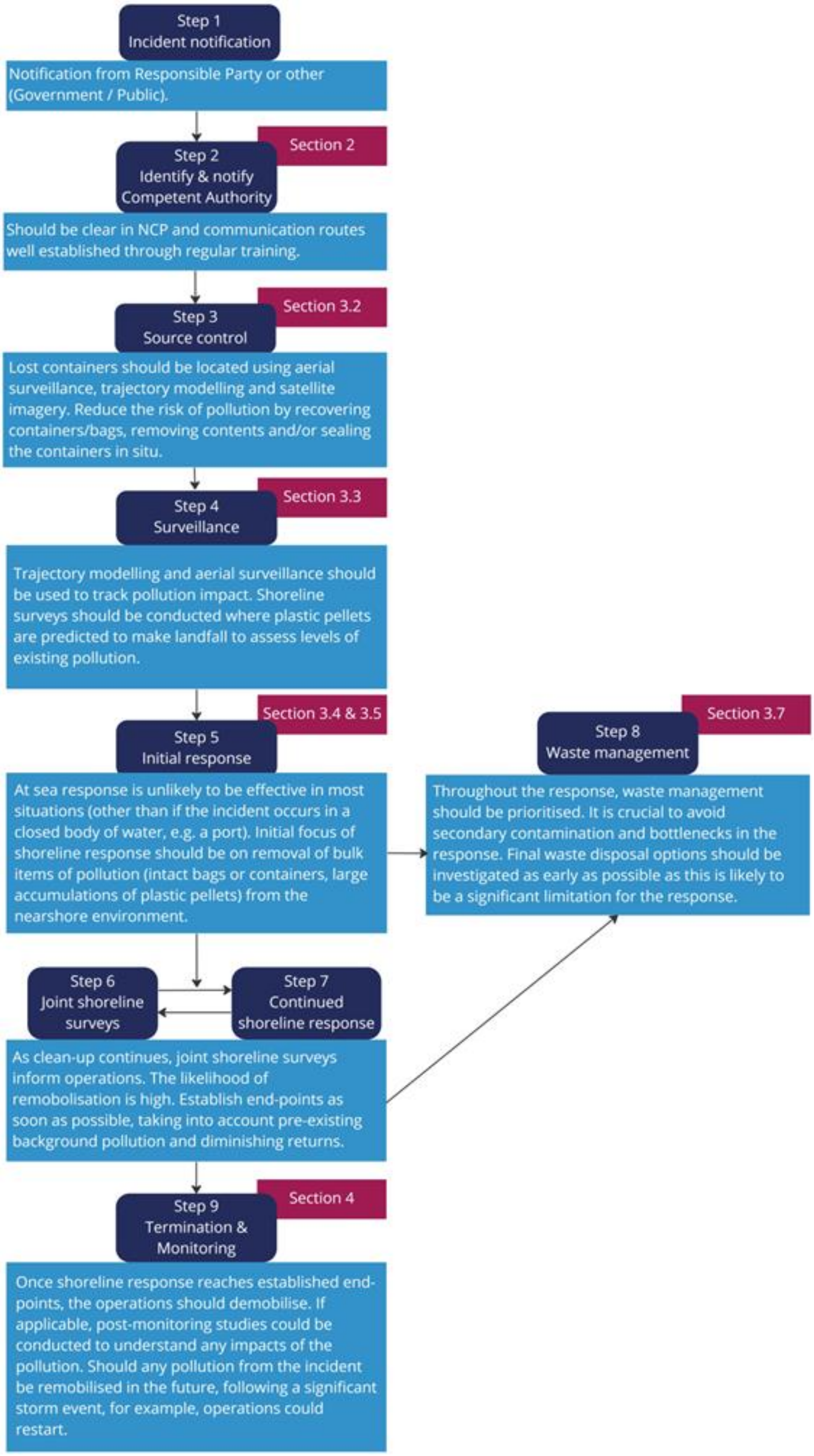

Figure 1: Flowchart to illustrate typical steps to take following a ship-source plastic pellet spill, with reference to sections of this document for further information.

1. Introduction

1.1. Objective

This is a reference document providing practical guidance when responding to ship-source spills of plastic pellets. These guidelines highlight how the response to spills of plastic pellets might differ from more established oil spill response. This document provides broad guidance on the development of large-scale strategies relevant to National Contingency Plans (NCPs), and also practical guidance relevant to developing smaller-scale site specific response plans (e.g. supplementing Local Contingency Plans (LCPs)), enabling readers to produce addendums to existing response plans.

Plastic pellet response is still in its infancy, with many techniques and strategies in development. The guidance provided here, therefore, is based on recent case experience and focusses mainly on spills of plastic pellets. Although this guideline makes reference to possible interactions with other substances (e.g. hazardous and noxious substances (HNS)), it does not comment on possible response techniques for plastic pellets mixed with oil. Guidance for responding to oil mixed with plastic debris should be taken from alternative guidelines on oil spill response. These guidelines should be considered to be a live document that will be updated as research develops and as the industry gains more experience.

1.2. Introduction to plastic pellets

Plastic pellets, otherwise known as nurdles or pre-production plastic resin pellets, are the building blocks of all plastic products. Each pellet is typically less than 5 mm in size (and is therefore classified as a microplastic) and can weigh approximately 0.02 - 0.025 g (Figure 2). Plastic pellets are considered primary microplastics because they are designed for commercial use, unlike secondary microplastics or nanoplastics (< 0.1 µm in diameter) which result from the breakdown of larger plastic items (meso & macroplastics).

Figure 2: White plastic pellets. Source: ITOPF

Plastic pellets are formed by the cracking, polymerisation and then pelletisation of petrochemical distillation products. During production, a range of chemicals can be added to alter the physical properties of the pellets. These pellets are then transported to manufacturers worldwide (**Error! Reference source not found.**) and are used to produce a wide range of e veryday plastic products via plastic extrusion and/or moulding.

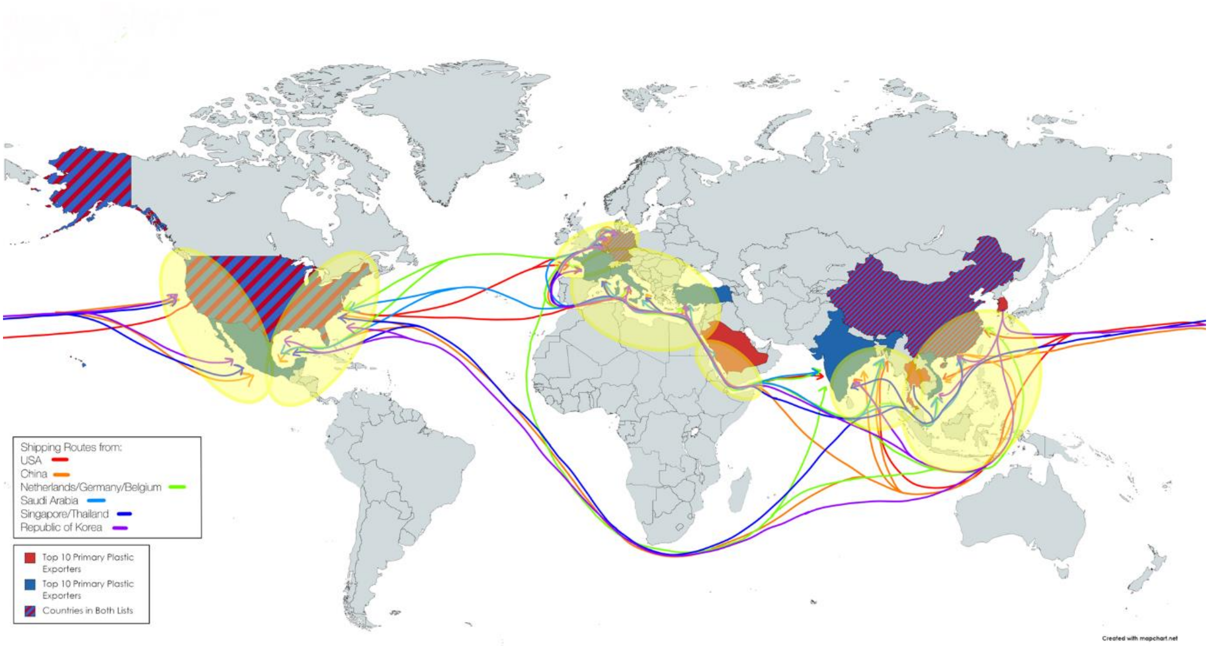

Figure 3: Shipping routes to the top 10 importers of plastic pellets globally with the area of highest plastic pellet transport traffic highlighted. Figure taken from Kerrison (2022)[1], University of Southampton with permission.

As of 2022, up to 368 million metric tonnes of plastic is produced worldwide each year[2]. Assuming that all of this plastic begins life as plastic pellets, and each pellet weighs approximately 0.025 g, this equates to up to ~15 quadrillion (15 x 10^{15}) pellets produced every year. For context, one small single-use plastic water bottle is formed from approximately 600 pellets[3].

1.3. Plastic pellets and marine pollution

Plastic pellets are transported around the globe from producers to manufacturers by road, rail, air or sea. At sea, plastic pellets are typically transported in shipping containers, either in packaged form or in bulk within the containers. Examples of these modes of carriage are shown in Figure 4.

It is important to note that on a ship's cargo manifest, the cargo is not always declared as "plastic pellets", but instead can have a number of labels including, amongst others, the specific polymer type (e.g. high density polyethylene (HDPE)), "pre-production pellets", "plastic resin" or, as seen during the X-PRESS PEARL incident[4,5] in Sri Lanka, 2021, "epoxy resin, plastic".

Pellets can be lost to the environment at many stages of the supply chain, particularly during handling, transport, and disposal. This document focuses on the loss of plastic pellets to the marine environment during shipping incidents, with emphasis on losses from container ships.

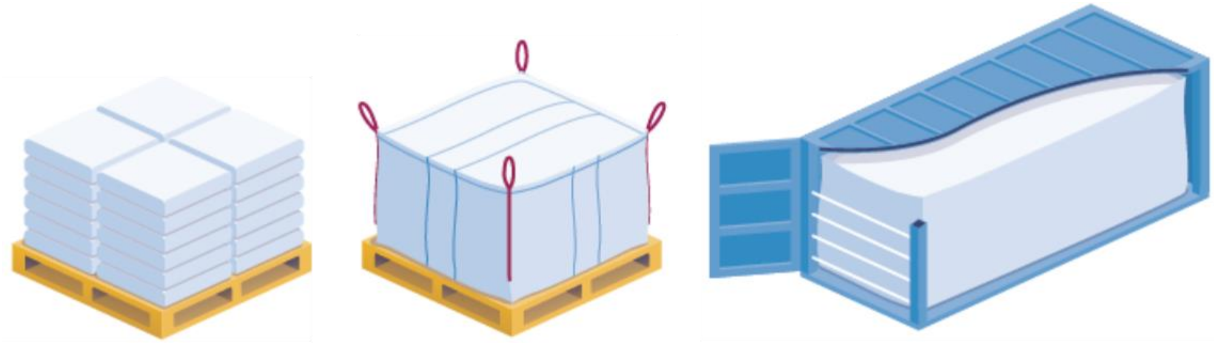

Figure 4: Types of plastic pellet packaging. Source: ITOPF

On average, between 2008 and 2021, an estimated 1,629 containers were lost at sea annually[6]. However, as of 2022, there is no mandatory container loss reporting system and therefore the actual number of containers lost is expected to be significantly higher - mandatory reporting of container losses is expected to be adopted in 2023 and enter into force in 2026[7]. Additionally, individual shipping incidents may lead to catastrophic container losses that far exceed the annual average by an order of magnitude. While there is currently no data available on the proportion of these lost containers that contained plastic pellets, past container shipping incidents demonstrate the risk of significant plastic pellet contamination following losses of containers (e.g. MV RENA, New Zealand 2011; TRANS CARRIER, Norway 2020; MSC SUSANNA, South Africa 2017; MV X-PRESS PEARL, Sri Lanka 2021). Plastic pellets have a relatively low density, so containers carrying plastic pellets are often stowed above deck and are, therefore, at a higher risk of loss during inclement weather conditions and shipping incidents.

Although data are sparse, a recent study estimated up to 167,431 tonnes of plastic pellets are lost to the environment each year from all stages of the supply chain in Europe alone[8]. However, obtaining baseline data on any pre-existing plastic pollution, prior to an incident occurring, can be difficult, and this has implications on the response (see Section 3.5). Unlike oil, which typically degrades when exposed to the environment over long time periods, plastic pellets are inherently inert so may remain in the environment for many years following release, and practical steps must be taken to remove them.

1.4. Properties of plastic pellets

Plastic pellets exist in various polymer types. Some of the most commonly manufactured and transported polymers consist of polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). While plastic pellets can vary in colour, size and shape, they are manufactured to relatively consistent proportions. Plastic pellets are typically between 2 – 5 mm in diameter, made of rigid plastic and are lentil, disk-shaped or cylindrical. Plastic pellets are manufactured as either clear or opaque in a variety of colours.

During production, chemicals are commonly incorporated into virgin plastic pellets. These chemicals, or ‘additives’, are included to alter the properties of the final product, such as the colour or flammability, and include phthalates (also known as ‘plasticisers’), Bisphenol A (BPA), flame retardants and organotins. As well as these intentional additives, some chemicals can be introduced to the plastic pellets as by-products of the manufacturing process. One such example is per- or poly-fluorinated alkyl substances (PFAS), which are an environmental concern as they do not degrade and have a tendency to accumulate inside organisms. Therefore, plastic pellets fresh from the production process contain a cocktail of different chemicals, some known and some unknown, before they enter the environment.

The density of plastic pellets can vary between polymer types. Polymers that are likely to float in freshwater (freshwater density at 4°C is 1.00 g/cm^3) and seawater (seawater density at 4°C is 1.025 g/cm^3) include PS (including PS in foamed form), high- and low- density polyethylene (HDPE and LDPE), and PP. Conversely, common polymers that are likely to sink include PVC and PET.

Overall, the specific density of plastics pellets varies considerably within the range of 0.8 – 2.3 g/cm^3 (see Table 1). Please note, however, these values do not take into account the effect of additives that might be incorporated into the production process and refer only to the virgin resin[9].

Table 1: Different common polymer types, their specific densities and example usages (modified from Hidalgo *et al.*, 2012[9].

Polymer type and acronyms	Polymer density (g/cm^3)	Usages
High- and low-density polyethylene (HDPE and LDPE)	0.917 – 0.965	Cleaners, cosmetic, air blast cleaning (scrubbers), packaging
Polypropylene (PP)	0.917 – 0.965	Carpets, ropes, scrubbers
Polystyrene (PS)	1.04 – 1.1	Scrubbers, plastic cutlery and dinnerware
Polyester (PES)	1.24 – 2.3	Packaging and textile applications
Polyvinylchloride (PVC)	1.16 – 1.58	Construction of pipes, doors, windows, non-food packaging, cards, electrical cable insulation
Polyethylene terephthalate (PET)	1.37 – 1.45	Beverage, food and other liquid containers

1.5. Fate and behaviour

The properties of plastic pellets, such as their density, is important to understand as it impacts how the pellets behaves once released into the environment. In general terms, however, plastic pellets mostly float in seawater. Once released into the marine environment, the characteristics of plastic pellets mean that they are easily influenced by meteorological and oceanographic (hereby referred to as metocean) conditions. Once released, plastic pellets can rapidly disperse over large distances. In one case, a relatively limited number of plastic pellets from one incident spread over 2,000 km along the South African coastline[10].

Figure 5 illustrates some of the processes that influence plastic pellets once released into the marine environment from a typical ship-source incident. The release of plastic pellets from a container can take place instantaneously or continuously. These are described as:

- **Instantaneous** – a rapid release of plastic pellets and intact packaging (e.g. 25 kg bags) from a container during a stack collapse on deck or following contact with marine environment;

- **Continuous –** a slow release of plastic pellets and intact packaging following a loss of a container. This slow continuous release will typically take place after the container sinks to the seabed and slowly deteriorates.

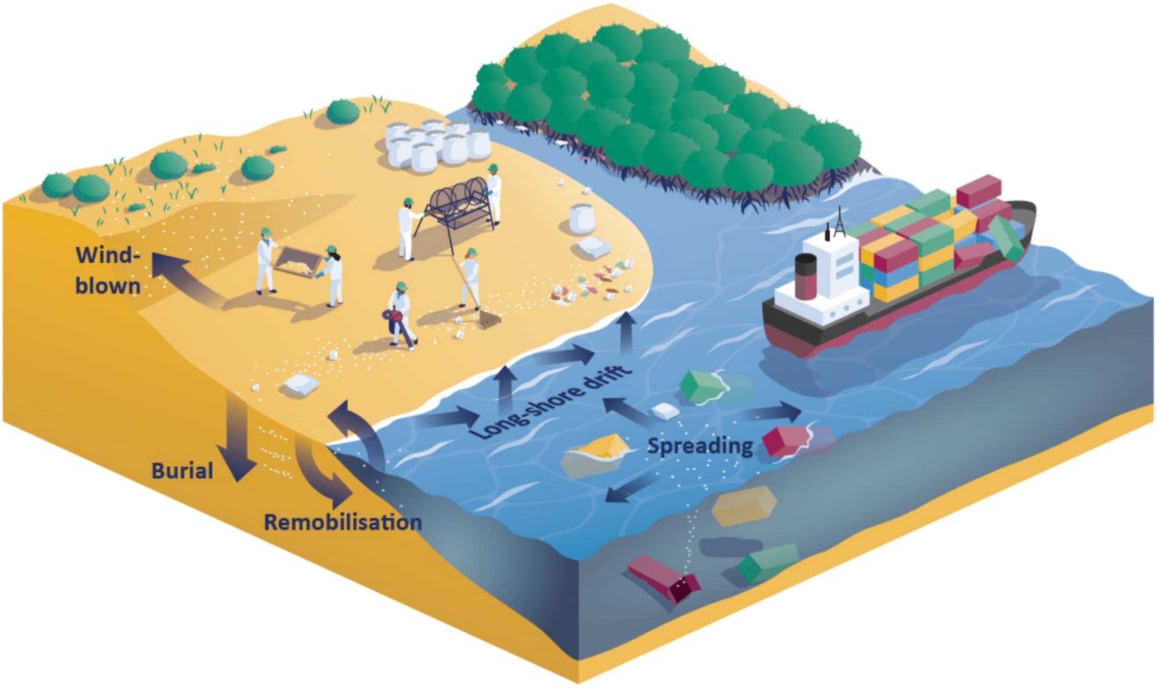

Figure 5: Behaviour of plastic pellets once lost to the marine environment. Source: ITOPF

Following a stack collapse, a container may be damaged before or after entry into the marine environment. Conversely, lost containers may remain intact and drift at-sea before ultimately sinking to the seabed. The duration a container will drift depends on factors such as, amongst others, sea-state, cargo density and volume, and container condition. Once at sea, a container may remain intact or break up over time. Consequently, plastic pellets may be released in loose or packaged form.

Once released into the marine environment, plastic pellets and intact bags can spread on or offshore, depending on the prevailing metocean conditions. The structural integrity of intact packing will eventually deteriorate, releasing its contents into the marine environment. This may happen at-sea or on the shoreline (Figure 6).

Depending on the incident location, time of release and prevailing metocean conditions, the time it takes for plastic pellets and packaging to make landfall can vary greatly (e.g. hours – weeks). Plastic pellet strandings have commonly been observed in areas of natural deposition and accumulation. Following release, plastic pellets are typically found in varying concentrations on the highwater mark or as multiple bands on sandy shorelines (Figure 7). In addition, however, plastic pellets have also been seen in other areas of natural deposition and accumulation, such as mangrove systems, as well as being trapped in artificial structures such as rip-rap.

Figure 6: Intact plastic pellet packaging observed on beaches following a stack collapse. Source ITOPF

Figure 7: Typical multi banded stranding pattern observed following a significant release of plastic pellets. Source: ITOPF.

Once stranded, plastic pellets, and intact and empty bags, may be remobilised through wind, tide and wave action. Once remobilised, plastic pellets may be transported along the shoreline through processes such as longshore drift. Plastic pellets may also be transported by winds to the back shore, into dunes and other habitat.

Under certain conditions, plastic pellets and their packaging can become buried within coastal sediments. Overtime, buried pellets may become uncovered as beach profiles change, resulting in plastic pellets to remobilise and be transported to other locations along the shore. These movements can complicate any response, such as depositing plastic pellets on a previously 'cleaned' beach. Seasonality can therefore play an important role in determining the fate of plastic pellets in the environment. Under storm surge conditions or seasonal typhoons, buried or stranded plastic pellets can be uncovered and remobilised.

Once released into the environment, plastic pellets undergo weathering processes (similar to any macroplastic litter) which change their shape and colour, and ultimately fragment the plastic into smaller pieces over time. Plastic pellets can degrade as a result of the action of ultraviolet (UV) and oxygen exposure, as well as abrasion processes. However, these processes are very slow, in the order of decades and centuries[11].

1.6. Environmental impacts of plastic pellets

The environmental impacts caused by plastic pellets are similar to those caused by microplastics derived from the fragmentation of plastic waste. The impact of microplastics on marine biota has been the subject of a great number of international scientific studies in recent decades[12], and is an on-going focus of both academic and industry research.

Worm *et al.*[13] argue that plastic waste in the marine environment is considered a form of Persistent Organic Pollutant (POP). POPs are defined under the *Stockholm Convention on Persistent Organic Pollutants* as potentially harmful organic compounds that resist chemical, biological, and photolytic degradation when released into the environment[14]. The known environmental impacts can be separated into physical and toxicological effects. Physical effects include smothering, ingestion and, potentially, starvation. Toxicological effects typically include assimilation of the chemicals and substances associated with plastic pellets. Pellets can eventually fragment into smaller microplastics or nanoplastics, which can also have potentially further physical and toxicological impacts.

Microplastic ingestion has been recorded in a wide range of marine organisms at all trophic levels, varying from zooplankton[15] to marine mammals[16]. Ingestion can be direct (primary ingestion) or indirect (secondary ingestion through contaminated food). Direct ingestion can be deliberate (plastic mistaken for food, such as fish eggs) or accidental (passively ingested through filter feeding, for example). Once ingested, the length of time the plastic pellets remain inside an organism varies, based on a variety of factors including the ability of organisms to regurgitate, excrete or otherwise process the ingested items. The length of time the pellets spend inside an organism can influence the rate of potential uptake of chemicals from the pellets into the tissues of the organism. This could also lead to increased risk of chronic impact through prolonged exposure.

In addition to the physical impacts of plastic pellets in the environment, their toxicological impacts are a focus of further research. The chemicals imbibed onto virgin plastic pellets from the manufacturing process have been shown to be toxic to some organisms[17]. In addition to these integrated chemicals, once plastic pellets enter the marine environment, they have the capacity to attract and concentrate further chemicals and microorganisms, a process termed as 'plastic rafting'. During shipping incidents where plastic pellets are released alongside other cargoes, such as fuel oil, this effect may be exacerbated. Examples of contaminants that have been found on plastic pellets in the marine environment include POPs such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs)[18], dichlorodiphenyltrichloroethane (DDT), polybrominated diphenyl ethers (PBDEs),[19–21] and bacteria, such as *Escherichia coli*[22,23]. This phenomenon happens because POPs have a greater affinity for the hydrophobic surface of plastic compared to seawater. Plastic pellets can become relatively heavily contaminated due to their large surface area to volume ratio. For example, levels of PCBs adsorbed on the surface of plastic pellets were found to be a million times higher than background seawater levels on some shorelines in Japan[24]. Through transport of plastic pellets via ocean currents, leaching of these adsorbed contaminants can act as a potential hazard to the wider environment. Moreover, microplastics can potentially releasing contaminants upon ingestion, or when exposed to heat, light, ultraviolet radiation, or other external factors.

As a consequence of their potential physical and toxicological impacts, a release of plastic pellets is likely to necessitate a clean-up response.

2. Plastic pellet contingency planning considerations

As with all ship-source pollution events, it is impossible to know when or where the next plastic pellet maritime release will occur. The likelihood of a release of plastic pellets may appear low because the proportion of the global fleet which carry plastic pellets at any one time is small. However, given the described fate and behaviour of plastic pellets once spilled, and the far-reaching consequences, thorough planning and preparedness for such an eventuality is strongly advised.

When undertaking a risk assessment, relevant risks should be considered:

- Are plastic pellet manufacturing and handling industries located within your jurisdiction?
- What is the procedure and are there any safety measures for the transport and handling of plastic pellets during loading and unloading operations in ports?
- What is the frequency of transportation of plastic pellets within your jurisdiction, e.g. are there high levels of relevant marine traffic in your Exclusive Economic Zone (EEZ), including vessels in transit?

An effective response to accidental releases of plastic pellets requires the relevant organisations and individuals to be prepared, much the same as within oil spill response. Member States and other interested stakeholders should already maintain a NCP for spills of oil and HNS. While spills of plastic pellets fall outside the scope of a traditional NCP, the initial response actions and decision-making processes are likely to be the same. Therefore, the addition of an addendum to a State’s NCP focussing on spills of plastic pellets is recommended, taking into consideration the information in this guidance document, for example, the specific equipment and resources required for recovering plastic pellets.

Contingency plans provide a pre-determined and assessed structure for mounting a response to an incident. This document aims to identify key points that should be considered for a plastic pellet contingency plan. However, each plan should be adapted by the relevant Member State to reflect the stakeholder’s culture and existing response structure, and should be updated regularly based on lesson learned during exercises or incidents.

2.1. Response organisation

Member States should be prepared to respond to releases of plastic pellets in order to mitigate any damage. Given the crossover in initial response actions and processes between plastic pellet releases and other marine pollution incident risks, Member States are recommended to build on existing plans and systems for emergency response and, given the behaviour of plastic pellets in the sea, engage with neighbouring States where appropriate.

One of the most important steps in contingency planning is the designation of a Competent National Authority or Lead Agency in establishing a National Response System. Experiences from plastic pellet incidents to date have shown that the response can contain many elements of an oil or HNS spill response operation and, as such, the Competent Authority may be the same for plastic pellet, oil or HNS pollution events. This organisation structure can translate from national to local levels, i.e. the competent local authority noted in a LCP can remain the same for local plastic pellet spills.

A rapid, appropriately sized response can greatly reduce the amount of released plastic pellets and mitigate the potentially long-term impacts of the spill on the environment.

2.2. Notification procedure

This document focusses on the release of plastic pellets from ship sources. As such, crucial initial information relating to the incident scenario (as detailed in Section 3.1) should be gathered to aid a response, and shared with the appropriate stakeholders as soon as possible.

Establishing a clear notification system and clear reporting requirements enables timely responses to ship-source spills. Establishing a notification system for oil and HNS incidents is a requirement under MARPOL Article 8(2)a[25]; a similar model should be employed for releases of plastic pellets. Critical elements to an effective reporting system include a national contact point for receiving notifications about the threat of spills/accidental releases of plastic pellets. In addition, it should also be clarified in a contingency plan how the Competent Authority should notify relevant agencies, government officials, local authorities and, if necessary, international parties.

In some situations, the source of the release might be unknown and the first notification may arise from the observation of plastic pellets at sea and/or following stranding on the shoreline. This might challenge the response planning, as in this instance there is unlikely to be any forewarning of plastic pellets stranding on the shoreline. In 2023, the IMO secretariat is expected to adopt amendments to SOLAS (safety of life a sea) Chapter 5 to require reporting of any container losses to the nearest Coastal state and the flag state[7]. This mandatory reporting requirement will increase the likelihood that stakeholders will be notified in advance of potential pollution on the shoreline.

2.3. Public communication

Communication within the response organisation should be identical to any oil spill response processes in place, and therefore should rely on established and well-known communication channels.

Communication from the response organisation to external parties is equally important. Ship-source plastic pellet releases have the potential to impact a wide area very quickly. Therefore, harnessing the public as a source of information for a response can have many benefits. The public can provide a large influx of information regarding the presence/absence of plastic pellets on publicly accessible shorelines very quickly. This information can be fed into a response to help with decision-making.

However, caution should be applied when utilising information gathered from the public. This is because background plastic pollution on shorelines can be relatively high, and the notification of a specific release may result in the recording of pre-existing plastic pellets that were already *in-situ* prior to the incident, once public awareness is raised. Furthermore, the public are typically untrained, and may not collect pertinent information in a consistent manner. In addition, information generated by the public can create a significant volume of data associated with a response, which needs to be collated, verified and prioritised by appropriate personnel in the response organisation. This information overload can generate an extra burden for the clean-up response and potentially distract from the response priorities.

One recommended solution, gained from experience, is to quickly establish a website related to the specific incident. Such a website could contain the following:

- General information on the incident;
- Health and safety information regarding the incident and the pollution;
- Information related to whether the Competent Authority is establishing a process for the public to record data;
- Reporting observations along the shoreline (what, where and when);
- Advice and recommendations regarding any clean-up along the shorelines (voluntary or paid work);
- Description on different manual recovery methods that could be employed by the public;
- Where to deliver collected material and how to report estimated quantity;
- An online reporting form in which the public can report observations, including the possibility to upload pictures from site;
- A general situation map with information on where plastic pellets have been observed and status of clean-up operations (if any) in different areas;
- Other relevant information related to the specific incident such as claims advice (see Section 5**Error! Reference source not found.**).

2.4. Sensitivity prioritisation

The plastic pellet addendum to a NCP could reference the existing sensitivity and prioritisation maps for oil and HNS spills. However, it should be noted that economic and ecological sensitivities will differ for a release of plastic pellets in comparison to an oil or HNS spill. Therefore, some specific considerations for the event of a plastic pellet spill should be described in the addendum. As with oil spill response, attention should be paid to the clean-up operations that might need to be undertaken in sensitive or vulnerable areas, such as protected areas, bird sanctuaries and national parks.

2.5. Pre-emptive mapping systems

Given the described fate and behaviour of plastic pellets in the environment (see Section 1.5), tools to help map stranded plastic pellets and monitor the progress of clean-up operations are recommended. These mapping tools should be established prior to an incident, so that relevant personnel and authorities are competent in their use.

Once plastic pellets have stranded, obtaining a general overview of affected areas is important. The availability of a flexible mapping system to display the location and relative abundance of plastic pellets and provide a 'live' source of reported information for the response organisation will be imperative. Mapping systems should be user-friendly, should include information about the quantity of pellets observed in each location (see Section 3.3.3 for quantification methods), and have the capability to upload photos for verification. Mobile data collection & survey tools (e.g. mobile phone apps) can be very useful to coordinate data collection in the likely occurrence that response activities are occurring in multiple locations simultaneously.

In addition, integrating the mapping tool online within the incident specific website as a source of information for the public, media, and other stakeholders, will give situational awareness and indicate progress of the response, as suggested in Section 2.3. The mapping tool could also provide statistics after the response for response evaluation or post-incident monitoring.

3. Plastic pellet response considerations

The following sections are intended to provide Member States with a checklist of aspects to consider when handling a spill of plastic pellets. These considerations are based on experience and lessons learnt during past incidents and supplemented by available literature on marine plastic pollution. The guidance provided below is based on the best available information at the time of writing and experience gained during past cases.

3.1. Incident notification and response actions

A Member State can be made aware of a potential plastic pellet spill via two mechanisms:

1. Notification by a vessel owner or operator of a loss of containers within a Member States' EEZ (up to 200 NM from the coast or equivalent area);
2. Discovery of concentrations of plastic pellets stranding on a Members States' shoreline by local authorities or members of the public.

In either case, those notified should make the responsible Competent Authority aware of the potential incident as early as possible.

If notified by local authorities or members of the public, it is best to collect as much information as possible to locate, date and time-stamp, and detail the observations made. Photos may be beneficial when observations are reported by untrained personnel as important information may be overlooked at the time of notification.

If notified by a vessel owner or operator of container losses within its EEZ, the Competent Authority should simultaneously begin collecting relevant information to guide any necessary response. Where possible, the following pieces of information should be collected:

- Contact details of the person reporting the incident;
- Name of vessel and owner;
- Date and time of incident;
- Position (e.g. latitude and longitude);
- Cause of the incident and the nature of the loss;
- Number of containers lost (if possible), and;
- Cargo manifest (if possible).

Using the collected information on the vessel and the incident, the Competent Authority should endeavour to understand the following:

- Number of containers lost which contain plastic pellets;
- The total weight (kilograms or metric tonnes) of plastic pellets lost;
- The type of packaging used to carry the plastic pellets (i.e. 25 kg packages or larger, in containers);
- The type of polymer (e.g. PP, PE, PVC) lost;
- If the plastic pellets have been subject to fire or another heat source, and;
- If the plastic pellets have interacted with other substances lost during the same incident (e.g. oil or HNS).

The collated information, similar to an oil spill response, should be used to inform trajectory modelling to understand the potential movement of lost containers and pellets. Further guidance on modelling of lost cargo can be found in Section 3.3.1

The initial action by the Competent Authority should be to notify the relevant district and / or municipal departments. Once notified, the competent departments should endeavour to promptly undertake rapid shoreline surveys to determine the extent and degree of contamination. As with spills of other substances (e.g. oil), rapid surveys may also include the pre-emptive assessment of baseline conditions (e.g. pre-existing plastic pollution) of locations at risk of contamination. Further guidance on assessing the level of contamination can be found in Section 3.3. If modelling indicates that lost cargo could affect neighbouring States, the Competent Authority should notify the relevant authorities so that the necessary actions and co-ordination can be taken.

3.2. Clean-up considerations

3.2.1. Mass balance

Experience from previous incidents has supported the accepted view that one hundred percent of the lost cargo will not be recovered – due to the various reasons previously mentioned. However, understanding the total potential quantity of released plastic pellets and the quantity recovered during clean-up activities is still important. Tracking the weight of recovered pellets by spill managers will allow progress to be monitored over time, while also contributing to the determination of suitable end-points (e.g. law of diminishing returns) (see Section 3.6). Therefore, it is important to uphold good record keeping and accurately monitor weights recovered by the clean-up teams.

During shoreline recovery, spill responders/managers should endeavour to collect the following information at suitable intervals from clean-up teams:

- Date;
- Location name;
- Location coordinates (latitude and longitude);
- Number of shoreline responders per team;
- Clean-up duration (hours) for a team on a given date;
- Weight (kg) of plastic pellets recovered (by type) (e.g. burnt or unburnt, if applicable);
- Weight (kg) of other plastic (i.e. pre-existing plastic) recovered, and;
- Weight (kg) of intact bags of plastic pellets recovered (where possible) and relevant.

The requirement to track weights of recovered plastic pellets is an example of the importance of selectivity and the use of appropriate response strategies. If plastic pellets are recovered while mixed with other materials, this can significantly skew important data. If *in-situ* removal of all other debris is not possible, recovery yields can be adjusted later to account for the inclusion of non-target material following inspection/survey of waste or following secondary sorting prior to disposal.

The importance of volunteer collections should not be overlooked (see Section 3.8). Spill managers should encourage volunteer collections to be physically submitted to a central repository so recovery yields and waste streams can be consolidated for monitoring and disposal purposes, respectively. Given the prevalence of volunteer shoreline clean-up activity observed in previous incidents, particularly following a catastrophic loss[1], government agencies are encouraged to publicly request all collections, or at least weights of recovered plastic pellets, are submitted and recorded.

[1] A catastrophic event can be defined as a high-volume, extended-duration loss of plastic pellets regardless of the cause (i.e. natural or man-made).

3.2.2. Source control

Once a notification of a container incident and/or release of plastic pellets has been received, the Competent Authority should prioritise identifying the location of the incident if this is still unknown.

For example, observations from past incidents have shown that, in some cases, a lost plastic pellet container can continuously release its cargo into the marine environment whilst resting on the seabed, thus providing an on-going source of potential contamination. Therefore, if feasible and appropriate, once the position(s) of the lost container(s) is/are identified, efforts should be made to determine if the sunken container(s) still contain(s) plastic pellet cargo. Possible methods to achieve this objective is through remotely operated vehicle (ROV) or dive surveys. In the event that sunken containers are fully or partially intact, where feasible and appropriate, efforts should be made to recover the lost containers, or if not feasible, the cargo therein, to prevent future releases of plastic pellets into the marine environment. By recovering these containers and/or the plastic pellet cargo, the Competent Authority and spill managers can ensure the source of continuous contamination has been controlled.

If recovery of sunken cargo is considered, the Competent Authority should ensure that suitable measures are employed by salvage teams to minimise the risk of subsequent releases of plastic pellets during recovery operations. During past cases, the transfer of 25 kg cargo bags into hessian sacks was carried out by salvors underwater to prevent the release of additional pellets into the water column while cargo was being lifted to the surface. During future incidents, suitable measures should be considered on a case-by-case basis.

3.2.3. Front-loading a response

Regardless of the quantity of cargo lost, spill managers should understand that recovering the bulk of the stranded plastic pellets as quickly as possible is essential to minimise the overall length and scale of the response. Mobilising a relatively high number of personnel at the beginning of a response, also known as ‘front-loading’ the response, can be crucial to ensure that plastic pellets are removed from the environment as quickly as possible. If stranded pellets are not collected quickly, remobilisation, wider dispersion and possible burial within sediment will occur, as described previously. Further dispersion can cause the geographical extent of contamination to grow, resulting in potentially more sensitive and remote locations becoming impacted – thereby causing additional clean-up challenges and pro-longing reaching the clean-up end point.

3.2.4. Identifying accumulation zones

The movement of spilt plastic pellets along the shoreline can be difficult to predict. Nevertheless, understanding the locations of collection points for other debris (natural or anthropogenic) can often assist in allocating resources appropriately and effectively – since dispersed plastic pellets may concentrate in such zones. Local knowledge, including coastal authorities, relevant stakeholders and the public, can assist Competent Authorities and spill managers in identifying potential accumulation zones or ‘hot-spots’ where targeted clean-up teams can be deployed on a regular or semi-regular basis. Sources of local knowledge on natural accumulations zones can also greatly aid this objective, and this should be considered when preparing a contingency plan.

3.2.5. Hazards to responders

Most plastic polymers have inherently low toxicity due to their insolubility in water and because they are biochemically inert. Consequently, plastic pellets are not classified as hazardous, nor as a marine pollutant in the International Maritime Dangerous Goods (IMDG) Code. Therefore, in its original state, plastic is not considered hazardous to touch by responders.

However, if the composition of the plastic is changed (e.g. during combustion through a fire on-board a casualty) (Figure 8), or the pellets are exposed to other hazardous substances, there is potential for the previously inert pellets to become hazardous to those responding to incidents. For example, when plastic is burnt, toxic substances such as dioxins and furans can be produced. Although these substances are mostly emitted as toxic emissions, some residues may remain present on the surface of the plastic, posing a potential risk to human health for those handling the recovered waste.

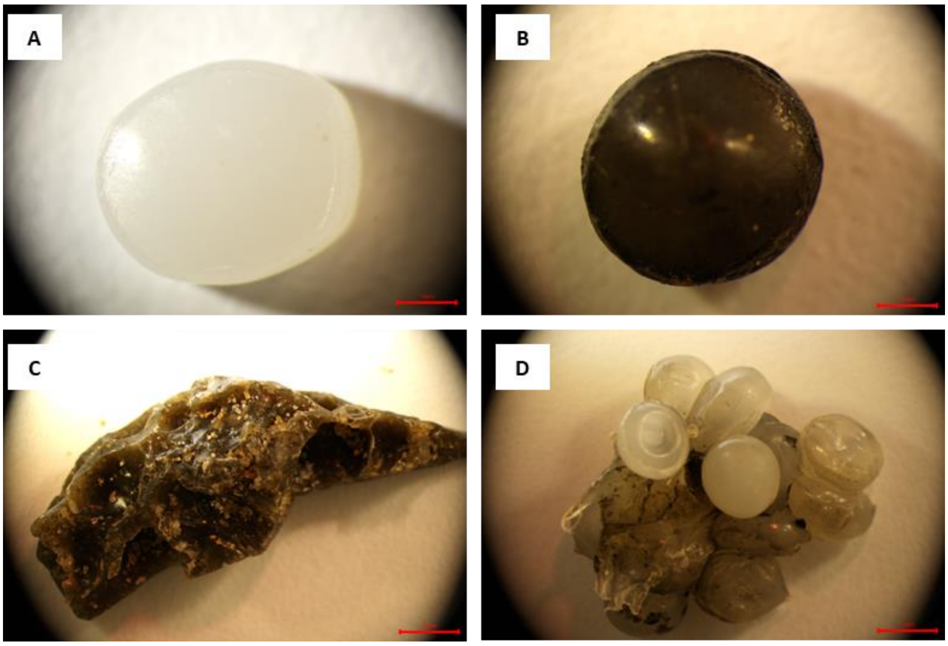

Figure 8: Morphological changes of plastic pellets following combustion during X-PRESS PEARL incident, Sri Lanka, 2021. A) original pellet; B) discoloured pellet; C) burnt plastic pellet fragment; D) fused pellets. Source: Cefas

If the composition of spilt plastic pellets is altered, and concerns over hazardousness exist, a precautionary approach should be initially followed. As soon as possible, efforts should be made by the Competent Authority or spill managers to arrange analysis of the stranded material to determine any changes in toxicity and consequent potential health risks to the responders. The results of analysis should be promptly used to inform the response. The final categorisation will ultimately determine the level of PPE required by shoreline responders, how the waste is collected and disposed of, the degree of shoreline cleaning and, finally, response end-points.

During the X-PRESS PEARL incident off the west coast of Sri Lanka in 2021, up to 442 containers of plastic pellets were exposed to high temperatures onboard) (Figure 8), before an unknown quantity were lost overboard and subsequently washed up on-shore. In addition, X-PRESS PEARL was also carrying 81 containers of dangerous goods at the time. Due to the fire and the potential interaction between plastic pellets and other harmful substances, the Government of Sri Lanka consequently categorised all stranded plastic as hazardous until determined otherwise. Similar precautions may be taken in future incidents involving spills of plastic pellets alongside oil and other HNS.

As previously described, once in the marine environment, plastic pellets also have the propensity to act as vectors for other persistent organic pollutants and microorganisms (e.g. bacteria). This should therefore be considered when determining suitable PPE (e.g. gloves). Maintaining good hand hygiene is also recommended during and after shoreline clean-up.

3.3. Spill assessment

3.3.1. Modelling

Trajectory modelling of plastic pellets, packaging and containers can be undertaken as soon as the incident location is known. Modelling will provide insight into the potential extent of contamination and risks to sensitive habitats. The outputs will allow spill managers to prioritise sites and facilitate effective deployment of assets during shoreline response.

Several different modelling approaches can be used to assess transport of marine plastics, with different software products available. Fundamentally, the dispersion will depend on the metocean conditions within the area, as well as the buoyancy of the plastic pellets, packaging and containers. Given the uncertainties around these aspects, trajectory modelling should not be expected to give precise results for individual pellet tracking; instead, the results should be used to guide the likelihood of material stranding and accumulating along the shoreline.

Although specific models do exist for predicting the movement of marine plastic debris, these models are not always accessible to spill responders or Competent Authorities. Many States and response organisations, however, have third-party services or software in place for modelling the drift of oil.

Recent cases have demonstrated that oil spill trajectory modelling can be applied to accidental release of plastic pellets from ships, producing comparable results. Where the source of the spill is unknown, drift models has been used to backtrack the taken trajectory to the possible location of the spill. However, it has been noted that while the models are reasonably accurate in open waters, albeit across relatively short distances, modelling becomes increasingly difficult close to shorelines due to complex coastal interactions and local tidal processes that modelling technology is unable to replicate effectively.

In addition to modelling the trajectory of loose plastic pellets, search and rescue drift models have also been employed to predict the trajectory of packaging (e.g. 25kg bags) and intact containers. Understanding the drift of these items can aid source control; it is important to locate sunken containers and recover packaged cargo to prevent it being spilt into marine environment.

3.3.2. Surveillance

Surveillance is a fundamental activity during any spill response. The aim is to provide decision-makers with an up-to-date picture of the rapidly evolving situation, describe the extent of contamination, and identify the most appropriate clean-up strategy.

i. <u>At-sea surveillance</u>

Immediately following an incident, surveillance at-sea may be required. As with oil spills, this can be carried out from the air (usually a helicopter, fixed-wing aircraft or, unmanned aerial vehicles) or, with more limited success, from a vessel. Given the small size of plastic pellets, their light colour/transparency, and variations in buoyancy, it is often very difficult to identify plastic pellets at sea: especially if they are dispersed in low concentrations. Following incidents involving container ships, it is more efficient to perform surveillance to locate the containers themselves or any packaging relating to carriage of pellets. This information can then be used to guide the use clean-up resources. In the future, methods may be developed to enable the use of satellite images to locate spills of plastic pellets, or technology may develop to better enable aerial surveillance of plastic pellets at sea.

ii. Shoreline assessments

Shoreline surveys should be considered at every stage of the response to determine the extent of contamination over time. Where possible, gathering pre-existing baseline data on the level of plastic contamination, before plastic pellets make landfall, can help establish clean-up strategies and define relevant end-points.

Following an incident, preliminary surveys are essential to document the initial extent of contamination caused by the ship-source release. Due to the propensity of plastic pellets to remobilise from the shoreline, surveys should be frequently repeated at every affected location to obtain up-to-date situational information and guide response decisions. High energy shorelines can lead to very changeable levels of both surface and subsurface contamination, and shoreline surveys to assess these contamination levels should be carried out more frequently than on a low energy shoreline, to reflect the potential higher rate of remobilisation and consequences for response operations. See Section 3.3.3 for additional operational guidance.

iii. Recording data

During surveys, information should be recorded in a standardised form, either on paper (e.g. a "Coastal Plastic Pellet Pollution Assessment Sheet" (see Appendix)) or through field survey applications on a mobile device (see Section 2.5). All information gathered during shoreline surveys should then be centralised in an accessible database/geographical information system (GIS)/map to facilitate good visualisation and communication. This resource can be distributed to, and accessed by, all relevant authorities and stakeholders.

An overview of the entire impacted coastline should be collated and updated readily following repeated surveys throughout the response period. One such example is shown below for the X-PRESS PRESS incident in 2021 (Figure 9**Error! Reference source not found.**). These maps allowed the Competent Authority to understand the level and extent of contamination, readily enabling rapid prioritisation of response resources, and demonstrated the change in contamination levels over time. As discussed above, however, plastic pellets can remobilise very quickly along the shoreline and, hence, clean-up operations should be conducted as swiftly as possible following shoreline surveys to maximise the usefulness of the data.

3.3.3. Methods for determining contamination level

At the start of an incident, criteria should be established to classify the level of contamination in each shoreline segment. All members of the survey team should be aligned on the parameters defining different contamination level in order to minimise confusion and inaccurate recording. As a consequence, standardised recording methods are vital. To expedite this process, methods could be included in principle as part of the contingency planning process.

Shoreline surveys based on the Shoreline Clean-up Assessment Technique (SCAT), are typically applied in cases of coastal oil pollution[26–28]. In employing SCAT, both surface and sub-surface contamination should be investigated. There are two spatial methods for assessing the level of contamination on the shoreline; these are:

- Spot Surveys – completed quickly upon accessing a given location to rapidly assess the level of contamination, and;
- Continuous or Extended Surveys – completed systematically across the entire accessible affected coastline at pre-defined intervals (e.g. every 50 m or when level of contamination changes).

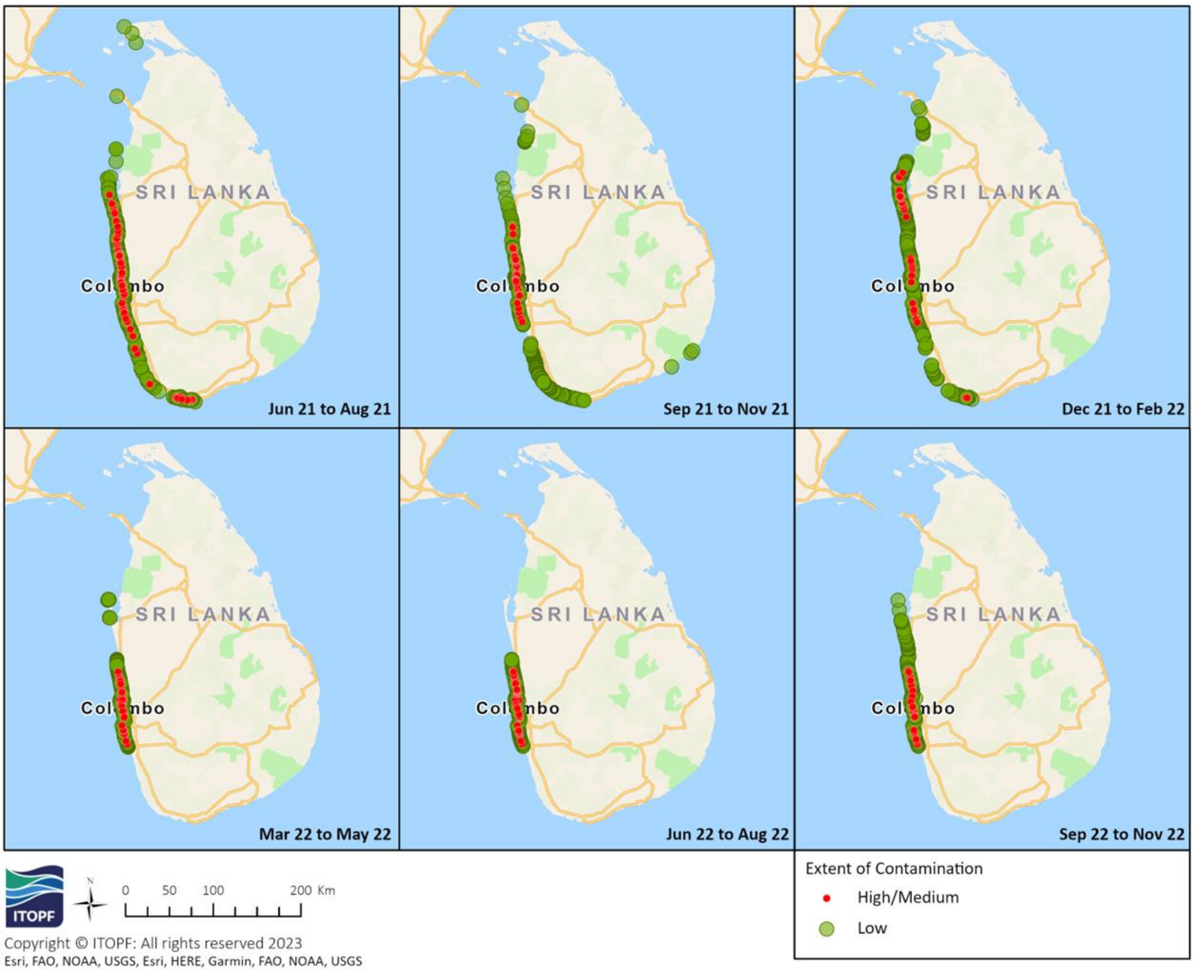

Figure 9: Map series showing collation of results from shoreline surveys completed during X-PRESS PEARL incident, Sri Lanka, 2021. Source: ITOPF

Spot surveys, on a spatially limited area, can be undertaken rapidly and, therefore, can be useful during the initial emergency phase of an operation to provide a snapshot of contamination levels across different sites. However, spot surveys can misinterpret the contamination level across a shoreline (e.g. the spot check can be undertaken in a pocket of uncharacteristically high or low contamination) leading to errors when prioritising shorelines and selecting appropriate clean-up methods. This bias should be considered by decision makers when mobilising resources. Therefore, spatially continuous shoreline surveys are recommended for use during the project phase of the operation (see Section 3.5.2).

Where buried plastic pellets are identified, systematic surveys to characterise the level and extent of buried plastic pellets is recommended. These surveys should therefore include transects of holes or trenches (Figure 10). There may be several strata of buried pollution, and each contamination layer should be measured (thickness of layer and depth from surface). Buried plastic pellets were occasionally observed down to 1.5 m depth in Sri Lanka following the X-PRESS PEARL incident, so care should be taken to perform thorough and sufficiently deep sub-surface surveys. Understanding the sediment and shoreline dynamics of an affected coastline will help when determining areas at risk of plastic pellet burial.

Figure 10: Digging trenches to investigate buried plastic pellets during X-PRESS PEARL incident, Sri Lanka, 2021**.** Source: ITOPF.

Below are three examples of generic methods for determining contamination level. Following an incident, these methods should be adapted to suit the situation. In many cases, more than one method of assessment will be used concurrently. Technical advice should be obtained when drafting the national and local contingency plans to ensure the best methods of quantification are selected for each specific region.

i. Visual assessment

Visual assessment is a basic tool for determining the level of contamination following a release of plastic pellets. However, the criteria which determine how a site is classified may vary between incidents. Criteria can be assigned relating to the thickness, spread, and propensity to remobilise (e.g. buried or surface pellets). Joint surveys with all stakeholders should be carried out early in the process, and example photos/guidance provided, to ensure that all parties are aligned on assessment of contamination levels (e.g.

Figure 11). These criteria may need to be reviewed as the project phase progresses (see Section 3.5.2).

ii. Timed count

Contamination can be assessed semi-quantitatively using a "timed count method". This method involves surveyors manually collecting plastic pellets for a pre-determined length of time, and then quantifying the final amount. Arbitrary limits are defined for low, medium and high concentrations and the sites are classified accordingly (Table 2).

This approach was originally designed by Tunnel *et al.*,[29] as a 10-minute assessment method where plastic pellets are counted manually at several locations on a beach. However, for recent incidents, this method has been adapted to render it more applicable. For example, during the X-PRESS PEARL incident, the Tunnel *et al*. method was modified because i) 10 minutes was considered too long to allow a sufficient number of shoreline segments to be surveyed within a given time-frame, and ii) the very high contamination levels rendered counting pellets impractical. Instead, the time limit was reduced to two minutes and batches of collected pellets were weighed instead of counted. These quantification methods are designed to be simple and accessible for untrained surveyors.

Below is a short description of the steps required to undertake a two-minute count survey:

- **Select a location** which best represents the “average” contamination level of the site (i.e. not the most /least contaminated areas);
- **Collect plastic pellets for two minutes using only your hands**, and collect into an open top container. Try to avoid collecting sticks, sand, burned plastic, or other substrate/debris;
- **Weigh container and plastic pellets** using a small set of scales placed on a flat surface. Then weigh the empty container to obtain the tare. Subtract the container tare from the total weight to calculate the net weight of plastic pellets;
- **Record this weight** in a database/mobile survey app/survey form, and;
- **Classify the shoreline** contamination level using the pre-defined limits (e.g. Table 2).

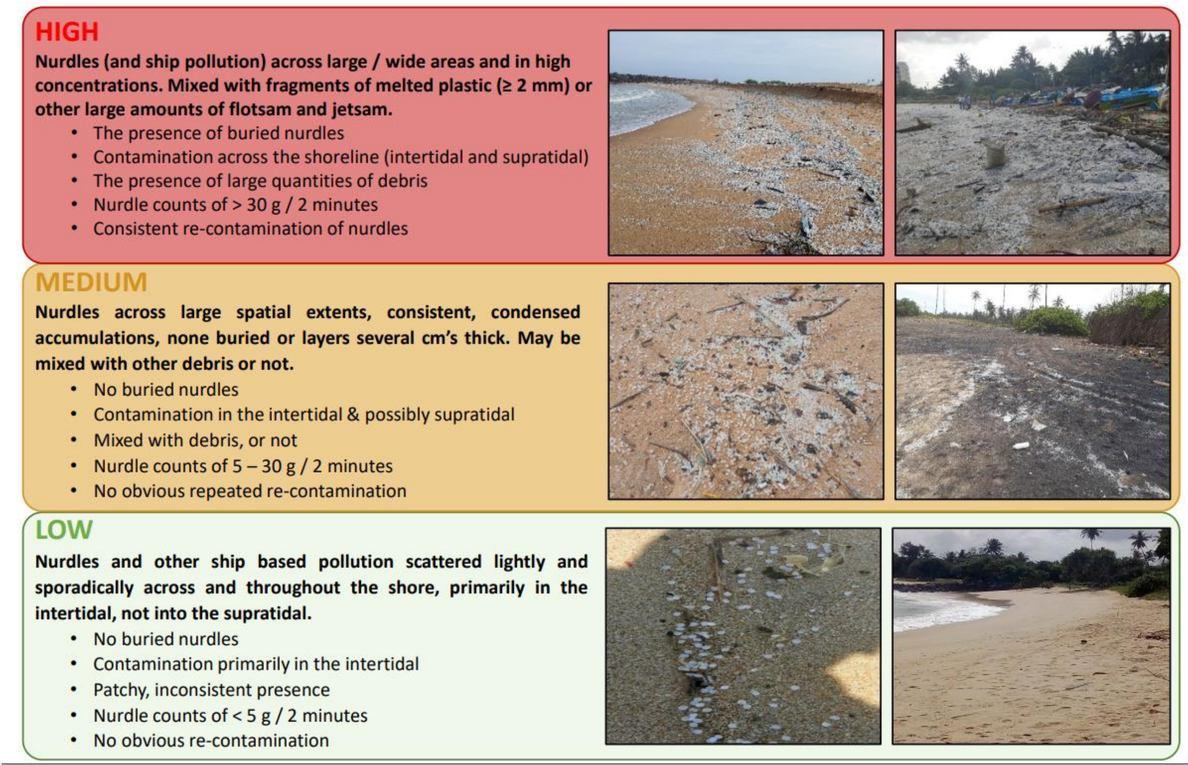

Figure 11: Example of criteria for visual assessment of shoreline contamination during X-PRESS PEARL incident, Sri Lanka, 2021**.** Source: ITOPF.

Consistent use of this method from the early stages of the X-PRESS PEARL incident proved to be indispensable for developing a database to keep a record of how contamination varied spatially and changed temporally throughout the response period, therefore guiding more effective response decisions.

Table 2: Classifications of high, medium and low contamination level according to the two-minute count method, as applied during the X-PRESS PEARL incident.

Contamination level	Weight of plastic pellets
High	> 30 g
Medium	5 – 30 g
Low	< 5 g

iii. Spatial/quadrat count

An example of a spatial count method, using a quadrat, is the Plastic Pollution Index (PPI) tool designed by Fernandino *et al*.[30]. The PPI is an adaptation of the Clean Coast Index (CCI)[31] and is used to classify sandy beaches according to the abundance of plastic pellets.

The approach requires the use of a 1 x 1 x 0.05 m quadrat. The quadrat is randomly placed on the most recent high tide line and a second is positioned at the landward obstacle that limits the shoreline. This limit could be either natural (e.g., vegetation) or anthropogenic (e.g. a wall). The surface layer of sediment from each quadrat is removed, and the sediments are mixed with seawater to separate the plastic pellets via flotation. For rocky shorelines, pellets can be individually collected by hand if needed. The number of pellets are then counted and recorded for both the high-tide and backshore samples. The level of contamination at both locations can then be classified according to the PPI method (Table 3). To obtain a clear representation of a beach segment, this approach should be repeated several times along the shoreline.

Table 3: Concentration of plastic pellets and corresponding Pellet Pollution Index classification.

PPI	Concentration of Pellets	Classification
0.0 < PPI ≤ 0.5	0 – 25	Very Low
0.5 < PPI ≤ 1.0	25 – 50	Low
1.0 < PPI ≤ 2.0	50 – 100	Moderate
2.0 < PPI ≤ 3.0	100 – 150	High
PPI > 3.0	> 150	Very High

As stated above, these methods must be adapted to suit each incident. “High” levels of contamination during one incident may look very different to the level of contamination that is classified as “high” during another. As a consequence, comparison of contamination levels across incidents should be avoided.

3.4. At-sea response

At-sea containment and recovery are often used as an effective means of minimising oiled shoreline contamination. For spills of plastic pellets, however, there are several reasons why at-sea recovery is unlikely to be. In the cases experienced to date, at-sea response has rarely been instigated, and when instigated, not proven to be effective, for the reasons described below.

Following a loss of a container carrying plastic pellets, there are three possible scenarios that might ensue:

- A container breaks up on deck/on contact with water, spilling its cargo directly into the environment;

- A container is lost overboard possible, after which it sinks or continues to drift for a period of time, and then breaks up and releases cargo, or;
- A container may eventually sink to the bottom intact, whereby no cargo is released immediately. However, if left *in-situ* for long periods, the structural integrity of a sunken container may be compromised, subsequently spilling its contents.

In the first two cases, it is most likely that the notification of a lost plastic pellet container will be received too late to allow effective containment and recovery of any cargo lost from that container. The proximity of the release location to land may also render at-sea recovery unfeasible, as seen during the X-PRESS PEARL incident, where the incident occurred close to shore, consequently the released pellets made landfall so quickly that it prohibited any at-sea response. Finally, given that the drift of plastic pellets is influenced by metocean conditions, they would quickly disperse from the spill location. As a result of this dispersion, as well as the described challenges observing floating pellets, effective at-sea recovery is unlikely to be effective, if undertaken at all.

In a situation where a container carrying pellets remains on the seabed fully intact, it is advised that the container is secured as quickly as possible and, if feasible and appropriate, recovered from the seabed. Emphasis should be placed on the proper containment of cargo at the seabed, rather than installing containment and recovery assets at the surface.

There may be cases where containers and their contents are lost in situations where a response at-sea may be practicable, for example within semi-enclosed environments such as ports and harbours. This was the case in 2017 when two containers of LDPE and HDPE, pellets were lost overboard during a storm in the Port of Durban, South Africa.

Where a loss has occurred in a port (and if notification is received early enough), on-water containment and recovery may serve to limit widespread contamination and protracted shoreline clean-up operations. Conventional floating barriers or oil boom can be used to contain pellets, while a scoop net with suitable mesh size may be used to quickly recover plastic pellets from the surface.

3.5. Shoreline clean-up

Past cases have demonstrated that shoreline clean-up of releases of plastic pellets is laborious and protracted. This is a result of the characteristics of the pollutant and its highly mobile behaviour when lost to the marine environment, as well the rudimentary tools available to recover spilled plastic. For these reasons, the recovery of pellets from contaminated shorelines has been observed to take between months and years until agreed sign-off of sites by the authorities. Even then, the complete recovery of lost cargo is considered to be largely impossible. Recent cases have demonstrated between a 40 – 70 % recovery rate.

While the technology currently available to expedite the clean-up and recovery process is limited, the following sections elucidate some of the lessons learnt during recent cases and highlight key considerations for contingency plan holders and spill managers in the event of a release of plastic pellets.

3.5.1. General guidance for responders

Personnel involved in the clean-up should undergo a basic introductory briefing. At the time of publication, available shoreline clean-up techniques are fairly basic and readily achieved by any physically-able responder. However, a short introduction should at least cover the following areas:

- How the response is organised and why (e.g. command structure, objectives, start/end/break times);

- Health and safety e.g. level of PPE, manual handling, site specific hazards. and considerations;
- Layout of supporting infrastructure (e.g. obtaining water, toilet locations);
- Clean-up techniques to be employed and how they work;
- Environmental sensitivity of the shoreline;
- Any restrictions associated with work on the shoreline (e.g. accessibility), and;
- Lines of communication and how to report on work completed.

The extent and magnitude of a spill will be an important factor when determining which personnel are mobilised during the clean-up and how many are required. For example, smaller spills might be handled by teams from local municipalities (e.g., fire brigade or other response units), whereas larger spills might also require the involvement of military forces or a dedicated response contractor organising a significant workforce to clean shorelines over a protracted period. All personnel should work in small teams (e.g. 15 – 20 people) within a well-defined hierarchical management structure. In general, personnel and health and safety planning should be carried out according to national regulations and best practices, similar to oil spill incidents.

Some of the potential hazards posed to responders during collection of plastic pellets is akin to those during an oil spill response. Section 3.2.5 has, however, highlighted additional potential risks hazards associated with the collection of plastic pellets.

The level of mandatory equipment PPE required may vary and should be determined on a case-by-case basis. The general work environment should be considered for the welfare of those involved in repetitive collection activities. For example, some mechanical recovery equipment will generate a significant amount of noise and, therefore, suitable ear protection should be provided.

3.5.2. Response phases

As with oil spills, the response to plastic pellet spills can be broken down into three distinct categories. These categories and a brief explanation are provided below. Section 3.5.4 details the different tools applicable during the different response phases.

i. Emergency Phase

The initial period of the response, during which the situation may not be fully under control, is often termed the 'emergency phase'. This phase may last from a few days to several weeks. During this period, crucial decisions will be required that will have longer term consequences.

As seen during the X-PRESS PEARL incident, due to prevailing metocean conditions, significant quantities of 'clean' and 'burnt' plastic (micro – macro) washed up on beaches within hours of containers falling overboard. In the event of large quantities of plastic pellets making landfall during future incidents, spill managers should endeavour to prioritise bulk removal to prevent remobilisation and further contamination. Despite selectivity being important during this initial phase the main priority is to remove the bulk contamination from the shoreline. Therefore, the goal should be to recover plastic pellets, and/or relocate them far away from the active shoreline to prevent remobilisation by wind and wave action.

In cases of the stranding of massive quantities of plastic pellets, the use of heavy equipment (e.g. bulldozers) to move plastic material away from the beach line may also be appropriate at an early stage. These piles will be sorted at a later stage, where the use of mechanical aids may also be appropriate. Decisions relating to the use (or not) of heavy equipment would depend on its availability, as well as the shoreline type, suitability, sensitivity and accessibility.

ii. Project Phase

The emergency phase can be contrasted with the subsequent 'project phase', which is characterised by a clearer understanding of the overall situation and an appreciation of how the response is expected to develop thereby allowing for a greater level of forward planning. Typical indicators that the emergency phase is evolving into the project phase might include:

- the casualty or source of pollution has been stabilised and the threat of further releases of plastic pellets has reduced significantly or been eliminated, or;
- sufficient response resources have been mobilised to address the prioritised concerns and these are working effectively.

Following the termination of the initial emergency phase, significant quantities of plastic pellet pollution typically remains on the shoreline, albeit at lower concentrations than encountered initially. Plastic pellets are likely to wash up in relatively small quantities, over a long period of time, over a large stretch of shoreline. During this phase, spill responders should continue to target the regions of highest contamination, while also maintaining good levels of prioritisation and selectivity. Both surface and subsurface contamination should be considered and addressed as far as possible. The main aim of the project phase is to progress shorelines towards pre-determined clean-up endpoints (see Section 3.6).

iii. Monitoring Phase

During the monitoring phase, most clean-up operations will have been terminated and clean-up end-points (see Section 3.6) will have been reached on most shorelines. However, plastic pellets can continue to re-strand for several years following termination of clean-up operations. From experience gained to date, in most situations recovery of 100% of lost cargo from the shoreline is considered impossible. Where appropriate, post-spill monitoring can be arranged to assess any significant recontamination and potential associated impacts, with the aim to evaluate if further mitigation (e.g., clean-up activities) should recommence. Such monitoring should bear in mind subsequent standing of plastic pellets from sources unrelated to the specific incident, particularly in locations with chronic contamination.

3.5.3. Shoreline clean-up strategy

The overarching strategy of any response to spills of plastic pellets is to limit their geographical spread and to recover the greatest quantity of lost cargo as quickly as possible. As an initial step, this requires targeted clean-up of the most highly contaminated areas to minimise the remobilisation of plastic pellets and subsequent widespread secondary contamination.

The most highly contaminated areas are typically natural accumulation points, where microplastics and other organic debris strand or become trapped under pre-spill conditions. To identify the areas of greatest accumulation of plastic pellets, understand the extent of contamination and aid the prioritisation of clean-up sites, shoreline surveys (see Section 0) are strongly recommended as soon as possible after notification.

Much of the clean-up operations experienced to date have involved recovery efforts focussed on sand shorelines. Hence, this section focusses on strategies for recovery from sand beaches, however, mention of other types of shorelines, namely mangroves, are also discussed below.

In the event of future incidents where other shoreline types may be impacted, commonly known principles employed during oil spills, namely Net Environmental Benefit Analysis (NEBA), should also be followed when developing clean-up strategies and identifying suitable plastic pellet recovery techniques (see Section 3.5.4).

Net Environmental Benefit Analysis is a structured approach used by spill responders and other stakeholders during spill response, to compare the environmental benefits of potential response tools and develop response strategies that will minimise the impact of a spill on the environment. In the case of plastic pellet spills, following the principles of NEBA, spill mangers should assess the environmental benefits of removing a potentially inert substance from sensitive habits (e.g. mangroves).

Segmentation

Similar to oil spills, systematic cleaning of the entire coastline affected by a pollution event is most effectively completed by subdividing the coastline into operational units called 'segments' (Figure 12). The segments will be identified on the basis of morphological (physical) and sedimentary homogeneity. Each segment must be assigned a unique ID. The segments should be between 200 m and 2 km long, but this will be largely determined by the nature of a particular shoreline and the availability of personnel. Segmentation can be completed *in-situ* by operational personnel or using mapping software, with the latter requiring verification surveys to be completed.

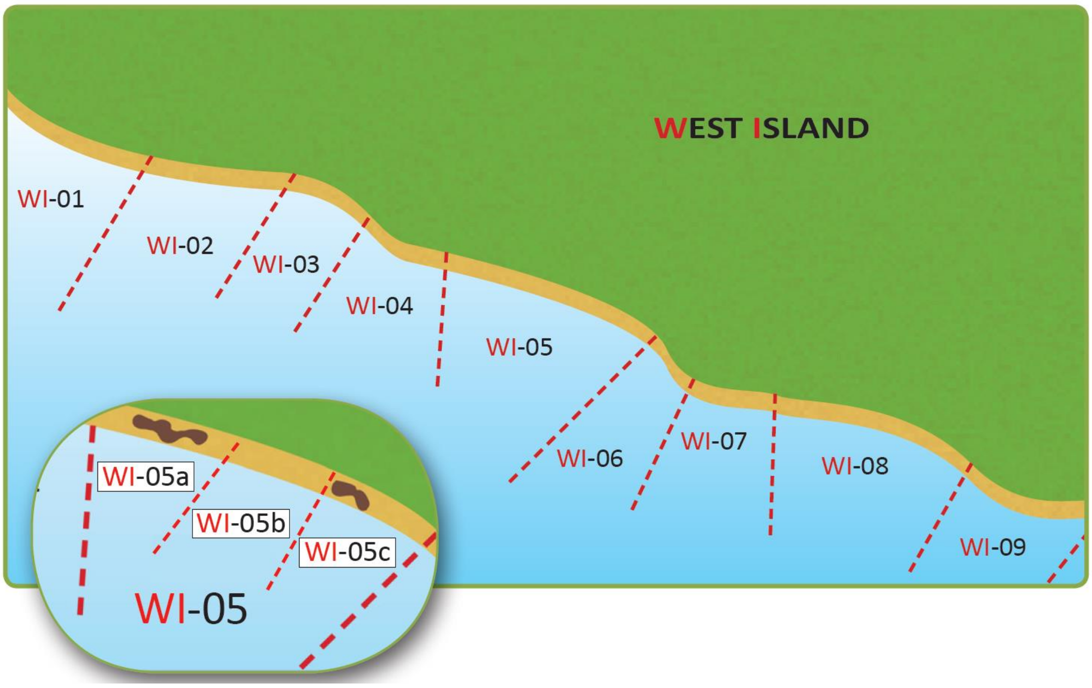

Figure 12: Example of subdivision of a coastline into segments assigned a unique ID. Source: Oil Spill Response Limited, SCAT Field Guide[27].

For each shoreline segment, field observations should be recorded to answer the following questions:

- What is the level of contamination in this segment (surface and sub-surface)?
- Is there a need for cleaning in this segment?
- If cleaning is required, which cleaning methods are appropriate or recommended?
- What are the environmental and socio-economic sensitivities of this segment?
- What care is needed to protect sensitive resources located within this segment?
- What is the priority for cleaning in this segment, compared to other segments?
- Are ongoing cleaning operations being conducted effectively?
- Is the current cleaning method effective, or is it causing additional damage?
- Does the level of effectiveness require testing of an alternate cleaning method?
- Does the segment meet the agreed cleaning endpoints when defined?

Sand beaches

Along an archetypal sand beach shoreline profile, the greatest accumulation is typically observed along the high-water mark or strandline (Figure 13**Error! Reference source not found.**). Plastic pellet deposition on shorelines has also been shown to be relatively high on beaches with higher-than-average strandlines and shorelines that face the direction of high energy waves.

Figure 13: Plastic pellet accumulation on the high-water mark and multiple strandlines. Source: ITOPF

Due to dynamic nature of shoreline condition, plastic pellets can quickly become buried. Following which, buried plastic pellets can become uncovered and remobilised as part of the natural accretion/erosion cycle. Consequently, once buried, significant effort, time and costs may be committed to systematically excavate sediment to recover plastic pellets.

Therefore, to minimise the potential for remobilisation and burial to occur, once contaminated shorelines are identified, clean-up teams should be mobilised as soon as possible to systematically recovery plastic pellets. Where resources are limited, the mostly highly contaminated shorelines should be targeted as a priority over more lightly contaminated sites. In any circumstance, priority should be made for the recovery of plastic pellets most likely to be remobilised, for example, those on the most recent high-water mark.

Mangrove habitats

Mangroves can form natural deposition locations for plastic pollution, and the intricate root system can act as an effective trap to enable pollution to accumulate (Figure 14). In addition, these habitats are characterised by low water energy and hence once pollution becomes stranded in these environments, it is unlikely to be remobilised except in significant storm events.

Figure 14: Pre-existing plastic and ship-sourced plastic pellets trapped in mangrove during X-PRESS PEARL, Sri Lanka, 2021. Source: ITOPF

Mangroves are particularly sensitive environments, and any clean-up response should be carefully evaluated to ensure that operations do not damage the habitat. The principles of NEBA should be followed, with particular considerations on the presence of pre-existing debris and the risk of further damage when trying remove plastic pellets.

With this in mind, only non-invasive techniques are recommended to be used in mangroves. As with all operations in a mangrove, access to the shoreline from the stable backshore of the mangrove is preferred, to avoid damaging the sensitive sediment and root structure of the trees.

Some recovery methods may be more applicable than others, such as the use of vacuum systems. Likewise, low pressure flushing and flooding techniques from the back of the mangrove to containment and collection at the front of the mangrove may be applicable to recover plastic pellets. Small-scale trials should always be conducted to assess the efficacy on a case-by-case basis

As with all shoreline types, an assessment of the background levels of plastic contamination in the mangrove and the relative sensitivity and accessibility of the available tools is important to understand when assessing the reasonableness of undertaking clean-up operations.

To date, the recovery of stranded plastic pellets in mangroves habitats has been limited, and hence, it might be expected that lessons learnt are quickly generated should any future incident impact this type of shoreline. See Section 3.5.8 for further details.

<u>Sea defences</u>

Various designs of sea defences (e.g. rip-rap) has been shown to trap plastic pellets following a release (Figure 15). Plastic pellets are likely to penetrate deep into the structure through the spaces between the rocks of concrete structures. These man-made structures are relatively insensitive, therefore allowing various techniques to be used, however due to access challenges, this may be limited to manual recovery, vacuum removal and low pressure flushing and flooding techniques. With the latter technique, suitable containment (e.g. fence boom) and recovery (i.e. scoop nets) methods should be put in place to prevent plastic pellets escaping.

Figure 15: Plastic pellet trapped in sea defence systems during X-PRESS PEARL, Sri Lanka, 2021. Source: ITOPF

<u>Other shoreline types</u>

As described previously, this document focusses on lessons learnt from past cases. Hence, this document does not describe in full detail the application of different techniques for a range of shoreline types. It is expected that as the industry evolves, as more research and development is focussed on this subject area, and as more potential incident occur, this document will be updated to reflect these experiences.

3.5.4. Recovery methods overview

The techniques available for shoreline recovery of plastic pellets are often rudimentary and the industry currently lacks dedicated, sophisticated equipment. The burgeoning nature of plastic pellet pollution means the spill response industry has not benefited from the decades of research and development as available for oil spill response. As a consequence, responders are required to optimise the use of readily available tools at the time and improvise as the situation requires.

Recovery strategies should be selected with the aim of minimising the amount of sediment, vegetation, marine fauna etc., that is removed alongside plastic pellets. This is to:

- Reduce any additional shoreline erosion linked to clean-up operations;
- Reduce disturbance to the ecological equilibrium of the site, and;
- Minimise the volume of waste to be managed (see Section 3.7).

Separation of plastic pellets from surrounding sediments, vegetation etc., (see Section 3.7.1) should be carried out as close to the clean-up area as possible. This allows the sediment to be replaced, ideally from the area from which it was removed.

The current techniques available can be categorised as manual and mechanical (see Sections 3.5.5 and 3.5.6). The guidance provided below is based on lessons learnt during recent cases and highlights tools available at the time of writing. The benefits and limitations techniques used during past cases can be found in Section 3.5.7.

3.5.5. Manual recovery techniques

Manual recovery of plastic pellets from affected shorelines has been the primary strategy for clean-up operations to date. Manual recovery is labour intensive, sometimes requiring hundreds of people covering large areas of coastline for prolonged periods of time. The main methods of manual recovery typically involve the use of sieves (Figure 16 & Figure 17) and hand trommels (Figure 18), with supplementary use of spades, rakes, brushes and buckets as required.

i. Sieves

Single layered wooden sieves (Figure 16) have demonstrated good effectiveness in removing plastic pellets from sediment shorelines. Wooden sieves can be readily available (i.e., rice screener) or easily constructed. The mesh size, however, needs to be altered depending on the size of the plastic pellets being recovered.

Figure 16: Single layer wooden sieve. Source: ITOPF

Double layered sieves (Figure 17) have been previously used to assist in the separation of plastic pellets from other debris. Double layer sieves consist of two layers of different size mesh resulting in an extra layer of separation; primarily used in locations with high degrees of back ground debris (natural or anthropogenic).

i. Hand-Trommels

A trommel, or rotary screen, is a cylindrical sieve often used in the aggregate industry. Material is fed into the trommel and sorted by size. Trommels consist of a perforated cylindrical drum that is elevated at an angle, with the feed end at the top (Figure 18). The cylindrical screen can consist of one or more mesh sizes, with a greater number of screens resulting in greater sorting capacity. The smallest mesh is situated near the feeding end, with mesh size increasing down the trommel. This results in smaller sized material passing through the earlier sections and being retained, with large pieces of debris exiting the far end of the drum. Dependent on the mesh size used, hand trommels can be used to segregate large items from microplastics, or sand from plastic pellets.

Figure 17: Double layer used during the XPRESS PEARL incident, Sri Lanka, 2021. Source: ITOPF

Figure 18: A hand-trommel. Source: ITOPF

3.5.6. Mechanical recovery techniques

To date, the available means of mechanically recovering plastic pellets from affected shorelines is limited. Despite some research and development now taking place to create bespoke methods of recovering plastic pellets, so far only off-the-shelf tools and adapted technology has been used, to varying success, during recent plastic pellet spills.

i. Vacuums

Vacuum systems have been shown to be relatively effective at recovering high concentrations of plastic pellets from the shoreline. Off-the-shelf garden vacuums (Figure 19) have been used on multiple occasions to improve the recovery rates of plastic pellets. These are often readily available from general hardware stores and can be easily utilised by untrained personnel. However, as these tools are not made for operating on sandy shorelines, or for recovering hard objects (garden vacuums are originally designed for the removal of leaves), the structural integrity of the internal components can quickly deteriorate due to physical abrasion or corrosion (due to saline conditions). Moreover, they must be slightly adapted (i.e. addition of filters) to prevent the recovery of other pieces of macro debris. It is also worth noting that these vacuum pumps require additional batteries and charging stations when working on remote shorelines.

Figure 19: Vacuum recovery units. Source: ITOPF.

Other industrial vacuum systems designed for the recovery of oil may also be adapted for the removal of plastic pellets. Mobile and non-mobile systems are widely available from the public utilities and agriculture sector, as well as other sources. Both varieties can be used when recovering large quantities of stranded pellets. Some larger types may face challenges when access is limited. Likewise, when concentrations of pellets are low, the ratio of sediment to plastic pellets being collected may result in these tools becoming redundant.

ii. Mechanical Trommels

Similar to the method of using hand-trommels, this equipment can be scaled-up and mounted to trailers, and All Terrain Vehicles (ATVs) to increase processing speed. Mechanical trommels adopt the same principles as manual trommels but are motorised to reduce the labour demands (Figure 20). These systems can be bought off-the-shelf or constructed on site if unavailable in-country. Due to the mechanical element of this tool, greater amounts of sediment can be sieved in a given period of time compared to manual trommels.

Figure 20: Mechanical trommels. Source: ITOPF.

iii. Vibrating Table Screeners

Vibrating table sieves or screeners (Figure 21) follow the same principles of hand sieves, with the added benefit of being mechanised. This tool can be designed as a single or multi-stack screening system depending on the location, plastic pellet size, sediment type and level of pre-existing marine debris. These systems can be purpose built, or adapted from pre-existing technology (e.g. those used during industrial sorting activities) and can be used to good effect. As with hand-trommels, this equipment can be scaled-up and mounted to trailers, and ATVs to increase mobility and processing speed.

Figure 21: Mechanical table screeners. Source: ITOPF

iv. Beach Cleaners

Beach cleaners, or combers, are widely available tools designed to remove macro litter from beaches (Figure 22). This equipment is often seen clearing beaches at popular tourist destinations and can be tractor drawn, walk-behind, or self-propelled. Given that this equipment is designed for the recovery of larger pieces of debris, their efficacy is limited when employed for the removal of plastic pellets. Despite its limited effectiveness, spill managers may wish to consult with manufactures to determine if models can be retrofitted with finer mesh to recover microplastic. If available, however, beach cleaners may only suitable on wide, flat beaches with dry sand and good access. On beaches with high degrees of other macro debris (e.g. plastic, coconuts or other organic debris) which may impede clean-up efforts, beach cleaners may be a useful tool for a preliminary sweep of an affected site.

Figure 22: Different types of beach cleaners. A) walk-behind; B) tractor drawn. Source: ITOPF.

v. Mechanical excavators

Some heavy machinery, such as bulldozers and excavators, can be used to remove plastic from the near surface sediment. Mechanical excavation can be employed to rapidly remove bulk quantities of plastic pellets from the shoreline, which can be useful when remobilisation is a particular concern. This method is most applicable to sandy beaches with good access points to the shoreline for the heavy equipment. However, mechanical excavation can produce large amounts of additional waste, due to the inherent low selectivity and high probability of mixing plastic pellets with otherwise uncontaminated substrate.

As a consequence, this technique is best used in combination with a secondary separation method preferably *in-situ* before transfer to waste storage facilities. Techniques aimed at improving *in-situ* selectivity may include the manual transfer of plastic pellets to the heavy machinery assisting recovery. Alternatively, water separation can be used on-site to separate plastic pellets from sediment and other debris (see Section 3.7.1). Consideration of the amount of 'clean' substrate being removed should be made to minimise disturbing coastal processes and significantly altering the shoreline profile.

vi. Flushing and flooding systems

In some circumstances, the use of flushing and flooding techniques (Figure 23), similar to those employed to remobilise oil buried in sediment, could be adapted to recover plastic pellets. There are several ways this could be achieved, for example using low-pressure high-volume flushing or flooding lances or utilising natural streams with artificial traps to mobilise and recover pellets.

The use of water pressure in these instances can help to mobilise the lightweight pellets and enable their containment in mesh traps, booms, or similar, after which they can be recovered using manual sieves. However, experience of these techniques has indicated many other light debris can also be collected using these methods, which can quickly overwhelm containment equipment, and require additional segregation of recovered material.

In a previous incident in Norway, a natural stream was utilised in a trial to recover plastic pellets to good effect in a relatively large area, although the method was labour-intensive and required the use of mechanical equipment such as excavators to move contaminated sediment for flushing (Figure 24). This method may also impact physical processes on the beach if large quantities of sediment is removed.

Figure 23: Flushing being used to remobilise plastic pellets trapped in shoreline vegetation. A) trench system to contain run off; B) flushing contaminated vegetation; c) remobilised plastic pellets; D) trapped plastic pellets. Source: ITOPF

Figure 24: Containment and recovery using natural stream. Source: NCA

3.5.7. Benefits vs limitations of clean-up techniques

A variety of techniques can be employed to recover pellets from the environment. Many of these techniques have been used in recent response operations and Table 4 summarises some of the main benefits and limitations of these methods.

Table 4: Benefits and limitations of field-tested recovery tools

Recovery Tool	Benefits	Limitations	Selectivity
Manual methods			
Sieves	• Readily available and cheap to manufacture if not available, • No training required, • Easy to maintain or fix if broken, • Effective on most sediments, • Highly selective (dependent on mesh size), • Easy to transport.	• Efficacy can be reduced on wet sediment, • Can easily break if not properly maintained, • Double-layered sieves can be heavy to transport and cumbersome, • Large resource requirement for both the equipment and personnel, • Can be physically demanding on the workforce, • Can be a slow process to recover pellets distributed over a wide area.	High
Hand trommels	• Widely available and cheap to manufacture if not available, • Easy to maintain or fix if broken, • Effective on most sediments, • Highly selective (dependent on mesh size), • Can process large amounts of debris relatively quickly,	• Efficacy can be reduced on wet sediment, • Some have limited mobility (e.g. trommels without wheels) • Sometimes heavy and difficult to manoeuvre, • Less favoured than the more mobile hand sieves,	High
Mechanical methods			
Vacuum systems	• Good for surface recovery on certain sediments, • Readily available equipment (for example, from public utilities and agriculture) that needs minor adaptations, • Variety of types (backpack, wheeled, truck or trailer) allow flexibility of use.	• Backpack-mounted vacuums can be laborious to carry over long periods of time, • Potential for noise pollution to disrupt wildlife in sensitive habitats, • Can easily break if not maintained properly, • Potential for blockages in areas of high levels of other macro debris,	Moderate

	• Backpacks varieties can be deployed quicky and are easily manoeuvred, • No training required, • Vacuum trucks provide vacuum, temporary storage and transport in a single system, • Effective at recovering plastic pellets in large concentrations, • More effective when pellets are in high concentrations on hard surfaces (e.g. wet sand or rocky shorelines).	• Requires energy supply to maintain operations, • Good access required for the deployment of vacuum trucks, • Less effective for lower concentrations of pellets; can recover large quantities of sand in dry conditions.	
Mechanical trommels / vibrating tables	• Mechanical trommels can reduce labour effort of manual methods, • Highly selective (dependent on mesh size), • Can be mounted on vehicles for ease of transport, • Widely available for industrial purposes, or can fabricated quickly if needed. • Highly effective on dry sediments, • Mechanical trommels could be used as a secondary waste separation technique on site or in storage facilities.	• Requires access for vehicles and suitable terrain, • Requires suitable sediment, • Requires finding suitable manufacturer or supplier in country, • Currently not a stockpiled piece of equipment for global use in spill response.	High
Beach cleaners	• Readily available, • Less laborious, • Often able to cover larger areas of shoreline in a given time than manual techniques, • Can be applied to recover other macro debris.	• Typically requires adaptation to be suitable for plastic pellet recovery, • Expensive, • Requires specific training, • Relatively slow on challenging terrain, • Poor selectivity • Reduced efficiency on beaches with high background debris levels and large shoreline gradients.	Low
Mechanical excavators	• Can be used to quickly remove bulk quantities of pellets from shoreline to prevent remobilisation, • Able to move large quantities of recovered pellets over a large area, • Combined with manual sorting techniques to accelerate removal of recovered pellets from the shoreline zone.	• Poor selectivity can lead to generation of large amounts of additional waste, • Requires secondary segregation of waste which may add time and cost to operations, • Not as selective so requires additional training to operator prior to starting operations, • Careful management of operations to not disrupt the beach profile of the shoreline,	Low to Moderate

		• Not to be used in sensitive shorelines such as salt marshes	
Flushing and flooding	• Potentially applicable to a wide variety of shorelines (e.g. sandy and rocky shorelines, mangroves, rip-rap), • Equipment is readily available from oil spill responders, • Can utilise natural water supplies, • High selectivity in areas with low background levels of other debris.	• Requires constant water supply; sometimes difficult in rough sea conditions. • Containment and recovery methods needs to be robust, • Requires trained personnel and good planning, • Lower selectivity in areas with high levels natural and anthropogenic background debris.	Moderate - high

3.5.8. Recovery method-efficacy matrix

The most appropriate recovery method for plastic pellets spills is largely determined by the shoreline type. Through experience gained from spills of plastic pellets to date, Table 5 provides general guidance on suitable recovery techniques based on shoreline type. However, trials should always be conducted with the available equipment to understand the most suitable methods on a case-by-case basis, and the below is not intended to be taken verbatim, nor is the list exhaustive.

There are caveats to the below matrix. For example, on hard, compacted and wet sandy beaches, vacuuming may be a possible method to recover pellets. However, on dry, soft sandy sediment, vacuum pumps may recover large proportions of sediment as well as pellets, making it an unsuitable method in this instance.

The below table is adapted from a shoreline field guide being developed by the Plastic Pollution Working Group of the UK & Ireland Spill Association, in addition to a similar table developed by the NCA in its TRANS CARRIER report[32].

Table 5: Matrix of recovery techniques on different shorelines

Recovery techniques	Exposed rocky shores (supratidal)	Sandy beach	Gravel beach	Riprap structures	Exposed tidal sand flats	Marshes	Mangroves
Manual (using sieves and hand trommels)	[green]	[green]	[green]	[green]	[green]	[amber]	[amber]
Vacuum systems	[green]	[green]	[amber]	[green]	[green]	[green]	[green]
Mechanical trommel	[red]	[green]	[green]	[red]	[amber]	[amber]	[amber]
Beach grader	[red]	[green]	[red]	[red]	[amber]	[red]	[red]
Mechanical excavation	[red]	[green]	[green]	[red]	[red]	[red]	[red]
Flushing and flooding	[green]	[amber]	[amber]	[green]	[amber]	[green]	[green]

[green]	Suitable method
[amber]	Possible method
[red]	Unsuitable method

3.6. Clean-up end-points

Shoreline clean-up endpoints are the specific criteria assigned during a response to establish a point where sufficient treatment effort has been completed to return the affected area to a state of cleanliness acceptable to all parties. End-points influence the choice of response strategies, set an objective for clean-up teams and are a standard against which the progress of operations can be referenced so that termination can be achieved[33].

Defining end-points typically occurs on a case-by-case basis for oil spills, and no international standards exist. However, within the oil spill community, clean-up end-points are generally well understood through decades of application. Conversely, defining end-points following spills of plastic pellets can be challenging as several factors influence the definition of these clean-up goals. Some of these factors are listed briefly below:

- **Shoreline sensitivity**: an assessment of the impacts or risk of impacts of plastic pellets to a particular system, compared with the potential impacts of prolonged clean-up should be undertaken. For example, does the risk of recovering pellets from within a mangrove system outweigh the potential impacts of those pellets being left *in-situ*? Could an alternative approach be considered to minimise any additional environmental and/or socio-economic disturbance to sensitive locations?
- **Remobilisation**: plastic pellets can become seasonally buried and later exposed, resulting in continuous re-contamination. Pellets remain highly mobile throughout a spill incident, causing the situation to be dynamic.
- **Background contamination:** end-points need to be determined within the context of the local environment, including the presence of other pre-existing plastic debris. What threat residual pellets might have on the environment, compared to other non-ship related plastic, should be considered when determining end-points. Once the bulk removal of plastic pellets is completed, and if subsequent recharging events are small, engaging in prolonged shoreline clean-up activities could be considered unreasonable if pre-existing shoreline contamination is high.
- **Chronic plastic pellet contamination**: plastic pellets are ubiquitous in the marine environment and, originating from various sources, are found on shorelines throughout the globe. Areas that experience chronic strandings outside the specific incident may require unique end-points to take account of subsequent strandings of pellets unrelated to the incident.
- **Environmental impacts**: the potential impacts of plastic pollution on the environment have been documented in scientific literature, but the acute and chronic impacts of catastrophic losses of plastic pellets is less clear, making defining suitable end-points challenging.
- **Toxicity:** most plastic polymers are inherently inert and, in their original state, pose little toxicological threat to humans or the environment. However, there is potential for plastic pellets to alter in physical and chemical composition, as well as adsorb surrounding pollutants from the environment. Therefore, if toxicity testing indicates that the spilled plastic pellets may cause significant harm due to these new properties, end-points must be adapted to reflect this risk of impact.
- **Persistence**: plastics are designed to be biochemically inert and, therefore, do not biodegrade in the environment, primarily disintegrating through photo- and mechanical degradation. Once lost to the marine environment, any residual plastic will remain for a significant length of time, in the order of ten’s and hundreds of years, impacting end-point considerations.
- **Sustainability considerations**: The use of NEBA to determine end-points can also be used to consider the wider environmental impacts of clean-up operations, such as resource consumption or the greenhouse gas (GHG) emissions associated with daily operational activities. For example, the global impact of GHG emissions associated

with the operation of heavy equipment, or the mobilisation and housing of large numbers of workers, may outweigh the local environmental impact of small quantities of plastic pellets remaining on a shoreline.

- **Net weight removal**: A more efficient use of time and resources, and therefore more environmentally sustainable, may be collection of a pre-agreed quantity of marine litter that includes both existing background macroplastics and the spilled plastic pellets, rather than to carry out a protracted clean-up that seeks to remove only a small concentration of plastic pellet contamination.

3.6.1. Practical approaches to defining end-points

Principles applied in the context of oil spills can be followed when discussing end-points for plastic pellets spills:

i. <u>Qualitative Observations</u>

This type of observation can be used to describe the presence or absence of plastic pellets on a given shoreline. Defining this type of end-point is relatively straightforward and quick to establish. For example, a qualitative end-point defined for a given location might be no macro (>5 mm) pieces of burnt plastic pellets observed.

ii. <u>Quantitative Measurements</u>

This type of approach is based on quantitative measurements, for example, the quantity of plastic pellets found in a given location, as per the methods described in Section 3.3.3. Alternatively, a quantitative end-point could be applied based on a percentage recovery figure throughout the entire response (e.g. 70 % of total cargo lost is recovered). This example would need to consider the law of diminishing returns and that collecting 100% of lost cargo would be impossible to achieve. The law of diminishing returns considers the weight collected per person per hour or day at specific locations. Over time, this method can be used to determine the effectiveness of clean-up operations and the progress of a response. When the weight collected per person diminishes over time, clean-up at a specific site can be terminated and teams can be deployed at alternative sites or demobilised from the incident. To accurately apply the law of diminishing returns to an incident, proper record keeping of recovery yields need to be undertaken from the outset (see Section 3.2.1).

Assigning a percentage recovery figure should also factor in the qualitative appearance of pellets on the shoreline, potential toxicity of the plastic, the presence of other pre-existing plastic (including pellets) on the shoreline and environmental sustainability goals (ESG).

iii. <u>Interpretive Impact Assessment Methods</u>

This method of end-point determination is based on the assessment of impacts or risk of impacts on the environment. This will include environmental, social, economic and/or cultural factors. Following the bulk removal of plastic pellets, this approach could address the concerns such as:

- Would the remaining pellets likely have an unacceptable environmental or socio-economic impact?
- Will the protracted recovery of plastic pellets cause further environmental impacts?
- Are the costs of continued clean-up excessive in relation to the potential threat of pellets to the environment or the perceived benefits of complete removal?
- Within the context of ESG, is the continued removal of plastic pellets sustainable?

Based on experiences in cases to date, this approach is often the most appropriate choice. Different methods have been developed, but all generally have the same goal. Some examples include:

- As Low As Reasonably Practical (ALARP)
- Lowest Practicable Level of Contamination (LPLC)
- Net Environmental Benefit Analysis (NEBA)
- Spill Impact Mitigation Assessment (SIMA)

Once end-points have been defined, ensuring a common understanding between decision makers and relevant stakeholders is important as interpretation of said end-points can vary from one individual to another. Therefore, throughout the process of defining end-points, regular joint shoreline surveys are recommended to maintain good calibration between all relevant stakeholders.

3.7. Waste management

Similarly, to clean-up strategies involving contaminants such as oil, any clean-up strategy involving plastic pellets must take into consideration the objective of reducing and segregating any waste generated. During the early stages of an emergency response, management of suitable temporary storage sites is vital pending the subsequent transfer and final disposal of waste[34] (Figure 25), and plastic pellet response operations are no exception. As with oil spill response operations, good waste management can be easily overlooked during an emergency, but is crucial nonetheless to an efficient and effective response operation. Figure 26 shows the waste hierarchy to advise on how the quantity produced during an incident can be reduced.

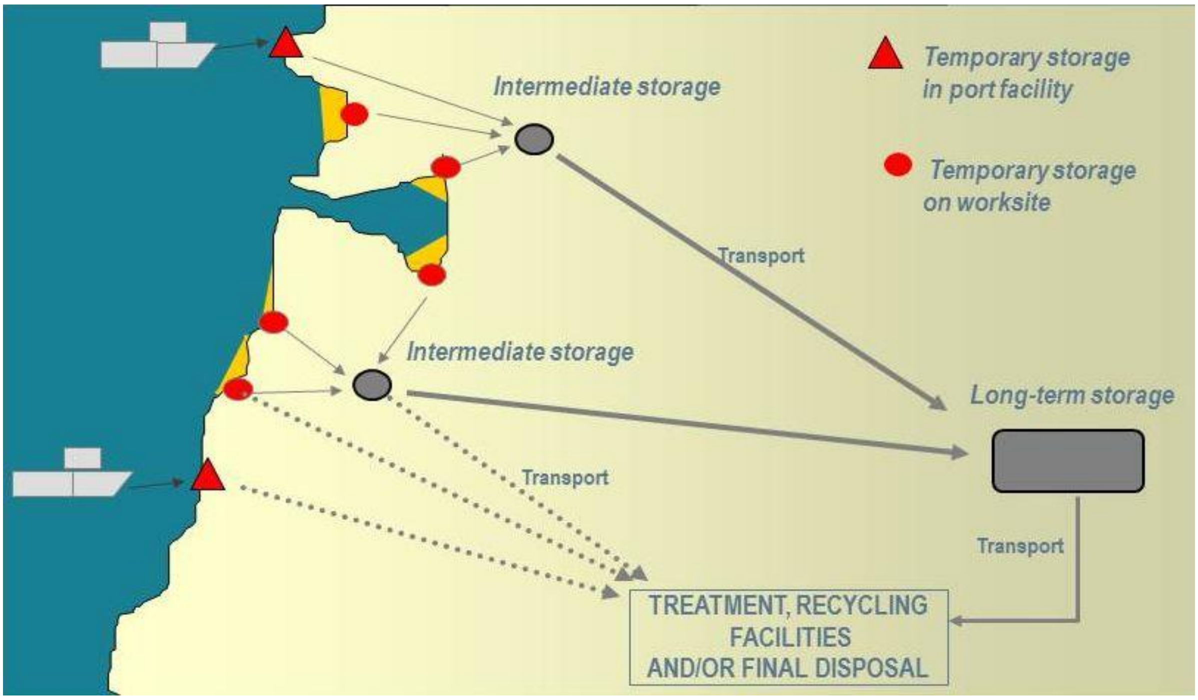

Figure 25: Waste storage and transport options between spill sites and treatment or disposal facilities[34].

Figure 26: The waste hierarchy[35]

One notable potential complication when dealing specifically with waste generated from a plastic pellet incident is the need to understand whether the spilled pellets are classified as a HNS. Catastrophic losses of plastic pellets have coincided with losses of a variety of chemicals and products carried by vessels, as well as vessel fires. These factors can cause inert plastic pellets to change their chemical and physical composition. Chemical analyses may need to be conducted as a matter of priority to understand the post-spill properties of the pellets in such instances.

The results of the chemical assessment should inform the characterisation of the plastic waste as hazardous or non-hazardous, based on local legislation standards. If found to be hazardous, additional waste criteria testing (e.g. leachate analysis) may need to be undertaken to determine the appropriate disposal method. If found to be non-hazardous, then the potential for the reuse and recycling of the plastic waste should be prioritized.

3.7.1. Waste separation and minimisation

Waste minimisation is necessary to reduce excessive removal of unpolluted sediment. The excessive removal of sediment from the shoreline could potentially accelerate coastal erosion processes and, in addition, increases the volume of waste material, typically leading to an increase in cost. Excessive and unreasonable costs generated due to poor waste management may not always qualify for reimbursement from the responsible party (see Section 5.4).

As the clean-up operation progresses towards termination, the quantity of plastic pellets recovered tends to decrease in comparison to the quantity of sediment collected. During the X-PRESS PEARL incident, a substantial number of bags were observed to contain a large proportion of sediment (Figure 27). In these instances, separation techniques should be employed following initial recovery. While waste can be separated on-site, and/or at a later stage at waste storage sites, separation is best conducted *in-situ* to minimise unnecessary transport, storage and potentially disposal of uncontaminated sediment[36].

Figure 27: Evolution of waste composition during clean-up operation after X-PRESS PEARL incident. On the left, contents of bags collected at the beginning of the clean-up operations, and on the right as a result of collection after several weeks. Source: ITOPF

Early separation processes on-site can help to prevent bottlenecks in the response, as well as helping to minimise the quantity of waste produced and enabling potential recycling of separated materials. Common waste separation practices applied during oil spill incidents can be replicated for spills of plastic pellet.

Waste segregation can be conducted through:

i. Size filtration

Size filtration could be carried out using industrial scale trommels (Figure 20). These are mechanically powered and can effectively process large amounts of waste on a continual basis. Alternative methods include industrial scale sand sifters. In both cases, devices can be fabricated, hired or purchased if available. The successful use of this equipment largely depends on the grain size of the sand, i.e. there must be a significant difference in grain size between sand and plastic pellets.

ii. Density separation

Density separation uses water to float plastic pellets away from denser sediment (Figure 28). This technique is recommended to be undertaken *in-situ* as it is important to consider the fate of discharged water and treated sediments from this method. Residual sediments and water following this process may contain other microplastics or nanoplastics. If the system is located on-site the water and sand can be re-introduced into the marine environment, allowing a significant reduction in waste and minimising impacts on erosion processes. If plastic pellets have been deemed hazardous, testing of residual products (i.e. sediment and water) may be considered prior to re-introduction.

3.7.2. Secondary contamination

Collection, transport and storage processes must be organised to avoid secondary contamination through accidental loss of particles (

Figure 29).

Secondary contamination can occur during the clean-up operations, particularly during transport and storage of recovered material. Typically, during clean-up operations on a beach, recovered material is collected in bags gathered in small piles at the point of collection, then transported by hand or heavy equipment (excavators, trailers) to an intermediate storage site located at the backshore of the beach. If the containers being used are fragile, they may become compromised during handling, causing recovered pellets to re-contaminate areas.

Secondary contamination can be a significant issue and cause additional time and cost consequences to the response operation.

Figure 28: Density separation and sorting process. A) density separation; B) sieving; C) removal; D) further manual sorting. Source: ITOPF.

Figure 29: Secondary contamination observed during the X-PRESS PEARL incident. Source: ITOPF.

Secondary contamination can be avoided using some precautions, for example:

- Ensure the use of suitably robust storage, double bagging in instances were robustness is brought into question;
- Protecting the temporary storage areas by placing a tarpaulin/geotextile or equivalent under the storage containers;
- Avoid overfilling storage containers (i.e. bags), thereby avoiding tears, but also aiding manual handling and reducing likelihood of bags being dropped, and;
- Improving handling and transportation of storage bags particularly from the shoreline to the waste collection point (e.g. use wheelbarrows for transportation); for example by placing individual filled small bags in more robust 1-tonne (bulk) bags.

3.7.3. Waste storage considerations

In some cases, particularly following the emergency phase, large quantities of clean and missed waste may require temporary medium– or long-term storage prior to sorting and disposal (Figure 30). This may result in large quantities of organic debris remaining *in-situ* in enclosed spaces for extended periods of time.

Figure 30: Long-term waste storage of recovered material during the X-PRESS PEARL incident, Sri Lanka 2021.

Under the right conditions, the microbial decomposition of this organic matter can potentially lead to the productions of gases, including hydrogen sulphide. In addition, following an incident where the composition of plastic pellets may have changed (e.g. during combustion), or where an interaction with other substance may have occurred, consideration should be made when identifying suitable storage spaces for potentially hazardous substances. Ideally, large, well ventilated storage units should be chosen to avoid bottle necks and the build-up of potentially harmful gases, respectively. In the event that poorly ventilated storage units have been used to temporally store recovered debris, appropriate gas monitoring should be undertaken on a regular basis to assess the concentration of potentially harmful gases (Figure 31).

Figure 31: Monitoring gasses within temporary storage containers during XPRESS PEARL, 2021. Source: OSRL.

3.8. Volunteer and public involvement

Given that plastic pollution is ubiquitous, some States have established volunteer organisations cleaning shorelines. These volunteer organisations can be harnessed during a catastrophic spill incident. These volunteers are likely to have good local knowledge of the shoreline and be well practised in methods of recovering plastic pollution, although this may be focussed on macroplastics rather than plastic pellets. The organisations are likely to have pre-existing health and safety protocols and skillsets that can be adapted to the spill incident.

In addition to contributing to recovery operations, these volunteer organisations can use their local knowledge of the shoreline to quickly and efficiently conduct surveys to assess the level and extent of contamination throughout a response. Surveys can be labour-intensive and hence utilising experienced volunteers for this task can aid a response, especially when time is of the essence. In some past cases, authorities have utilised citizen science to map the presence/absence of plastic pellets on the shoreline. However, this method can result in an overwhelming influx of unfiltered data, which needs to be sorted and prioritised.

The public awareness of plastic pollution is well established. A response can utilise this awareness and engagement, for example, by deploying waste containers at public access points to encourage members of the public to collect plastic pellets during their activities on the shoreline. Other incentive programs, such as financial rewards for weight of recovered plastic pellets, or a lottery among those who recover plastic pellets for a prize, can be used to increase public engagement.

4. Post spill monitoring and analysis

Post spill monitoring and analysis may be carried out to meet a number of objectives. These typically include: 1) identification of the source of pollution, 2) provision of data and evidence to inform post spill impact assessment and 3) provision of data and evidence to inform on rates of progress/recovery towards end points. Whilst the approach to post spill monitoring and assessment is relatively well established for oil spills, the supporting science underpinning post spill monitoring of plastic pellets is less mature. However, the knowledge base is growing on 'best practice' monitoring and analytical approaches following spills of emerging pollutants, including plastics. These will be summarised in the following section.

Whilst the methods for sample collection and analysis will be specific to the pollutant in question (in this case plastic pellets), the general approach to monitoring survey design will follow common principles. Further detail can be found in a number of reference sources[37,38] but general principles are underpinned by a Before – After – Control – Impact (BACI) survey design, whereby post spill monitoring results are compared with pre-spill baseline data (from the same sampling stations) and/or data collected from unimpacted reference stations (which have similar environmental characteristics to the impacted area). Time series data generated using a BACI design will be useful for assessment of both potential environmental impacts and subsequent recovery rates towards end points.

Following a significant spill of plastic pellets there will often be a need to monitor their presence and concentration in a variety of environmental compartments. These typically include: 1) Water – offshore and coastal areas, surface water and water column, 2) Sediments – intertidal and subtidal and 3) Biota – e.g., fish and shellfish. In order to optimise use of the monitoring data available (often collected by a variety of organisations, including government departments/agencies, Non-Government Organisations (NGOs), universities and other academic institutes) it is important to establish scientifically robust and consistent data collection protocols, thereby embedding the principles of 'collect once, use many times', as part of the monitoring programme.

4.1. Sample collection & preparation

The approach for sample collection, handling and storage will differ according to the environmental compartment or matrix being sampled[39]. Sampling approaches have also been developed to facilitate the involvement of 'citizen science' in pre and post spill data collection[29]. A brief summary of 'best practice' approaches to sampling is provided below:

Water

Sample collection from the water surface and/or water column may be required where there is an interest in the likelihood (and impacts) of potential interactions between plastic pellets and pelagic organisms. Water sampling can be carried out using a variety of approaches, including the use of bottles (e.g. niskin) or pumps (e.g. for sampling larger volumes of water). Alternatively, pelagic marine biota (e.g. plankton) can be sampled as a proxy for ambient water conditions using e.g., neuston or manta trawls, plankton nets. Each of the options have pros and cons and these are detailed in a number of literature sources[39,40].

Sediment

Approaches to sediment sampling will vary depending on the location of the sediment (e.g. coastal beaches, intertidal or subtidal)[40]. For beaches and intertidal sediments, scoops and cores are effective and can be used for either qualitative or quantitative sampling. For subtidal sediment sampling, a range of grabs or corers (deployed either from a vessel or by diving) are available. However, there are a number of things to consider when selecting a grabbing or coring device, such as whether the sediment surface of the sample remains intact on recovery of the grab (e.g., important where 'availability' of pollutants to bottom dwellers/feeders is of interest) or depth of penetration of the corer (e.g., where a sediment profile is required for time series analyses).

Biota

Fish are commonly sampled for presence of plastic pellets and microplastics. Several methods exist to process biota samples for microplastic contents, depending on the target tissues, size of the organism and aim of the study[40]. In general, widely applied protocols include the removal of the gastrointestinal tracts (GITs) by dissection (Figure 32). **Error! Reference source not found.**GITs are then dissolved, filtered and suspected anthropogenic items are then manually picked for further chemical characterisation. Additional methods, such as Nile Red (NR) tagging of polymers can also be applied to increase detection of microplastics[41] and for the fast screening of microplastics in biota[42–44]. When preparing samples for analysis, "sample blanks" must be collected to quantify any background microplastic pollution in the laboratory setting.

4.2. Analysis of plastic pellets

Following a plastic pellets spill, sample analysis can be undertaken in several different ways depending upon the objectives of the programme. Based on recent cases, three areas of post-spill analysis of plastic pellets are considered relevant:

- Polymer physical & chemical characterisation
- Polymer source identification
- Environmental impact assessment & toxicity testing

The guidance provided below on these types of assessment is not exhaustive but intends to provide a brief introduction to the options that are available to affected Members States, Competent Authorities and spill managers.

4.2.1. Methods for physical and chemical characterisation of plastic pellets

From a post spill monitoring perspective, there may be a number of reasons why an understanding of the physical and chemical characteristics of plastic pellets is required. These include: 1) improved understanding of how they will behave in the water (e.g., to assist with fate and transport modelling), 2) identification of their potential source/sources, 3) improved understanding of any interactions between the pellets and other substances and chemicals onboard the ship and 4) likelihood of impacts on the environment (e.g. due to potential toxicological effects).

To date, no single widely accepted method is available for the sampling, extraction and analysis of microplastics within the environmental industry. The lack of standardised methods makes direct comparisons between data sets difficult, limiting the production of robust scientific evidence on which guidelines and policy measures can be based. Standardisation, of microplastics analysis, is currently the focus of a number of international expert groups (e.g. OSPAR, ICES, EU-TGML) and organisations such as the International Organization for Standardisation (ISO).

At the time of writing, Fourier-transform infrared spectroscopy (FTIR) and Raman are favoured as powerful analytical techniques for the identification and characterisation of microplastics in the environment. An overview of the advantages and disadvantages of available microplastics particle identification techniques is provided in **Error! Reference source not found.**.

Figure 32: Illustration of the removal of GITs from fish. Source: Cefas.

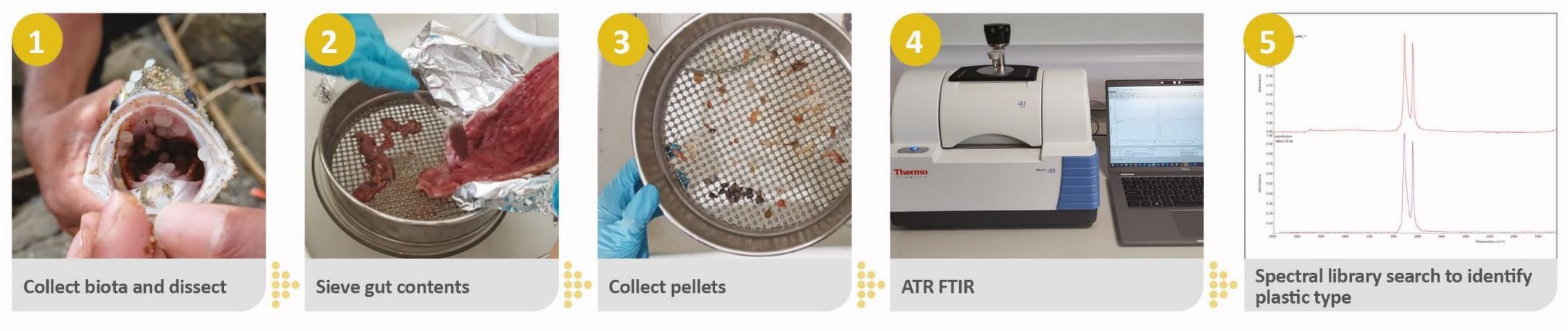

Figure 33: Illustration of workflow for characterisation of plastic type. Source: Cefas

Table 6: Microplastics particle identification technical overview.

Analytical method	Minimum particle size (mm)	Filter requirement	Degree of automation	Acquisition speed	Advantages	Disadvantages	Relative cost	Analytical method
ATR-FTIR spectroscopy	> 500	N/A	Very low	Fast	- Ease of use - Minimum sample preparation	Contact analysis (ATR)	€	ATR-FTIR spectroscopy
FT-IR microscopy	> 10	IR transparent	High	Fast	- Ease of use - Minimum sample preparation		€€	FT-IR microscopy
ATR-FTIR microscopy	> 5	Any filter Any substrate	High	Medium	- Ease of use - Minimum sample preparation	Contact analysis (ATR)	€€	ATR-FTIR microscopy
FT-IR imaging	> 5	IR transparent	Very high	Very fast	- Ease of use - Minimum sample preparation		€€€	FT-IR imaging
ATR FT-IR imaging	> 2	Any filter Any substrate	High	Medium	- Ease of use - Minimum sample preparation	Contact analysis (ATR)	€€€	ATR FT-IR imaging
LDIR imaging	> 10	Flat, reflective surface (e.g. kevley slide or IR reflective filter)	High	Very fast		New technique, not applied for environmental samples	€€€	LDIR imaging
Raman imaging	> 0.5	Non-fluorescent	Very high	Fast	Resolving particles down to 1 micron and less	Less commonly used as FTIR, limited reference spectra	€€€	Raman imaging
Pyr-GC-MS		N/A			- Suitable for nanoplastics identification - Analysis of polymer type and additive chemicals	- Destructive analysis - Reporting unit (mass vs number) - Complex data	€€€	Thermal analysis

Polymer identification of plastic pellets is typically carried out using benchtop ATR-FTIRs (attenuated total reflectance – Fourier transform infrared) (Figure 33). The resulting spectra are compared to published spectra databases of known plastics to assist with the identification of plastic type. Reporting parameters should include a list of any commercial or open access FTIR spectra databases used, including the name of specific libraries. Minimum acceptable % match against the database should also be specified. Generally, library matches of ≥ 80 % are deemed acceptable. In some cases, matches ≥ 60 % are acceptable and further validation can be achieved by confirmation of characteristic IR-peaks for different polymers. Any spectral post-processing applications should also be documented for transparency and repeatability purposes.

4.2.2. Methods for identification of the source of plastic pellets

For the purpose of identifying the source of the plastic pellet pollution, it may be necessary to carry out a more detailed characterisation of the pellet properties, similar to the detailed analysis required for oil fingerprinting[45]. Plastic fingerprinting is most commonly undertaken by thermal analysis (e.g. pyrolysis gas chromatography mass spectrometry (pyr-GC-MS), differential scanning calorimetry, or thermogravimetry (TGA) based methods). These methods rely on the identification of unique properties that may be linked directly to the source. For example the presence/absence of chemical additives, thermally decomposed plastic products, and/or differential melting points.

The identification of unique surface contaminants, including metals, organics and biofilms could also be used for source tracking of plastic items[46]. It is, however, more difficult to relate a plastic item to specific sources as this type of approach would require a clear understanding of the interaction between surface contaminants and sources, weathering processes and competitive sorption of surface contaminants with other suspended particulate and organic matter.

4.2.3. Assessing potential environmental impacts

Monitoring biota for the presence and effects of marine plastic pellets and litter[12] can provide useful information on:

- Potential impacts on biota;
- Potential impacts on human health and wellbeing; and/or
- Potential impacts at the ecosystem level.

Marine biota interact with both small and large items of plastics (**Error! Reference source n ot found.**). Subsequent related environmental effects will also be dependent on the size of the plastic item as well as the size of the marine organism. At the European level (Marine Strategy Framework Directive 2008/56/EC[47]), some common indicators (based on rates and levels of ingestion) are available for seabirds (i.e. Fulmars) and sea turtles. While these common indicators are mainly focussed on meso- and macrolitter, rather than plastic pellets, other types of biota have been used for microplastic monitoring in coastal and offshore environments including mammals[48], fish[49–51] and invertebrates[52].

Feeding strategies are also an important component to consider when selecting suitable organisms to monitor impacts, as this will dictate how, and to what extent, they interact with plastic litter and with microplastics[12] (Figure 34).

While plastic pellets are broadly inert and therefore not considered a marine pollutant in their original form, the ecotoxicological risk associated with plastic pellets is not fully understood. Of particular concern are the hazards associated with chemical additives within the pellets and their propensity to be released into the environment, or the likelihood of other chemicals to adsorb to the pellet surface. Research is ongoing into characterising the toxicological risk associated with plastic pellets, and their impact on flora and fauna. Post-spill monitoring strategies could include sampling of biota and comparison to baseline levels of chemical pollutants.

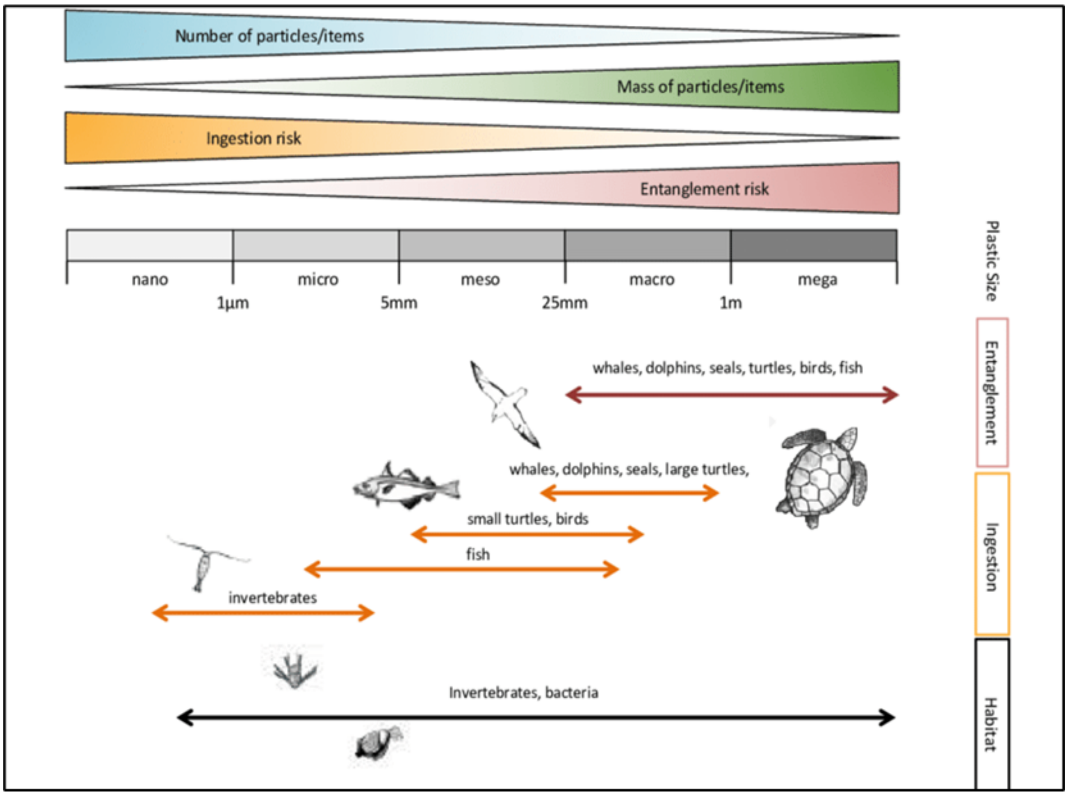

Figure 34: Schematic representation of the impacts of different sized plastics on marine biota including entanglement, ingestion and habitat associated risk. Source: (GESAMP, 2019)[12].

5. Intervention and cost recovery

5.1. Introduction to current legislation

Recovery of costs incurred as a result of a discharge of plastic pellets from a ship, should always be based on the statutory position in the jurisdiction in whose waters the damage or loss incurred. This could be the jurisdiction in which the incident occurred i.e. the coastal State in whose waters the discharge occurred. However, discharges of plastic pellets from ships may also occur on the high seas and the plastic pellets subsequently wash up on a coastal State's shoreline, or there may be transboundary movement of plastic pellets where discharge takes place in the waters of one State but other littoral States are subsequently affected. It is important therefore that all coastal States, no matter the level of either maritime traffic into ports or terminals in the State or passing maritime traffic in transit, have the necessary legislation in place to govern liability and compensation following a ship sourced discharge of plastic pellets from ships, whether carried as cargo or as packaging.

Requirements for clean-up and compensation will therefore be subject to the domestic law in place and in force in the State affected by a ship sourced discharge of plastic pellets.

Existing international rules and regulations have been adopted that may govern liability and compensation for the costs of locating, marking and removing plastic pellets following a ship sourced discharge when defined as a "wreck" and where such pellets pose a "hazard" in the form of a danger or impediment to navigation, major harmful consequences to the environment or damage to the coastline of one or more States. The Nairobi International Convention on the Removal of Wrecks, 2007 (WRC) [53] was adopted by the IMO in 2007 and provides the legal basis for States to remove, or have removed, wrecks that may have the potential to adversely affect the safety of lives, goods and property at sea, as well as the marine environment. The WRC defines "wreck" as including any object that is or has been on board a sunken or stranded ship, or any object that is lost at sea from a ship and that is stranded, sunken or adrift at sea. This could include a discharge of plastic pellets when carried either as packaging or as cargo.

The WRC is in force in a significant number of States worldwide. It should be noted that the WRC only applies within the exclusive economic zone of a State party. However, States can elect to extend the application of certain provisions of the Convention to wrecks located within their territory, including territorial sea. States that have not given effect to the WRC are recommended to do so through the deposit of an instrument of ratification, accession or signature with the IMO coupled with the necessary implementing legislation into domestic law.

In terms of cost recovery for the locating, marking and removing of plastic pellets from a ship-sourced discharge and the subsequent application of the WRC, it should also be noted that the WRC provides that:

i. The registered owner of the ship shall be held strictly liable for the costs of locating, marking and removing a "wreck", and therefore if a discharge of plastic pellets is deemed to be within the definitions of a "wreck" and a "hazard" under the WRC, the registered owner will be deemed liable for such costs irrespective of any fault on their part (subject to certain specific defences),
ii. The registered owner of such a ship (where greater than 300 gross tonnes) is required to maintain insurance or other financial security to cover their liabilities, and claimants have the right under the WRC to bring a claim directly against the provider of such insurance or financial security, and;
iii. The registered owner and their insurer retain the right to limit their liability for such costs if such a right exists under any applicable national or international regime, such as the Convention on Limitation of Liability for Maritime Claims, 1976, as amended (LLMC Convention).

States should therefore be aware that a shipowner or their insurer may retain the right to limit their liability for claims for the costs of locating, marking and removal of plastic pellets from a ship-sourced discharge. States should therefore be cognisant of their implementation of the 1976 LLMC Convention, 1996 LLMC Protocol[54] or any other corresponding limitation provisions within their legislative system.

Liability and compensation for other losses or damage arising from a ship-sourced discharge of plastic pellets, beyond the locating, marking and removal of plastic pellets, would not be governed by the WRC. Reference should be made to the statute of the affected State to determine the liability and compensation in respect of any such loss or damage. The shipowner and their insurer may also retain the right to limit their liability for loss or damage arising from such a discharge, beyond the costs of locating, marking and removal of plastic pellets. There are no international funds (by means of an IMO Convention) available in the event that the costs of locating, marking, removal of, or other loss or damage arising from, a ship sourced discharge of plastic pellets exceeds the limit of liability that is available to the shipowner. Claimants are recommended to seek advice from their central government in such an event.

There are also proposals to update other existing international rules that will govern liability and compensation for damage arising from the carriage of HNS by sea, so that such rules would also govern liability and compensation for damage arising from a discharge of plastic pellets when carried by sea as cargo. However, any such change and its subsequent application is unlikely to occur in the immediate future.

It should also be noted that, as well as the shipowner, there will be a number of different parties that will be involved in the transportation of plastic pellets by sea, including cargo interests if carried as cargo. The shipper (or consignor) will be the party that is the supplier or owner of the plastic pellets when carried as cargo and will contract with the carrier (either the shipowner or the charterer) for the carriage of the cargo. The consignee (or receiver) is the party to whom the plastic pellets cargo is shipped and to whom the delivery of the cargo will be made under the contract of carriage.

In terms of cost recovery, States may wish to focus on the responsibility of each of these parties within their legislative systems given their respective roles in the maritime transportation of plastic pellets.

5.2. Identification of responsible parties

If the name of the ship from which the plastic pellets were discharged is known; the ship registry of the Flag State may provide more information on the shipowner. Alternatively, online databases such as Equasis can be used to identify the shipowner and/or their insurer. The International Group of P&I Associations (the Group) (www.igpandi.org) also maintain an online ship search function for ships that are entered for insurance (P&I) cover with an International Group P&I Club, and the individual P&I Clubs maintain online ship search databases on their websites[2].

If the identity of the ship is unknown, claimants should contact their State government for assistance.

In the event of a discharge of plastic pellets from a ship that is flying the Flag of a State where the WRC is in force, there is a requirement on the Master and the operator of the ship to report to the "Affected State", without delay, when that ship has been involved in a maritime casualty resulting in a wreck, and which can include a discharge of plastic pellets. Such reports shall provide the name and the principal place of business of the registered owner for the Affected State to determine whether the discharge of plastic pellets poses a hazard to the environment, navigation or related interests of that State.

If the Affected State determines that such a discharge (from a "wreck") constitutes a "hazard", that State shall immediately (i) inform the State of the ship's registry and the registered owner and (ii) proceed to consult the State of the ship's registry and other affected States regarding the measures to be taken.

Time will be of the essence since, once released, plastic pellets disperse widely, as described above. It is therefore important that an affected state initiates their national contingency plan with immediate effect and, if the WRC is in force, in accordance with the provisions of the WRC. Any subsequent response measures should be reasonable and proportionate, and all such measures should be properly recorded from the outset (see Section 5.4).

In the event that the Master or operator of the ship that discharged the plastic pellets does not report the discharge to the affected State and/or the WRC is not in force, then the State may still wish to follow the reporting and locating provisions contained within the WRC as consistent with global practices. This will be dependent on the regulatory regime in the State concerned.

The registered owner shall remove the plastic pellets ("wreck") determined to constitute a "hazard". In circumstances where the WRC applies and immediate action is required, or if the registered owner cannot be contacted, or the registered owner does not remove the plastic pellets within the deadline set by the Affected State, the Affected State may remove the plastic pellets by the most practical and expeditious means available, consistent with considerations of safety and protection of the marine environment. In such circumstances, the registered owner shall be held strictly liable for the costs of locating, marking and removal of the plastic pellets, subject to certain exceptions.

It will be necessary to have a clear and firm understanding of the legislative regime governing liability and compensation in the event of a ship-sourced plastic pellets discharge since, if there is no statute imposing strict liability on a responsible party, it may be necessary to pursue recompense on the basis of proven fault or negligence i.e. did the loss or damage arise due to the fault or negligence of any of the parties involved in the maritime transportation of the plastic pellets. Appropriate legal advice should be sought in such circumstances.

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[2] https://www.igpandi.org/ship-search/

5.3. Responsible parties' role in response

The WRC provides that the registered owner of the ship from which the discharge occurred may contract with a salvor or other person to seek removal of, the ship-sourced plastic pellets, although it is not necessary for the WRC to be in force for the owner to do so.

The registered owner's insurer will usually appoint experts to monitor clean-up operations and wider damage, to investigate the technical merits of claims and to make independent assessments of any losses.

The P&I Clubs and other insurers have developed a worldwide network of experts with expertise in the various sectors likely to be affected by ship sourced incidents. They also draw on the advice of ITOPF Ltd. ITOPF's technical staff has acquired considerable experience in incident response and are familiar with claims for loss or damage arising from ship-sourced plastic pellets discharges. During the clean-up phase of an incident members of ITOPF's technical staff usually attend on site where they are able to offer technical advice on the most appropriate response measures consistent with the intention and objectives of international best practices. Members of ITOPF's technical staff often provide remote/virtual assistance as well as on site advice.

Although the P&I Clubs rely on experts to assist in the assessment of claims, the decision as to whether to approve or reject a particular claim rests entirely with the relevant P&I Club.

5.4. Record keeping and preparation of claims

From the outset, detailed records should always be kept. This discipline should be adhered to by all persons, parties, entities and authorities engaged in the response, and their 'agents' (i.e. contractors and, in some instances, local authorities) involved in incurring costs (e.g. by activating assets, equipment, stockpiles, vessels and internal staff), and any other person who has suffered damage or loss or incurred costs arising from the discharge of plastic pellets.

It will be necessary to demonstrate to the [responsible parties]/[liable parties] and their legal and/or insurance representatives (and to the court if legal proceedings for the recovery of costs are initiated) what was done, when it was done and why it was done.

A standard format for keeping records should be used by all those involved in incurring costs as a result of activating assets, contractors, equipment, stockpiles, vessels and internal staff. This format should be detailed enough to provide the information, but simple enough to be useable. Importantly, it should also be a format that can be used by people who are working under time constraints and in physical conditions which may be less than ideal. Early engagement with the ship's insurer and/or experts on the ground is imperative.

Claims should be submitted in writing (preferably by electronic mail) to the [responsible parties]/[liable parties] and/or their insurers. If appropriate, the insurer will issue claim forms to assist claimants in the presentation of claims.

A claim should be presented clearly and with sufficient information and supporting documentation to enable the amount of the damage to be properly assessed and quantified. Each item of a claim must be substantiated by an invoice or other relevant supporting documentation, such as work sheets, explanatory notes, accounts and photographs. It is the responsibility of claimants to submit sufficient evidence to support their claims. It is important that the documentation is complete and accurate. If the documentation in support of a claim is likely to be considerable, claimants should contact the insurer's local correspondent (see below) or local claims office as soon as possible to discuss claim presentation.

As a minimum, each claim should contain the following basic information:

- The name and address of the claimant and of any legal or other representative.
- The identity of the ship involved in the incident.
- The date, place and specific details of the incident, if known to the claimant.

- The type of loss or damage sustained and incurred, and
- The amount of compensation claimed together with supporting evidence.

The following general criteria apply to all claims:

- Any expense, loss or damage should actually have been incurred.
- Any expense should relate to measures taken that are considered reasonable and justifiable.
- There should be a close link of causation between the expense, loss or damage covered by the claim and the damage or loss arising from the discharge of plastic pellets.
- A claimant has suffered a quantifiable economic loss, and
- A claimant has to prove the amount of their expense, loss or damage by producing appropriate documents or other evidence.

An aim of the WRC is the amicable settlement of claims by the parties without the need to involve lawyers or the courts. However, whether the WRC is in force and applicable or not, if it is not possible to reach an agreement on the assessment of the claim, the claimant has the right to bring their claim before a competent court (normally in the State in which the loss or damage occurred). Since the WRC entered into force, court actions by claimants have not been necessary in the majority of incidents that have arisen under the scope of the WRC.

However, it should be re-emphasised that the WRC only governs liability and compensation for the locating, marking and removing of a wreck, and therefore potentially plastic pellets arising from a ship-sourced discharge, and not other losses or damage that may arise from such a discharge.

Whilst this guidance may assist States, authorities, claimants, shipowners and insurers and other interested parties, the appropriate and relevant national courts will be the final arbiters on the applicable domestic legislation, the interpretation of the WRC, the admissibility of claims arising under it, and on liability and compensation following a ship-sourced plastic pellets discharge whether the WRC is in force and applicable or not.

As each State will have its own rules and procedures governing such matters, claimants are encouraged to seek local legal assistance as required.

Claimants are strongly encouraged to submit their claims as soon as possible after the damage has occurred. If the WRC is in force and applicable and a formal claim cannot be made shortly after an incident, claimants should endeavour to provide notification as soon as possible to the registered owner and the registered owner's insurer of their intention to present a claim at a later stage. To avoid requests for further information and to speed up the process, claimants should provide as much of the information detailed above as possible.

Claimants will ultimately lose their right to compensation under the WRC, if applicable and in force, unless they bring court action against the "shipowner" and/or the registered owner's insurer within three (3) years of the date on which plastic pellets discharge has been determined to be a hazard under the WRC and in accordance with the WRC. Although damage may occur sometime after an incident takes place, court action must in any event be brought within six (6) years of the date of the maritime casualty that resulted in the wreck and that led to the determination of the plastic pellets discharge as a hazard under the WRC. Claimants are recommended to seek legal advice if they are unsure and/or unable to settle their claims to avoid their claims becoming time-barred.

5.5. The role of the P&I Clubs

In the event that the WRC is in force and applicable and/or claims are made against the registered owner of the ship that resulted in the discharge of plastic pellets, claims will usually be handled by the owner's insurer and who is often one of the Protection and Indemnity Associations (P&I Clubs) that insure the third-party liabilities of shipowners, including liability for loss or damage arising from a ship sourced discharge of plastic pellets. In practice, claims are often channelled through the office of the insurer's correspondent closest to the location of the incident. Claims, together with supporting documentation, can be sent to either the insurer or the insurer's local correspondent who will usually make themselves available in the locality of the incident to ensure that claimants have the necessary contact details for the submission of claims.

Details of insurers of other interests involved in the maritime transportation of plastic pellets should be sought either from the affected State or from local legal advice.

6. References

1. Kerrison, A. (2022). Using past maritime incidents and travel data to predict the area of shoreline with the highest probability of future nurdle spills. *The Nurdle Project, University of Southampton*.

2. PlasticsEurope. (n.d.). *Plastics-the Facts 2021 An analysis of European plastics production, demand and waste data*.

3. Fauna & Flora International. (n.d.). *Taking action on nurdle pollution*. Retrieved 15 February 2023, from https://www.fauna-flora.org/nurdles/

4. de Vos, A., James, B., Mazzotta, M., Michel, A., Reddy, C., Walsh, A., Ward, C., Hahn, M., & Youngs, S. (n.d.). *2021 M/V X-PRESS PEARL nurdle spill fact sheet*. Retrieved 15 February 2023, from https://www.whoi.edu/wp-content/uploads/2021/06/Fact-Sheet-XPressPearlSpill24Jun.pdf

5. de Vos, A., Aluwihare, L., Youngs, S., Dibenedetto, M. H., Ward, C. P., Michel, A. P. M., Colson, B. C., Mazzotta, M. G., Walsh, A. N., Nelson, R. K., Reddy, C. M., & James, B. D. (2022). The M/V X-Press Pearl Nurdle Spill: Contamination of Burnt Plastic and Unburnt Nurdles along Sri Lanka's Beaches. *ACS Environmental Au*, *2*(2), 128–135. https://doi.org/10.1021/ACSENVIRONAU.1C00031/ASSET/IMAGES/LARGE/VG1C00031_0005.JPEG

6. World Shipping Council. (2022). *Containers Lost at Sea*. https://static1.squarespace.com/static/5ff6c5336c885a268148bdcc/t/62b2d93516eba2026ec97cee/1655888181926/Containers_Lost_at_Sea_2022.pdf

7. IMO. (n.d.). *Sub-Committee on Carriage of Cargoes and Containers (CCC 8), 8th session, 14-23 September, 2022*.

8. Hann, S., Sherrington, C., Jamieson, O., Hickman, M., & Bapasola, A. (2018). *Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products - Eunomia*. https://www.eunomia.co.uk/reports-tools/investigating-options-for-reducing-releases-in-the-aquatic-environment-of-microplastics-emitted-by-products/

9. Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. (2012). Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. *Environmental Science & Technology*, *46*(6), 3060–3075. https://doi.org/10.1021/es2031505

10. Schumann, E. H., Fiona MacKay, C., & Strydom, N. A. (2019). Nurdle drifters around South Africa as indicators of ocean structures and dispersion. *South African Journal of Science*, *115*(5–6), 1–9. https://doi.org/10.17159/SAJS.2019/5372

11. Brandon, J., Goldstein, M., & Ohman, M. D. (2016). Long-term aging and degradation of microplastic particles: Comparing in situ oceanic and experimental weathering patterns. *Marine Pollution Bulletin*, *110*(1), 299–308. https://doi.org/10.1016/J.MARPOLBUL.2016.06.048

12. GESAMP. (2019). *Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean* . http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean

13. Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. (2017). Plastic as a Persistent Marine Pollutant. *Https://Doi.Org/10.1146/Annurev-Environ-102016-060700*, *42*, 1–26. https://doi.org/10.1146/ANNUREV-ENVIRON-102016-060700

14. United Nations Environ. Progr. (2001). *Stockholm Convention on persistent organic pollutants (POPs)*. http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx

15. Desforges, J.-P. W., Galbraith, M., & Ross, P. S. (2015). Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean. *Archives of Environmental Contamination and Toxicology*, *69*(3), 320–330. https://doi.org/10.1007/s00244-015-0172-5

16. Lusher, A. L., Hernandez-Milian, G., O'Brien, J., Berrow, S., O'Connor, I., & Officer, R. (2015). Microplastic and macroplastic ingestion by a deep diving, oceanic cetacean: The True's beaked whale Mesoplodon mirus. *Environmental Pollution*, *199*, 185–191. https://doi.org/10.1016/j.envpol.2015.01.023

17. Nobre, C. R., Santana, M. F. M., Maluf, A., Cortez, F. S., Cesar, A., Pereira, C. D. S., & Turra, A. (2015). Assessment of microplastic toxicity to embryonic development of the sea urchin Lytechinus variegatus (Echinodermata: Echinoidea). *Marine Pollution Bulletin*, *92*(1–2), 99–104. https://doi.org/10.1016/J.MARPOLBUL.2014.12.050

18. Jiang, X., Lu, K., Tunnell, J. W., & Liu, Z. (2021). The impacts of weathering on concentration and bioaccessibility of organic pollutants associated with plastic pellets (nurdles) in coastal environments. *Marine Pollution Bulletin*, *170*, 112592. https://doi.org/10.1016/J.MARPOLBUL.2021.112592

19. Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, *44*(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

20. Teuten, E. L., Rowland, S. J., Galloway, T. S., & Thompson, R. C. (2007). Potential for Plastics to Transport Hydrophobic Contaminants. *Environmental Science & Technology*, *41*(22), 7759–7764. https://doi.org/10.1021/es071737s

21. Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, *178*, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

22. Rodrigues, A., Oliver, D. M., McCarron, A., & Quilliam, R. S. (2019). Colonisation of plastic pellets (nurdles) by E. coli at public bathing beaches. *Marine Pollution Bulletin*, *139*, 376–380. https://doi.org/10.1016/J.MARPOLBUL.2019.01.011

23. Rios, L. M., Moore, C., & Jones, P. R. (2007). Persistent organic pollutants carried by synthetic polymers in the ocean environment. *Marine Pollution Bulletin*, *54*(8), 1230–1237. https://doi.org/10.1016/J.MARPOLBUL.2007.03.022

24. Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., & Kaminuma, T. (2001). Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. *Environmental Science & Technology*, *35*(2), 318–324. https://doi.org/10.1021/es0010498

25. MARPOL. (n.d.). *International Convention for the Prevention of Pollution from Ships, 1973*. Retrieved 15 February 2023, from http://www.marpoltraining.com/MMSKOREAN/MARPOL/intro/

26. REMPEC. (2009). *IMO/UNEP: Regional Information System, Operational Guides and Technical Documents, Mediterranean Guidelines on Oiled Shoreline Assessment*.

27. OSRL. (2014). *FIELD GUIDE: Shoreline Clean-up Assessment Technique (SCAT)*. http://www.shorelinescat.com/Documents/Manuals/OSRL%20SCAT%20Field%20Guide.pdf

28. Preparedness for Oil-polluted Shoreline clean-up and Oiled Wildlife interventions – POSOW project. (2013). *Oiled Shoreline Assessment Manual*. https://www.posow.org/documentation/manual

29. Tunnell, J. W., Dunning, K. H., Scheef, L. P., & Swanson, K. M. (2020). Measuring plastic pellet (nurdle) abundance on shorelines throughout the Gulf of Mexico using citizen scientists: Establishing a platform for policy-relevant research. *Marine Pollution Bulletin*, *151*, 110794. https://doi.org/10.1016/J.MARPOLBUL.2019.110794

30. Fernandino, G., Elliff, C. I., Silva, I. R., & Bittencourtc, A. C. S. P. (2015). How many pellets are too many? the pellet pollution index as a tool to assess beach pollution by plastic resin pellets in Salvador, Bahia, Brazil. *Journal of Integrated Coastal Zone Management*, *15*(3), 325–332. https://doi.org/10.5894/RGCI566

31. Alkalay, R., Pasternak, G., & Zask, A. (2007). Clean-coast index-A new approach for beach cleanliness assessment. *Ocean and Coastal Management*, *50*(5–6), 352–362. https://doi.org/10.1016/J.OCECOAMAN.2006.10.002

32. Norwegian Coastal Authority. (2020). *Experience from the plastic pellets incident, TRANS CARRIER, focusing on shoreline clean-up methods.* . https://www.kystverket.no/globalassets/oljevern-og-miljoberedskap/forskning-og-utvikling/experience-from-the-plastic-pellets-incident.pdf/download

33. Sergy, G. A., & Environment Canada. (2001). *Guidelines for selecting shoreline treatment endpoints for oil spill response.* . https://publications.gc.ca/collections/collection_2011/ec/En4-84-2008-eng.pdf

34. REMPEC. (2012). *Mediterranean Oil Spill Waste Management Guideline*. https://wastemanagement.rempec.org/en/documentation/guidelines/mediterranean-oil-spill-waste-management-guideline

35. Preparedness for Oil-polluted Shoreline clean-up and Oiled Wildlife interventions – POSOW. (2016). *Oil spill waste management manual*. https://www.posow.org/documentation/manual

36. Partow, H., Lacroix, C., le Floch, L., & Alcaro, L. (2021). *X-Press Pearl Maritime Disaster Sri Lanka - Report of the UN Environmental Advisory Mission (July 2021) | UNEP - UN Environment Programme*. https://www.unep.org/resources/report/x-press-pearl-maritime-disaster-sri-lanka-report-un-environmental-advisory-mission

37. Kirby, M., Brant, J., Moore, J., & Lincoln, S. (2018). *PREMIAM – Pollution Response in Emergencies – Marine Impact Assessment and Monitoring: Post-incident monitoring guidelines.* . https://www.cefas.co.uk/media/frwmhths/ccs0118760460-1_prem_2nd_ed_web.pdf

38. IPIECA. (2020). *Oil Spill Monitoring and sampling: good practice guidelines for incident management and emergency response personnel, IOGP Report 639*. https://www.ipieca.org/resources/good-practice/oil-spill-monitoring-and-sampling/

39. Prata, J. C., da Costa, J. P., Duarte, A. C., & Rocha-Santos, T. (2019). Methods for sampling and detection of microplastics in water and sediment: A critical review. *TrAC Trends in Analytical Chemistry*, *110*, 150–159. https://doi.org/10.1016/J.TRAC.2018.10.029

40. Miller, E., Sedlak, M., Lin, D., Box, C., Holleman, C., Rochman, C. M., & Sutton, R. (2021). Recommended best practices for collecting, analyzing, and reporting microplastics in environmental media: Lessons learned from comprehensive monitoring of San Francisco Bay. *Journal of Hazardous Materials*, *409*, 124770. https://doi.org/10.1016/J.JHAZMAT.2020.124770

41. Shruti, V. C., Pérez-Guevara, F., Roy, P. D., & Kutralam-Muniasamy, G. (2022). Analyzing microplastics with Nile Red: Emerging trends, challenges, and prospects. *Journal of Hazardous Materials*, *423*, 127171. https://doi.org/10.1016/j.jhazmat.2021.127171

42. Bakir, A., Desender, M., Wilkinson, T., van Hoytema, N., Amos, R., Airahui, S., Graham, J., & Maes, T. (2020). Occurrence and abundance of meso and microplastics in sediment, surface waters, and marine biota from the South Pacific region. *Marine Pollution Bulletin*, *160*, 111572. https://doi.org/10.1016/J.MARPOLBUL.2020.111572

43. Bakir, A., van der Lingen, C. D., Preston-Whyte, F., Bali, A., Geja, Y., Barry, J., Mdazuka, Y., Mooi, G., Doran, D., Tooley, F., Harmer, R., & Maes, T. (2020). Microplastics in Commercially Important Small Pelagic Fish Species From South Africa. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.574663

44. Silburn, B., Bakir, A., Binetti, U., Russell, J., Kohler, P., Preston-Whyte, F., Meakins, B., van Hoytema, N., Andrews, G., Carrias, A., Maes, T., & Hoytema, van. (2022). A baseline study of macro, meso and micro litter in the Belize River basin, from catchment to coast. *ICES Journal of Marine Science*. https://doi.org/10.1093/ICESJMS/FSAB268

45. Ogden, W., & Everard, M. (2020). Rapid 'fingerprinting' of potential sources of plastics in river systems: An example from the River Wye, UK. *International Journal of River Basin Management*, *20*(3), 349–362. https://doi.org/10.1080/15715124.2020.1830783

46. Fahrenfeld, N. L., Arbuckle-Keil, G., Naderi Beni, N., & Bartelt-Hunt, S. L. (2019). Source tracking microplastics in the freshwater environment. *TrAC - Trends in Analytical Chemistry*, *112*, 248–254. https://doi.org/10.1016/J.TRAC.2018.11.030

47. *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) (Text with EEA relevance)*. (2008). https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32008L0056

48. Zantis, L. J., Carroll, E. L., Nelms, S. E., & Bosker, T. (2021). Marine mammals and microplastics: A systematic review and call for standardisation. *Environmental Pollution*, *269*, 116142. https://doi.org/10.1016/J.ENVPOL.2020.116142

49. Makhdoumi, P., Hossini, H., & Pirsaheb, M. (2022). A review of microplastic pollution in commercial fish for human consumption. *Reviews on Environmental Health*. https://doi.org/10.1515/REVEH-2021-0103

50. Wang, W., Ge, J., & Yu, X. (2020). Bioavailability and toxicity of microplastics to fish species: A review. *Ecotoxicology and Environmental Safety*, *189*, 109913. https://doi.org/10.1016/j.ecoenv.2019.109913

51. Wootton, N., Reis-Santos, P., Dowsett, N., Turnbull, A., & Gillanders, B. M. (2021). Low abundance of microplastics in commercially caught fish across southern Australia. *Environmental Pollution*, *290*, 118030. https://doi.org/10.1016/j.envpol.2021.118030

52. Li, P., Wang, X., Su, M., Zou, X., Duan, L., & Zhang, H. (2021). Characteristics of Plastic Pollution in the Environment: A Review. *Bulletin of Environmental Contamination and Toxicology*, *107*(4), 577–584. https://doi.org/10.1007/s00128-020-02820-1

53. *The Nairobi International Convention on the Removal of Wrecks*. (2007). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228988/8243.pdf

54. *Protocol of 1996 to amend the Convention on Limitation of Liability for Maritime Claims, 1976*. (1996). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/238229/8281.pdf

7. Appendix

Coastal Plastic Pellet Pollution Assessment Sheet (modified from IMO/UNEP, 2009)

Coastal Plastic Pellet Pollution Assessment Sheet (Part 1)

1. GENERAL INFORMATION	Date (dd/mm/yy)	Survey time (local) From to
Incident:		
Segment ID:		sun / Cloud / Fog / Rain / Windy

2. SURVEY TEAM	Organisation	Telephone number

3. SEGMENT	Total length:_______________ m.	Length surveyed:_____________m.
Start GPS: LAT	LONG	
End GPS: LAT	LONG	

4. SHORELINE TYPE		✓✓ = primary (one only) ✓ = secondary Circle the boxes of shoreline types and other features	
	Bedrock cliff		Mud sediments
	Platformed-rock slope		Sand sediments
	Man-made solid		Mixed sediments
	Man-made permeable		Pebble – cobble - shingle
	Salt marsh		Boulder
	Other (describe):	Wave exposure (circle one): Very exposed / exposed / partially sheltered / very sheltered	
Other features:			

	Estuary / river outlet		Historical artefact/structure		Dead seagrass *(Posidonia)* deposits
	Amenity area		Polls		Deep cracks or crevices

5. OPERATIONAL FEATURES	Debris? Yes/ No Contaminated? Yes/ No Amount: _________bags/trucks
Direct backshore access? Yes/ No Along from next segment? Yes/ No	Access restrictions
Backshore cliff? Yes/ No Ht.____________m.	Suitable lay-down area? Yes/ No
Ongoing clean-up activity? Yes/ No	

6. SURFACE PLASTIC PELLETS

TICK HERE IF NONE OBSERVED:											
Zone ID	Position				Plastic pellet coverage			Plastic pellet characteristics			
Zone ID	Position				Plastic pellet coverage			Plastic pellet characteristics			
	L	M	U	S	Length	Width	Distr. %	Virgin plastic pellets	Burnt plastic pellets	Melted plastic pellets	Other
L, M, U & S = Lower, Middle, Upper & Supra tidal											

7. SUB-SURFACE PLASTIC PELLETS							TICK HERE IF NO INVESTIGATION:			
Pit ID	Position				Pit depth (cm)	Contaminated zone (cm-cm)	Sub-surface plastic pellet characteristics			
	L	M	U	S			Virgin plastic pellets	Burnt plastic pellets	Melted plastic pellets	Other

Coastal Plastic Pellet Pollution Assessment Sheet (Part 2)

8. GENERAL COMMENTS:
Use the space above as needed to provide comments about the site not covered by part 1 of the Form. If no further comments write "NONE". Comments may address following questions: ✓ How contaminated is this segment (surface and sub-surface)? ✓ Is there a need for cleaning in this segment? ✓ Which cleaning methods are appropriate or recommended? ✓ What is the environmental and socio-economic sensitivity of this segment? ✓ What care is needed to protect sensitive resources? ✓ What is the priority for cleaning in this segment? ✓ Are cleaning operations conducted correctly? ✓ Is the cleaning method used the most effective or does it cause collateral damage? ✓ Is it necessary to test another method? Does the segment meet the cleaning endpoints?

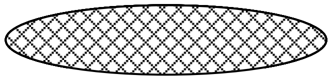
Coastal Plastic Pellet Pollution Assessment Sheet (Part 3)

CHECKLIST

SEGMENT________DATE__/__/___

- ☐ NORTH ARROW
- ☐ CONTAMINATED ZONES
- ☐ WIDTH & LENGTH.
- ☐ PELLET CHARACTERISTICS
- ☐ % COVER
- ☐ SCALE
- ☐ SEGMENT BOUNDARY
- ☐ SHORELINE TYPE

LEGEND



CONTAMINATED ZONE

Zone ID — A

2 x 20 m — Zone dimensions

PIT [1] △: No Sub-surface Plastic Pellets

Pit [2] ▲: Sub-surface Plastic Pellets

1 ●→ Photo location, direction and numbers

2 ○→ Video location, direction and numbers